Evaluation of the FHWA’s Sign Management and RetroReflectivity Tracking System (SMARTS) Van

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July, 2001

Prepared for:
Alaska Department of Transportation
Statewide Research Office
3132 Channel Drive
Juneau, AK 99801-7898

FHWA-AK-RD-01-01
**Title:** Evaluation of the FHWA’s Sign Management and RetroReflectivity Tracking System (SMARTS) Van

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**Funding Numbers:**
- FHWA-AK-RD-01-01

**Perfoming Organization:**
- Alaska DOT&PF
  - Research and Technology Transfer
  - 3132 Channel Drive
  - Juneau, AK 99801-7898

**Sponsoring/Monitoring Agency:**
- State of Alaska, Alaska Dept. of Transportation and Public Facilities
  - Research and Technology Transfer
  - 2301 Peger Rd
  - Fairbanks, AK 99709-5399

**Abstract:**
This report documents a performance evaluation of the Federal Highway Administration’s Sign Management And Retroreflectivity Tracking System (SMARTS) van. The van’s purpose is to photograph, record the location, and measure the retroreflectivity of traffic signs while traveling at highway speeds.

Alaska needs a cost-effective method of inventorying signs and measuring their reflectivity to manage its $20+ million investment in signs, to know what signs are missing or illegible, and to analyze its compliance with impending national standards for sign retroreflectivity.

Testing consisted of evaluating signs with the van on one rural and one urban road segment, evaluating signs on the rural road segment with a handheld sign retroreflectivity meter, and analyzing the results.

The report concludes that the van’s performance was not acceptable. Multiple readings on individual signs varied widely from one run to the next, the percentage of signs captured by the operators on a single pass was unacceptably low, and van readings did not correlate with those of a handheld meter (handheld meters are considered the most accurate measuring device).

13. **KEYWORDS:** Retroreflectivity, Retroreflection, Retroreflectors, Sign Sheeting, Materials Management

14. **NUMBER OF PAGES:** 54

15. **PRICE CODE:** N/A

16. **LIMITATION OF ABSTRACT:** N/A
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Report # FHWA-AK-RD-01-01

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FINAL REPORT

Prepared for the
Alaska Department of Transportation
& Public Facilities

Authors
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Acknowledgements

The ADOT&PF Research Section funded this report. Al Fletcher, FHWA Safety / Operations Engineer, handled the logistics and brought the van to Alaska from Denver. He and Kurt Smith, ADOT&PF State Traffic Engineer, ran the tests, did the analysis, and wrote the report. Clint Adler was the Research Section contact for the project.

The van and its equipment were supplied by the Federal Highway Administration. It is one of four such vans in the country.
Abstract

This report documents a performance evaluation of the Federal Highway Administration’s Sign Management And Retroreflectivity Tracking System (SMARTS) van. The van’s purpose is to photograph, record the location, and measure the retroreflectivity of traffic signs while traveling at highway speeds.

Alaska needs a cost-effective method of inventorying signs and measuring their reflectivity to manage its $20+ million investment in signs, to know what signs are missing or illegible, and to analyze its compliance with impending national standards for sign retroreflectivity.

Testing consisted of evaluating signs with the van on one rural and one urban road segment, evaluating signs on the rural road segment with a handheld sign retroreflectivity meter, and analyzing the results.

The report concludes that the van’s performance was not acceptable. Multiple readings on individual signs varied widely from one run to the next, the percentage of signs captured by the operators on a single pass was unacceptably low, and van readings did not correlate with those of a handheld meter (handheld meters are considered the most accurate measuring device).
CHAPTER 1 - INTRODUCTION AND RESEARCH APPROACH

Problem Statement and Research Objective

The purpose of this study is to analyze the effectiveness and cost-effectiveness of using the Federal Highway Administration’s Sign Management And Retroreflectivity Tracking System (SMARTS) van for inventorying signs and evaluating sign retroreflectivity in Alaska.

Although Alaska has a $20+ million investment in road signs, we currently don’t know when signs are knocked down, stolen, or have deteriorated to the point they are no longer legible at night. This creates a potential for safety and liability problems.

The Highway Safety Act of 1966 requires states to have traffic control device inventories. The ITE Traffic Signing Handbook calls a sign inventory "an essential tool" for managing signs.

In addition to the need for an inventory, impending national standards for sign retroreflectivity are going to make it necessary to have a method of measuring it.

In anticipation of the new standards, and to promote sign inventories, the FHWA funded a project to design a van capable of doing inventories and retroreflectivity measurements at highway speeds. If successful, this would greatly reduce the time and money required for these tasks.

Scope of Study

This study was initially intended to determine:

1) The accuracy of van-collected data measured by:
   a) Consistency of multiple retro-reflectivity readings for the same signs.
   b) Comparison of van readings to handheld meter readings

2) Typical sign capture rates for the van under rural and urban conditions (sign capture rate= Number of sign photos taken / Number of target signs).

3) How much it would cost to inventory all signs on Alaska’s contiguous road system using the van.

4) Whether the data collected by the van is sufficient for a sign inventory.

5) Whether van data was easily transferable to a personal computer database.

The scope of the study was limited to items 1 and 2 when we learned that the van did not perform acceptably on them.
Research Approach

Our research consisted of:

1) Evaluating signs with the van on a 10 mile rural segment of the Seward Highway (24 signs).

2) Evaluating the same 24 signs with a handheld meter.

3) Evaluating signs with the van on a 1.2 mile urban segment of Spenard Road in Anchorage (23 signs).

4) Analyzing the results.
CHAPTER 2 - FINDINGS

SMARTS Van Operation

Two people are required to operate the van, a driver and a computer operator. The computer operator watches the road on a video screen and targets signs by holding crosshairs on them with a mouse. The system then should lock on to the sign and track it automatically. If successful in tracking the sign, the system will fire a flash and take two pictures (one color, one black and white) of the sign when it gets 200’ from the roof-mounted camera pod. The system then stores the pictures as well as sign location data (derived from a GPS system that gives the van’s location and a camera-pod mounted laser device that measures the distance to each sign).

The system’s automatic tracking lock was not functional during this test, making it necessary to manually hold the crosshairs on signs. This was a difficult task in many instances, especially on bumpy or curvy roads or when signs are installed close to each other.

The sign hardware and software were user-friendly and have a professional appearance.

SMARTS Van Performance

Reliability

In our three-day test, the van’s computer system failed several times and needed to be re-booted. At times, the camera system seemed to have a mind of its own and would not respond to operator input. However, the system generally restored itself after rebooting and would resume proper functioning.

Accuracy of Retro-Reflectivity Measurement

Repeatability of van retro-reflectivity readings was unacceptable. As shown in Appendix B, readings on the same signs varied widely from one run to the next. The average difference between high and low readings on signs ranged between 41 and 75 cd / lux / m^2.

These numbers constitute too high a proportion of normal sign readings (the minimum standard is likely to be 100 cd / lux / m^2 or less) for the results to be meaningful.

The accuracy of the van-based system as compared to a handheld meter (generally considered the most accurate type of available device) was also unacceptable (see Appendix B). While the van readings were always lower, they correlated poorly with handheld meter readings. The average difference for sign legends was 351%. For backgrounds it was 297%. Individual readings varied widely above and below these figures.
Accuracy of Sign Location

After excluding outliers that may have been the result of incorrectly entered data, the van located signs within an average of 100’ of latitude and 180’ of longitude, when compared to its readings from other runs. See Appendix C.

Sign Capture Rate

Sign capture rate (number of sign photos taken / number of target signs) varied from 27% to 45% in an urban environment and from 59% to 68% in a rural environment. See Appendix B.

Due to road roughness, road curvature, or the close spacing of signs, some signs were not captured once during four runs.
CHAPTER 3 - INTERPRETATION, APPRAISAL, AND APPLICATIONS

The SMARTS van was an ambitious undertaking for the FHWA. Highly sophisticated technology is required to accurately measure the retroreflectivity of sign legends and backgrounds from a van traveling at highway speed. The FHWA deserves high marks for vision and ambition but, unfortunately, not for execution.

In its current configuration, the van does not provide useful information.

However, if it were modified to live up to its promise, it would be very useful to highway agencies.

General Recommendations

The following improvements would make the van more useful:

1) Make retroreflectivity measurement accurate.

2) Install a gyro on the camera pod to make it easier for the operator to track signs.

3) Make the tracking mechanism work.

4) Create a process for doing comprehensive inventories with multiple passes. Ideally, the computer would keep track of missed signs on the first pass and tell the operator which signs to pick up on subsequent passes.
CHAPTER 4 - CONCLUSIONS

1) The SMARTS Van’s retroreflectivity measuring system is too inaccurate to be useful.

2) Even if all its systems were functional, the van is unlikely to ever be capable of collecting data on 100% of the signs along a road on a single pass in urban conditions. Multiple passes will be needed to get comprehensive inventories.

3) If the bugs can be worked out, a mobile data collection van of this type is likely to be the most cost-effective method of inventorying signs and measuring retroreflectivity.

4) The van provides a much-needed excuse for video game players. Our experience indicated that gamers are much better at running the targeting system than non-gamers.
APPENDIX A – SMARTS Van Background Information

The Retroreflectivity issue started with the recommended use of glass beads in the 1948 MUTCD. The 1954 revision to the MUTCD required pavement marking to be retroreflectorized. The MUTCD has required all markings that have a night time application to have retroreflective properties since 1961.

In 1985 the Center for Auto Safety petitioned FHWA to address standards for retroreflective traffic control devices.

Congress required the MUTCD to be revised to include minimum retroreflectivity levels for pavement markings and traffic signs on all public roads in the 1993 appropriations act (ISTEA).

In response to the requirement for minimum levels FHWA initiated research studies one of which was a mobile van used to measure retroreflectivity at highway speeds. The early version developed at FHWA’s Turner Fairbanks facility had a camera and flash that was connected to periscope similar to a submarine’s. This required the operator to look through the viewing reticule to target the sign. (It didn’t work very well for Al).

The early version of the van was abandoned in 1994. FHWA decided to let a contract to build a new van meeting certain specifications. Dan Bay and Associates were awarded the contract to develop the new van. The new van was to have auto tracking, one monitor (the original version had three) and measure the entire sign. The new van became the Sign Management And Retroreflectivity Tracking System (SMARTS) van.

To date minimum retroreflectivity standards have not been included in the MUTCD. They are due toward the end of 2001.
APPENDIX B – SMARTS Van RetroReflectivity Performance Data
## RetroReflectivity Van Performance Summary

<table>
<thead>
<tr>
<th>Measure</th>
<th>Seward Hwy 5/29/01</th>
<th>Spenard Rd 5/30/01</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Legend</td>
<td>Background</td>
</tr>
<tr>
<td>Capture Rate</td>
<td>59% to 68%</td>
<td></td>
</tr>
<tr>
<td>Repeatability (Range of readings)</td>
<td>75</td>
<td>72</td>
</tr>
<tr>
<td>Avg Difference btwn van &amp; handheld:</td>
<td>351%</td>
<td>297%</td>
</tr>
</tbody>
</table>

Seward Highway Run. Starts at the weight station and goes about 10 miles south. 24 signs.

Spenard Road Run: Starts at Minnesota Drive and goes about 1.2 miles west. 23 signs not including small street name parking, and other minor signs.

Capture Rate: Number of photos captured / Number of signs that should have been captured.

Repeatability: The average difference between low and high reflectivity readings (candels / lux / meter^2).

Average difference between van and handheld: The difference between the van reading (with a user-selected evaluation area) and the handheld meter reading.
## Seward Hwy RetroReflectivity Data - 5-29-01, Computer-selected evaluation area

<table>
<thead>
<tr>
<th>Sign No</th>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
<th>Run 4</th>
<th>Legend Background</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data? Legend Bkgnd</td>
<td>Data? Legend Bkgnd</td>
<td>Data? Legend Bkgnd</td>
<td>Data? Legend Bkgnd</td>
<td>Avg Lo Hi SD</td>
</tr>
<tr>
<td>1.0</td>
<td>9.6</td>
<td>138</td>
<td>115.6</td>
<td>28.4</td>
<td>40.1 116 79.5</td>
</tr>
<tr>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td>55 MPH</td>
<td>White</td>
<td>36.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4.1</td>
<td>1</td>
<td>-34.5</td>
<td>145</td>
<td>1</td>
<td>44.8 55 -26.4</td>
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<tr>
<td>5.12</td>
<td>Slow Veh Turnout 1000'</td>
<td>Blue</td>
<td>110.7</td>
<td>29.7</td>
<td>0</td>
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<tr>
<td>6.14</td>
<td>Veh Turnout - arrow</td>
<td>Blue</td>
<td>119.6</td>
<td>-37.4</td>
<td>1</td>
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<td>7.27 Brown Camera</td>
<td>Brown</td>
<td>1</td>
<td>54.9</td>
<td>-51.3</td>
<td>0</td>
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<tr>
<td>8.29 Brown-McHugh Ck</td>
<td>Brown</td>
<td>144.3</td>
<td>16.2</td>
<td>92.7</td>
<td>-24.8</td>
</tr>
<tr>
<td>9.31 Falling Rocks, Next 10 Mi</td>
<td>Yellow</td>
<td>1</td>
<td>5.1</td>
<td>170</td>
<td>0</td>
</tr>
<tr>
<td>10.35 Orange-End of Slide Area</td>
<td>Orange</td>
<td>1</td>
<td>0.4</td>
<td>108.3</td>
<td>1</td>
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<td>-31.6</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>18.77 Blue Trail&amp;Blu Camera</td>
<td>Blue</td>
<td>0</td>
<td>1</td>
<td>144.3</td>
<td>0</td>
</tr>
<tr>
<td>19.79 Yellow Ped Xing</td>
<td>Yellow</td>
<td>0</td>
<td>63.1</td>
<td>-29.7</td>
<td>0</td>
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<tr>
<td>20.8 Blue Trail Sign</td>
<td>Blue</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>21.88 55</td>
<td>White</td>
<td>1</td>
<td>13.6</td>
<td>174.2</td>
<td>1</td>
</tr>
<tr>
<td>22.9 Blue Trail Sign</td>
<td>Blue</td>
<td>1</td>
<td>42.6</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>23.91 Blue Trail Sign</td>
<td>Blue</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-18.4</td>
</tr>
</tbody>
</table>

No of Usable Shots: 13 15 14 15
Capture Rate: 59% 68% 64% 68% more than one reading

Retro-Reflectivity values are
Candels / lux / square meter.

Legend
Background

<p>| Average Range in Retro-Reflectivity Values: | 75.1 | 72.2 |</p>
<table>
<thead>
<tr>
<th>Sign No</th>
<th>Mile</th>
<th>Sign</th>
<th>Color</th>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
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<th>Background</th>
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</thead>
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<td></td>
<td></td>
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<td>Run 1 Data?</td>
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<td>Bkgnd</td>
<td>Data?</td>
<td>Legend</td>
<td>Bkgnd</td>
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<td>2</td>
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<td>Merge Symbol-W</td>
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<td>0</td>
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No of Usable Shots: 14 15 14 15
Capture Rate: 64% 68% 64% 68%

Lo's and Hi's are only shown when there is more than one reading

Retro-Reflectivity values are Candelas / lux / square meter.
### Spenard Road RetroReflectivity Data - 5-30-01, Computer-selected evaluation area

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No of Usable Shots: 6 7 10 8  
Capture Rate: 27% 32% 45% 36%

Retro-Reflectivity values are Candelas / lux / square meter.

Average Range in Retro-Reflectivity Values: 46.6 41.4
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</table>

No of Usable Shots: 6 7 10 8
Capture Rate: 27% 32% 45% 36%

Retro-Reflectivity values (Ra) are Candelas / lux / square meter.
# Seward Hwy RetroReflectivity Data, Comparison of Handheld Meter and Van Readings

<table>
<thead>
<tr>
<th>Sign No</th>
<th>Mile</th>
<th>Sign</th>
<th>Color</th>
<th>Handheld Meter Reading</th>
<th>Avg Van Rdg Difference</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Avg Van Rdg (User Selected eval area)</td>
<td>Difference</td>
<td>Handheld Meter Reading</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Left Lane Ends-W</td>
<td>Yellow</td>
<td>1</td>
<td>-7.8</td>
<td>880%</td>
</tr>
<tr>
<td>2</td>
<td>0.1</td>
<td>Merge Symbol-W</td>
<td>Yellow</td>
<td>0</td>
<td>n/a</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>0.2</td>
<td>55 MPH</td>
<td>White</td>
<td>0</td>
<td>-45.0</td>
<td>n/a</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>Delay 5 Veh -R</td>
<td>White</td>
<td>2</td>
<td>3.3</td>
<td>65%</td>
</tr>
<tr>
<td>5</td>
<td>1.2</td>
<td>Slow Veh Turnout 1000'</td>
<td>Blue</td>
<td>282</td>
<td>100.3</td>
<td>64%</td>
</tr>
<tr>
<td>6</td>
<td>1.4</td>
<td>Veh Turnout - arrow</td>
<td>Blue</td>
<td>329</td>
<td>96.7</td>
<td>71%</td>
</tr>
<tr>
<td>7</td>
<td>2.7</td>
<td>Brown Camera</td>
<td>Brown</td>
<td>298</td>
<td>54.9</td>
<td>82%</td>
</tr>
<tr>
<td>8</td>
<td>2.9</td>
<td>Brown-McHugh Ck</td>
<td>Brown</td>
<td>234</td>
<td>88.2</td>
<td>62%</td>
</tr>
<tr>
<td>9</td>
<td>3.1</td>
<td>Falling Rocks, Next 10 Mi</td>
<td>Yellow</td>
<td>3</td>
<td>-13.0</td>
<td>533%</td>
</tr>
<tr>
<td>10</td>
<td>3.5</td>
<td>Orange-End of Slide Area</td>
<td>Orange</td>
<td>19</td>
<td>-11.8</td>
<td>162%</td>
</tr>
<tr>
<td>11</td>
<td>4.2</td>
<td>Blue Camera</td>
<td>Blue</td>
<td>103</td>
<td>-6.8</td>
<td>107%</td>
</tr>
<tr>
<td>12</td>
<td>4.3</td>
<td>Beluga Pt-Brown</td>
<td>Brown</td>
<td>63</td>
<td>5.0</td>
<td>92%</td>
</tr>
<tr>
<td>13</td>
<td>4.5</td>
<td>Stop</td>
<td>Red</td>
<td>229</td>
<td>94.1</td>
<td>59%</td>
</tr>
<tr>
<td>14</td>
<td>5.9</td>
<td>Blue Camera</td>
<td>Blue</td>
<td>76</td>
<td>2.9</td>
<td>96%</td>
</tr>
<tr>
<td>15</td>
<td>6.1</td>
<td>Blue Camera</td>
<td>Blue</td>
<td>95</td>
<td>9.4</td>
<td>90%</td>
</tr>
<tr>
<td>16</td>
<td>6.3</td>
<td>Blue Trail Sign</td>
<td>Blue</td>
<td>58</td>
<td>-18.5</td>
<td>132%</td>
</tr>
<tr>
<td>17</td>
<td>6.4</td>
<td>Blue Trail Sign</td>
<td>Blue</td>
<td>49</td>
<td>n/a</td>
<td>3</td>
</tr>
<tr>
<td>18</td>
<td>7.7</td>
<td>Blue Trail&amp;Blu Camera</td>
<td>Blue</td>
<td>63</td>
<td>0.0</td>
<td>100%</td>
</tr>
<tr>
<td>19</td>
<td>7.9</td>
<td>Yellow Ped Xing</td>
<td>Yellow</td>
<td>1</td>
<td>-34.2</td>
<td>3520%</td>
</tr>
<tr>
<td>20</td>
<td>8</td>
<td>Blue Trail Sign</td>
<td>Blue</td>
<td>76</td>
<td>n/a</td>
<td>4</td>
</tr>
<tr>
<td>21</td>
<td>8.8</td>
<td>55</td>
<td>White</td>
<td>0</td>
<td>-4.4</td>
<td>n/a</td>
</tr>
<tr>
<td>22</td>
<td>9</td>
<td>Blue Trail Sign</td>
<td>Blue</td>
<td>58</td>
<td>-5.4</td>
<td>109%</td>
</tr>
<tr>
<td>23</td>
<td>9.1</td>
<td>Blue Trail Sign</td>
<td>Blue</td>
<td>73</td>
<td>0.0</td>
<td>100%</td>
</tr>
</tbody>
</table>

Retro-Reflectivity values are Candelas / lux / square meter.

Average: 351%  
Minimum: 59%  
Maximum: 3520%

Average: 297%  
Minimum: 45%  
Maximum: 911%
APPENDIX C – SMARTS Van GPS Performance Data
## Seward Hwy GPS Sign Location Data, 5-29-01, Summary (Excluding Run 2)

<table>
<thead>
<tr>
<th>Sign No</th>
<th>Mile</th>
<th>Sign</th>
<th>Color</th>
<th>No of Rdgs</th>
<th>Latitude (min.)</th>
<th>Longitude (min.)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Avg</td>
<td>Lo</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Minutes</td>
<td>~ Feet</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Left Lane Ends-W</td>
<td>Yellow</td>
<td>2</td>
<td>2.727</td>
<td>2.724</td>
</tr>
<tr>
<td>2</td>
<td>0.1</td>
<td>Merge Symbol-W</td>
<td>Yellow</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>0.2</td>
<td>55 MPH</td>
<td>White</td>
<td>2</td>
<td>2.663</td>
<td>2.661</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>Delay 5 Veh -R</td>
<td>White</td>
<td>3</td>
<td>2.088667</td>
<td>2.084</td>
</tr>
<tr>
<td>5</td>
<td>1.2</td>
<td>Slow Veh Turnout 1000'</td>
<td>Blue</td>
<td>3</td>
<td>1.996667</td>
<td>1.991</td>
</tr>
<tr>
<td>6</td>
<td>1.4</td>
<td>Veh Turnout - arrow</td>
<td>Blue</td>
<td>3</td>
<td>1.876667</td>
<td>1.87</td>
</tr>
<tr>
<td>7</td>
<td>2.7</td>
<td>Brown Camera</td>
<td>Brown</td>
<td>2</td>
<td>1.111</td>
<td>1.105</td>
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<tr>
<td>8</td>
<td>2.9</td>
<td>Brown-McHugh Ck</td>
<td>Brown</td>
<td>3</td>
<td>1.021</td>
<td>1.014</td>
</tr>
<tr>
<td>9</td>
<td>3.1</td>
<td>Falling Rocks, Next 10 Mi</td>
<td>Yellow</td>
<td>3</td>
<td>0.965333</td>
<td>0.96</td>
</tr>
<tr>
<td>10</td>
<td>3.5</td>
<td>Orange-End Slide Area</td>
<td>Orange</td>
<td>3</td>
<td>0.844333</td>
<td>0.837</td>
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<tr>
<td>11</td>
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<td>Blue Camera</td>
<td>Blue</td>
<td>3</td>
<td>0.638</td>
<td>0.63</td>
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<tr>
<td>12</td>
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<td>Beluga Pt-Brown</td>
<td>Brown</td>
<td>3</td>
<td>0.558667</td>
<td>0.55</td>
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<tr>
<td>13</td>
<td>4.5</td>
<td>Stop</td>
<td>Red</td>
<td>3</td>
<td>0.436333</td>
<td>0.429</td>
</tr>
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<td>Blue</td>
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<td>0.150333</td>
<td>0.145</td>
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<tr>
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<td>0.066</td>
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<td>Blue</td>
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<td>59.974</td>
<td>59.971</td>
</tr>
<tr>
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<td>6.4</td>
<td>Blue Trail Sign</td>
<td>Blue</td>
<td>2</td>
<td>59.663</td>
<td>59.332</td>
</tr>
<tr>
<td>18</td>
<td>7.7</td>
<td>Blue Trail &amp; Blu Camera</td>
<td>Blue</td>
<td>1</td>
<td>59.319</td>
<td>59.319</td>
</tr>
<tr>
<td>19</td>
<td>7.9</td>
<td>Yellow Ped Xing</td>
<td>Yellow</td>
<td>1</td>
<td>59.231</td>
<td>59.231</td>
</tr>
<tr>
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<td>Blue</td>
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<td>59.125</td>
<td>59.125</td>
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<tr>
<td>21</td>
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<td>58.946</td>
<td>58.94</td>
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<td>Blue</td>
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<td>58.949</td>
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<tr>
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<td>Blue</td>
<td>3</td>
<td>58.98933</td>
<td>58.981</td>
</tr>
</tbody>
</table>

### Average:
- Radius of Earth (approx.): 5000
- Circumference of Earth (approx.): 31416
- Feet per Degree (approx.): 460767
- Feet per Minute (approx.): 7679.4

### Feet per Minute Approximation

- Average: 360.1
- Avg w/o Outliers: 97.7
- Avg w/o Outliers: 179.3
The van malfunctioned on run 2 - all signs are recorded at the same location. This data was not included in the summary.
<table>
<thead>
<tr>
<th>Sign No</th>
<th>Mile</th>
<th>Sign</th>
<th>Color</th>
<th>Run 3</th>
<th>Run 4</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Latitude</td>
<td>Longitude</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Left Lane Ends-W</td>
<td>Yellow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.1</td>
<td>Merge Symbol-W</td>
<td>Yellow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.2</td>
<td>55 MPH</td>
<td>White</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>Delay 5 Veh - R</td>
<td>White</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.2</td>
<td>Slow Veh Turnout 1000'</td>
<td>Blue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.4</td>
<td>Veh Turnout - arrow</td>
<td>Blue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>2.7</td>
<td>Brown Camera</td>
<td>Brown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>2.9</td>
<td>Brown-McHugh Ck</td>
<td>Brown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>3.1</td>
<td>Falling Rocks, Next 10 Mi</td>
<td>Yellow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3.5</td>
<td>Orange-End Slide Area</td>
<td>Orange</td>
<td></td>
<td></td>
</tr>
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<td>Blue Camera</td>
<td>Blue</td>
<td></td>
<td></td>
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<td>12</td>
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<td>Beluga Pt-Brown</td>
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</tr>
<tr>
<td>13</td>
<td>4.5</td>
<td>Stop</td>
<td>Red</td>
<td></td>
<td></td>
</tr>
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<td>14</td>
<td>5.9</td>
<td>Blue Camera</td>
<td>Blue</td>
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<td>Blue Camera</td>
<td>Blue</td>
<td></td>
<td></td>
</tr>
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<td>16</td>
<td>6.3</td>
<td>Blue Trail Sign</td>
<td>Blue</td>
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<td>6.4</td>
<td>Blue Trail Sign</td>
<td>Blue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>7.7</td>
<td>Blue Trail &amp; Blu Camera</td>
<td>Blue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>7.9</td>
<td>Yellow Ped Xing</td>
<td>Yellow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>8</td>
<td>Blue Trail Sign</td>
<td>Blue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>8.8</td>
<td>55</td>
<td>White</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>9</td>
<td>Blue Trail Sign</td>
<td>Blue</td>
<td></td>
<td></td>
</tr>
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<td>23</td>
<td>9.1</td>
<td>Blue Trail Sign</td>
<td>Blue</td>
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</tr>
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</table>
Draft

RETROREFLECTIVITY SIGN VAN OPERATOR'S MANUAL
DECEMBER, 1999
EQUIPMENT DESCRIPTIONS

The following are descriptions of the major components of the Retrospectometer as well as their functions:

THE TURRET

There are three main components to the turret:
(1) A main flash unit - a Xenon flash tube located at the lower portion of the turret,
(2) Laser range finder located above the main flash unit, and
(3) Three cameras - one 50 mm monochrome lens; one 75 mm monochrome lens; and one 50 mm color tracking camera.

The turret is able to rotate 180 degrees for storage; however, its rotation is limited to less than ±80 degrees while in operation. This is a built-in safety feature so that during operation (tracking), the mount's position is limited to the general area of where the sign would be and won't "run away with itself" thus becoming uncontrollable.

Stow Pins

Located below (almost underneath) the turret are the stow pins. The main function of the stow pins are to prevent the turret from tipping while the van is moving with the system off. It is also important to note that the mount will not move if the stow pins are not in their storage location (at the base of the turret) during operation.

Stow Pin Positions (Non-operational Turret Storage)

The normal non-operational position for the unit (the turret) is backwards, that is, when the Turret is "stowed," the front of the unit is facing in the direction of the back of the van.

Operator Station
**Driver Electronics**

The Driver Electronics is a black box located on the floor and to the left of the operator station. The Driver Electronics (for the mount) contains the power supply for the laser and one to two small custom electronic boards for camera shutter control.

**Flash Power Supply**

Above the Driver Electronics box is a silver box which is the Flash Power Supply. It provides energy to activate the camera's flash.

**Inverter**

The Inverter is located underneath the passenger seats. It provides 2,000 watts of power and its function is to convert 12 volts of automotive power to 110 volts of AC. It is the main power supply - it gives power to all retroreflectivity components in the vehicle including the work station (everything that is powered by AC). For these vans, there are two different versions of inverters. Three of the vans have inverters which contain switches and plugs in the front of the unit (these are beige in color). One van has an inverter which does not contain any outward plugs or switches. Instead, this model has plugs wired within the box and the operating switch is located along with the other van controls - it is white in color. When external power is available, for example during trade shows, the AC can be removed from the inverter and plugged into an extension cord (or power strip) attached to external 120 volts.
Also, within the back of each van are 2 deep-cycle marine batteries that can provide power to run the inverter for up to 1 hour with the van’s engine off. These batteries are charged by vehicle power (via the van’s alternator). While the van is running (the motor is on), the batteries are always charging. However, there is isolation between the vehicle’s batteries and the batteries used for the inverter and operator station to prevent the marine batteries from discharging back through the van’s electrical system. The vehicle’s (heavy duty - 190 amp) alternator feeds them both.

Display Monitor and keyboard -
All vans have the same style (flat) computer monitor, keyboard and software installed, as well as the same standard color (black). The monitor is a 13.1 - 13.8 inch flat panel. The primary reason for the flat monitor vs. a regular monitor is that the image on a flat monitor is stable even when the van isn’t (the same isn’t true with a regular monitor.) Also there is the issue of depth. The flat monitor doesn’t interfere with the driver’s view of the side view mirror.

Computer Hardware

Zip Drive -
For all vans, the operator's station will include the following:
One Dual Pentium 200 - 233 Mhz Machine,
One IOMEGA - 100 megabyte zip drive,
One CD ROM drive,
One 2-gigabyte removable,
One 2 to 4-gigabyte internal hard drive and standard floppy drive, and
64 megs of RAM
The primary purpose of the zip drive is to give data to the persons who are participating in the demonstration. The computer is capable of retaining up to an hour’s worth of data including, reflectivity, images - both black and white and color, and putting a viewing package together. It’s a SCSI-based system, which allows maximum data speed between peripherals and the CPU.

Hard Drive -
2.1 gigabytes will store up to 1 day’s worth of data.

Storing data -
Data is stored directly on the internal 2.1 Gig hard drive and then is transferred to the removable drive that can later be taken back to the office and downloaded to another computer, tape, etc.
**Cooling Fan**

At the base of the monitor is the cooling fan. While the van is in operation, the excessive heat generated from the use of the computer (which can greatly affect the heat-sensitive components) is not really a concern while air conditioning from the van is available. However, during demonstrations when the van is stable (with its motor turned off) and the doors are open, temperature is not always easily controllable. It is under these conditions that the built-in cooling fan is most useful in eliminating potential (overheating) problems.

**Fold Down Table**

Each operator station includes a fold down table, which while in the “up” position allows for easy access to and from the seat. (This is important due to the limited amount of space for the “Operator’s Station.”)

**Fuse Box**

Located directly behind the computer monitor and drives (in front of the right of the driver’s seat), is the power supply box for the three cameras (located in the turret). In the supply box are four fuses and three LEDs. If any or all of the LEDs (indicator lights) are out, this indicates that one or all fuses are out. To discover this, look at the lights which are labeled accordingly, to see if any are out. The last fuse labeled is the AC fuse. Lights on indicate power going to the cameras.

**SOFTWARE/DISPLAY OUTLINE**

1. The Image Controls (left side of screen)
2. The System Status Calibration Box (across the top of the screen)
3. The Range Finder (across the bottom of the screen)
4. Menus (right side of screen)
Rotating Beacon

The Rotating Beacon is a small orange light located on the roof of the van behind the turret. It is used to warn other road users that a possibly hazardous operation in progress.

SOFTWARE DISPLAY

Under Functions Menu box:
These are functions you can choose from the function drop-down menu, shown in figure

- Operate View - used for operation
- Demo View - used for van demonstrations in trade shows
- Calibrate View - brings up screen calibrations for video, mount and sign(s). Normally, the video and mount settings are already calculated and established/set - the operator doesn’t have to concern his/herself with this feature.

*Brightness and Contrast controls are located on the left side of the screen

Brightness Value - is strictly a display feature and does not affect the settings of the camera(s) nor the contrast.

Contrast Value - Also, does not affect the settings of the camera or of the tracking. It merely changes what the operator sees (on the screen).
Delay Value - The Delay Value should NEVER be changed. It is the time difference between when the system gives the command to "flash" and the message gets to the (computer) card (designed by the van's engineers). The delay synchronizes the light from the flash with the shutter opening so that the image is taken as close to the peak brightness as possible. In other words, it is the delay from the vertical sync pulse of the camera and to where it flashes within the frame. This delay is approximately 10 microseconds. It's slightly different from every shutter position.

View Menu - Allows the operator to change the Brightness and Contrast values. Once changed, the numbered values will be stored, as well as the color shutter positions (which can also be changed when at this menu). This affects the camera, the black and white shutter, and the measurement.

Mouse Button Functions

The system uses a 3-button mouse.

The left mouse button - The mouse's aim moves immediately to the clicked point on the screen. This can be used while in motion as a course single step to a given location. However, this doesn't initiate track so the clicked point quickly moves from under the "crosshairs" cursor when used under motion.

The middle mouse button - This is the "go to" button. If the button is pressed (held down) while moving the mouse, the mouse is able to follow the cursor as the mouse is moved. The mouse will stop at whatever point the operator stops moving the mouse. This button can be used to initially find the sign in the image before initiating track. Once the desired sign is positioned in the center of the screen, the right mouse button can be pressed.

The right mouse button - This button is identical in operation to the middle button, with the additional function of initiating tracking. A red square appears on the screen when an object is actively tracked. The position of the red square shows where the camera will move the mount when the right mouse button is released, which will activate the auto track function. The red square should be in the center of the screen directly over the green square. All signs should be manually aimed with the right mouse button depressed into this green square and the red tracking square should align over the green square when correctly tracking the sign. Slight movement of the red tracking square is normal. Once the red tracking square is consistently over the green square, the right mouse button can be released. The sign will now be tracked until the snap distance is reached.

**Definition:** Snap - the flashing and capturing of the sign's retro-reflective image.

**NOTE:** The system must be monitored while the sign is actively tracked. If an object, such as a tree, interferes with the tracking function, the mount and the red square will travel off of the desired sign. The operator must reinitiate the track with the right mouse button on the desired sign. Depending on the operational environment, this may happen several times before the snap occurs. If great difficulty is had in auto tracking the sign, the operator may have to manually track the object with the right mouse button depressed.

If the tracking system doesn't "lock" onto the desired object (i.e., a sign), but rather, locks onto another object (i.e., a truck), the tracking angle may go beyond the pre-established, software limits of the mount. The software program has a built in command that will cause the tracking system to automatically return to a setting of zero, zero (0,0) and the tracking at this point will be off. At this point, the operator must redesignate the sign to be tracked. Tracking will not occur beyond +80 degrees azimuth and -9 degrees to 25 degrees elevation. The system will permit tracking beyond these limits in the 'demo mode'.

**Auto Return to Center**

If 'auto return to center' is checked, the mount returns automatically to aiming straight ahead and level after each snap. If 'auto return to center' is not checked, the mount will stay where it was before the snap. In other words, If 'auto return to center' is checked (set) the aim point automatically returns to the center after every camera snap.

**Set-Up Menu**

When looking at the SET UP menu, a "default set up" is already in place. The values that were last stored in the registry, including the Brightness values, whether or not the Status Bar and Tool Bar was turned off, the same values will reappear until they are manually changed. Also, the set-up values are never the same from one session to the next. The values have to change.

The color shutter is very interactive. It depends on variables such as weather conditions (overcast - cloudy, days), the location of the vehicle (under bridges), etc.

The black and white shutter is something that is determined by the intensity of the sign. For brighter signs, the set-ups have to be changed so that the view isn't completely saturated or "white-out." For weaker signs, the set-ups have to be changed such that the sensitivity of the lens is increased. It is recommended that the operator begin with viewing values of around 4 or 5 (making changes as necessary while viewing the screen). The changes can be made under Operate View — located under the Functions Menu option.
Other Descriptions:

**Auto Store Data Set**

This setting will store data captured for each sign reading (in incrementing file names). If not set, the system snaps a picture of the sign, but doesn’t store any data.

The range designation is measured in feet by default, but can be switched to metric. This number changes based on the image being viewed. There is a range sensitivity of 3-4 feet.

Signal strength (laser) is 50-90%. This is so a good return from the sign is achieved.

As mentioned earlier, for the purpose of conducting demonstrations, there is 45 minutes to 1 hour of full charge when running the system using the battery without aid from the van’s engine. After that, the operator runs the risk of having the entire system shut down (and possibly losing valuable information).

**System status** - Shows operational condition of system. The values can be “standby”, “storing data”, “Filing Home” or “tracking”. The system is generally in standby mode.

**Image Quality** - Refers to the tracking parameter for the van. It sometimes indicates how well the equipment is tracking.

**Data Index** - The index into the data set that the operator is running on at any given moment. This feature shows the number of images which have been stored.

**Master File Name** - This does not change in a session unless the operator goes to the file (menu) and then to the “new” or “save as” (option) which automatically assigns a new data index and data set name (which has embedded in it the julian date, year and 24 hour time in minutes).

Also, within the ‘data set’ is an index number for each point taken. The data is stored in separate files with separate file names with black and white images as well as color images. The data set name is different. There are three types of files that can be stored in this system. Each image is a separate file. This is automatically assigned by the system.

The default file naming convention is the following:

Data set master file (smarts file type): DataSet(julian day of the year)(hr and min of first sign collect)(yr).smd i.e.: DataSet142183498.smd - 142nd day of 1998 at 18:34 hrs

Black and white bitmap image file: BW(julian day of the year)(hr and min and sec of specific sign collect)(yr).bmp i.e.: BW14219053398.bmp - 142nd day of 1998 at 19:05:33 hrs

Color bitmap image file: Color(julian day of the year)(hr and min and sec of specific sign collect)(yr).bmp i.e.: Color14219053398.bmp - 142nd day of 1998 at 19:05:33 hrs

Set-up and Alignment:

First, the Stow Pins are to be taken down and placed in the drive position (being most concerned about the elevation pin)

Next, sit at the operator’s station and turn on the inverter (beige box under passenger’s seat directly behind the operator’s seat). The monitor will “power up” and the computer can be turned on. DO NOT turn on the drive electronics box until the program is running. As the computer is “booting up” go through the NT login (which is a standard NT login). Once the computer displays a login screen, simultaneously hit the “CTRL”, “ALT” and “DELETE” buttons. Next, enter the given “user level/demo level” password. At this point an icon for the “Shortcut to Smart EXE” should appear on the desktop. Double click on it. This brings the program up and if it isn’t already, you should enlarge it to fill screen.

Once the program is up, **NOW** turn on the driver electronics box as well as the flash (the silver box above the driver electronics box).
PLEASE NOTE: The program must be up before the driver electronics box can be turned on.

Now, adjust the color shutter so that a clear picture is obtained. The color shutter “box” as well as the black and white shutter “box” is located in the bottom left corner of the screen. Use of the up and down arrow keys will also allow the operator to adjust the color shutter. Next, find the home button and use it to find mount home position. It takes approximately 30 seconds to find the mount home position. Each time the computer and the mount are turned on, the system must find “home” first. It will show the “as now position” to be “0,0”. This is displayed at the top of the screen. The “0,0” position reading is the reference point by which all measurements are taken.

Calibration:
In order to perform calibrations, the object to be calibrated has to be placed 200 ft away from the van, as determined by the laser range value. Once an item has been identified for calibration, & placed at the correct distance, the operator will enter a lab-determined value for the calibration sign after pressing the “Sign Calibration” button of the “calibration view” function window. Next, the system will determine the bias value & then the scale value for that particular sign.

NOTE: Before beginning to take a bias value reading, the top portion of the turret, where the cameras are located, must be covered with a black sheet of cardboard. The entire turret does not have to be covered. However, the area of the camera must be entirely covered.

Bias value- Refers to the measurement of the black bias of the camera (the measurement of the black background noise).

Scale value- Refers to the multiplying value of a line equation (y = scale * x + bias). Calculated from the bias and the known measured value of the calibration sign (y).

To conduct bias calibration, simply place a black board in front of the cameras and press the “bias calibration” button. When the camera flashes, the bias calibration will be for the image taken (dark screen). The computer will measure the entire area. The operator should remember to make sure that the board used is blocking all direct sunlight to the camera(s). A 50 mm or 75 mm lens will be used for this purpose.

Next choose “gain calibration”. The system will flash and show the operator the entire image. If there is one sign with the image, the red square will be around it (the one sign) and will automatically select it. In cases, where this doesn’t happen automatically, the operator will select the desired image, using the left mouse button to put the red square around any part of the (white) sign, after which, a new gain value will be assigned. Thus, the sign will be calibrated using the lab value given.

In summary, the sign is calibrated using calibration values for the sign selected based on its measured lab value. The operator calculates the bias which is the background “noise” of the camera and then calculates the gain value based on the reflectivity measured from the area of the highlighted sign (using the red box) & only that which is contained within the red box.

Once the calibration is taken, its value will be used to calibrate all future measurements, until another calibration is taken.

NOTE: The operator does not have to calibrate differently based on different sign colors. Also, if the CANCEL button is pressed, all new calibrations will be discarded and the previous values reinstated. Therefore, it is important to save the data collected, by selecting the “OK” button (this will store the values collected). When taking measurements and doing calibrations, it is preferred that all-white signs are used. Also, when trying to take a measurement on a sign, the view of the sign must be placed within the red box.

Data Capture/Data Transfer— Operate View

Start and Stop Tracking: The operator has to be in the tracking mode in order to start and stop tracking.

Mount Controls - Is a pull down menu, which does the same as the tool bar buttons of the same name.

These are the options (selections):
Find Home - go to zero, zero (Must be used once at each power up to locate forward and level for the mount controller.)
SF - Store Forward
SB - Store Backward
Reset Mount - Reset mount
(All of these features are located on the tool bar)

Reset (button) - This button resets the camera and mount (“wakes up” the mount from any unusual location/position it may be in). This button doesn’t change any pre-established values, positions or calibrations.
50 mm camera or 75 mm camera - Determines which black and white camera is used for data capture.

**Demo view** -
This option is used for conducting demonstrations at a site. The operator will get a new screen that is almost identical to the “Operating View” screen. The buttons are in the same location as the ‘view’ feature (operate view) with a few additions.

The additions are:

**Under DEMO CONTROL**
- Start demonstration
- Stop demonstration
- Set demonstration

Both the ‘Start’ and ‘Stop’ demonstration controls are self-explanatory.

The ‘Set demonstration’ (show mode) feature allows the operator to select a particular point in a scene (within the aiming square - limited by the travel distance of the turret) that sets the selected point of reference. The aiming point will simulate a search mode by tracking around the screen for two or three minutes at a time. Once away for two or three minutes, it automatically returns to the selected reference point and will randomly flash, take a black-and-white image of the sign and then return to random motion.

While in the ‘Show Mode’, the color shutter and the black-and-white shutter are functional.

**Flash Only** -
This feature does just that. It flashes only and does nothing else - it remains in the black-and-white mode.

**Demo Mode** -
To use this feature, move the middle mouse button or left tracking button and the system will override the demo (which is still running) and move the aimpoint away from section initially selected. During a demonstration, click on a sign and select ‘flash only’—the camera will flash the sign and keep the black and white image of it. At this point, if the operator returns back to the ‘mono’ option, and the image is lost.

**Flash & Process** -
This option can be used to actually store the data only if ‘auto store’ preference is selected. Auto return to center also functions in the ‘demo mode.’

**System Shutdown**

The following are the procedures necessary to successfully shut off the system.

1. Store turret (press the SB button - Store backwards button) This causes the turret to go to the stowed position. It stops at approximately 180 degrees. The operator should make sure the turret is properly aligned with the pin positions. The operator will put the pins in before shutting off the computer to ensure that the mount does not drift.

2. Put the pins in the mount.

3. Turn the Black box (Driver Electronics) off. This will allow the operator to physically move the mount if step two was not done. Make sure that the pin and mount are properly aligned. If the Driver Electronics is not turned off at this point, it will be impossible to manually move the mount.

4. Next, press the “File Exit” button and then select “Start”, “Shut Down”. This turns the computer off (shuts down the computer)

5. Turn the computer power switch off

6. Turn off the Inverter under the rear seat.
RetroSign®
RETROREFLECTOMETER
Manual
On site quality verification of road signs
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APPENDIX C

QUICK GUIDE FOR RETROSIGN EXTENSION KIT

Connection
The battery is mounted by unscrewing the bottom plate and removing the battery container. Then inserting the new battery, notice that the red wire end of the battery container must be connected to + on the battery. Then assemble the Extension kit again.

Mount the Extension kit to the Extension pole by using the two screws and the back profile that is included in the package.

Connect the Extension kit to the RetroSign by inserting the cable connector into the RetroSign.

Getting started
Turn on the RetroSign.
Take a measurement by pressing the < R' > button on the Extension kit. In this order the display shows:
(The measurement is an example):

```
230
```

The result of the measurement is the same as shown on the RetroSign and the instrument is now ready for a new measurement, just press the < R' > button ones again.

If no measurements are made, the Extension kit will keep the RetroSign alive for app. 4 minutes, then the Extension kit will automatically shut down and the RetroSign will shut down according to the time-out for this instrument.

If an error occurs during a measurement the Extension kit show:

```
Err
```
There can be a calibration error, battery error or something else, according to the RetroSign manual. When this happens, take down the RetroSign for examination.

The <R> button is pressed on the Extension kit, when the RetroSign is turned off, the Extension kit will show "Err" the moment the RetroSign is turned on again. This is no error, just push the <R> once again and the measurement is made.

**Battery**

The battery should be changed at least every year.

If the Extension kit is not used, it will still use a small amount of power, so be sure to mount the battery before use.

The battery voltage is low, the display will show a battery warning. The "LO BAT" warning tells the user that the battery should be changed in the near future.

The battery is changed by unscrewing the bottom plate, removing the battery container and using a screwdriver to remove the old battery. Put in a new battery and assemble the extension kit again.

The battery type is: DL123A, 3V, 1.300mAh. (or similar)

---

**DISCLAIMER**

The information contained in this document is subject to change without notice.

DELTA Light & Optics makes no warranty of any kind with regard to this material, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. DELTA Light & Optics shall not be liable for errors contained herein or for incidental or consequential damages in connection with the furnishing, performance or use of this material.

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Rev. 280699
Dimensional drawings

RetroSign dimensions

324 mm

295 mm
**SECTION 1**

**INTRODUCTION**

**RetroSign® introduction**

The RetroSign retrometer is a portable field instrument, intended for measuring the retroreflection properties of road signs in car headlight illumination. The value $R'$ (coefficient of retroreflected luminance) is used. $R'$ is a measure of the lightness of the road signs as seen by drivers of motorized vehicles in headlight illumination. RetroSign is available in different versions. For type 4000 the sign is illuminated at an angle of +5° and the angle between illumination and observation is 0.33°. For type 4500 the sign is illuminated at an angle of +5° and the angle between illumination and observation is 0.33°. This corresponds to an observation distance of 100 metres. Thus, relevant for a motorist viewing situation under normal conditions.

![RetroSign Retrometer](image)

**Electrical characteristics**

EMC ........................................ EN 50081-1
........................................ EN 50082-1

Power supply:

Battery ........................................ Replaceable NiCd 9.6 V / 1.2Ah
........................................ Bosch part number: 2 607 335 012

External charger ............................. Mains voltage 230 VAC
Optional: 110V / 60Hz

Charge time ..................................... Approx. 15 minutes

Data memory ..................................... 1000 measurements
Data retention (from purchase) ................ Typ. 5 years

Interface ...................................... RS 232
Serial communication mode .................... 9600,N,8,1

**Environmental characteristics**

Temperature: .................................... 0°C to +45°C
........................................ 32°F to 113°F

Humidity ...................................... Non condensing

**Mechanical characteristics**

Length .......................................... 295 mm / 11.6 in
Width ........................................... 83 mm / 3.3 in
Height .......................................... 324 mm / 12.8 in
Weight .......................................... 2.1 kg / 4.6 lbs
Gross weight .................................... Approx. 6 kg / 13.2 lbs
The operation of the retrometer is very simple and requires a minimum of instruction. An error or warning message is given in case of unreliable or erroneous measurement.

The RetroSign measures the retroreflection and calculates R' according to international agreements. Results are presented on a LCD panel. The non-volatile memory provides on site registration of measurements with corresponding date and time.

RetroSign has a built in function to mark each measurement with a user defined name (measurement id) and a unique sequence number.

Data communication on RS232 port gives extended command, calibration, diagnostics and data dump facilities.

The RetroSign is powered by a rechargeable battery, giving several hours of measurement capacity. A mains powered battery charger is supplied as standard.

**RetroSign retrometer features**
- Portable self-contained instrument
- Measurement in full daylight
- Photopic corrected detector and source “A”
- Automatic stray light compensation and error diagnostics
- Measurement geometry and illumination corresponding to realistic viewing condition in night time traffic
- Direct digital read out
- Real time clock
- Automatic data storage in internal non-volatile memory
- RS232 serial communication for operation, data dump, extended control and diagnostics
- Communication cable
- Long battery life
- 230 V / 50 Hz or 120 V / 60 Hz mains powered battery charger

**APPENDIX B**

**SPECIFICATIONS**

**General characteristics**

**Type 4000:**
- Geometry ........................................... DIN 67520: 5°/0.36
- Illumination angle .................................. 4°
- Illumination / observation angle ................. 0.32
- Light source angular aperture .................... 0.16
- Receptor angular aperture ....................... 0.16

**Type 4500:**
- Geometry ........................................... ASTM-E-1709: -4°/0.2
- Illumination angle .................................. 4°
- Illumination / observation angle ................. 0.2
- Light source angular aperture .................... 0.1
- Receptor angular aperture ....................... 0.1

**Type 4000 / 4500:**
- Field of measurement ............................. ø 30 mm / 1.2
- Light source ........................................ Illuminant “A”
- Receptor sensitivity ............................... Precise eye correct (ASTM-E-1709 para. 6.4.2 for selected color filter)
- Min. reading (cd/lx·m²) ........................... Typ. 200
- Max. reading (cd/lx·m²) ........................... Typ. 200
- Automatic programmable power off function
- Easy calibration procedure
- Reference cap for calibration
- Carrying case (foam lined)

Options
- Extension pole kit
- Fast 12V powered battery charger (approx. 15 minutes)
- Battery (extra)
RZ  RetroSign Zero calibration. RZ is a part of the instrument's start-up and calibration procedure. Use RZ on the reference cap's zero-calibration standard. Confirm with <Y>. Must be succeeded by the RC-command.

SN [nnnnnn]  Sequence id text. Maximum 6 characters including spaces. 6 spaces disables the sequence id text.

SD   Status Dump. Returns instrument status. All settings and values are displayed. Used for verification and trouble shooting.

TI [hh mm ss]  Set TIme in real time watch.  TI without parameter returns current date and time from real time watch.

TO  Turn RetroSign Off immediately. Same as pressing OFF button on keyboard.

TX [T/F]  Text mode True/False. If TX is true RetroSign will return information to the serial port in plain English. At instrument power on TX will always be false.

VA  Voltage Alarm. Returns set point for low battery warning icon.

VB  Voltage Battery. Returns actual battery voltage.

VS  Voltage Status. Returns battery voltage with and without lamp switched on. Returned values are from last time lamp was switched on.

?  Returns help menu.
SECTION 2

OPERATING INFORMATION

Getting started
Turn the RetroSign on by pressing ON/C.
After approx. 2 seconds the display will show:
Calibrate instrument if necessary, see calibration.

Icons
Instrument status and operational mode are signalled by the use of icons. Icons are shown in the top line of the display.

Auto Off Timer n=seconds (0..599 sec.).
Sets the time for automatic instrument turn off. n < 60 disables the automatic off timer.

RetroSign Calibration. Use RC on the reference standard.
n=calibration value from the reference standard. RC without parameter returns the calibration value (n).

When is active the instrument is calibrated and ready for use.

Start a measurement by pressing the red trigger knob on the handle. A beep indicates the start of the active measuring cycle. The display shows an hourglass for the duration of the measurement, approx. 3 seconds. A new beep signals the end of the measurement.

If any errors are detected during the measurement or calibration sequence, an error icon and error number is shown. See also Section 3 - Note on error sources.

505 will respond like this:
50, 1996-07-25 11:15:00, 210, 0, xyz-a, 34
51, 1996-07-25 11:17:00, 180, 0, xyz-a, 35
52, 1996-07-25 11:20:00, 302, 0, xyz-a, 36
53, 1996-07-25 12:00:00, 210, 3
54, 1996-07-25 13:15:00, 235, 3, xyz-a, 37
End of Log File

A log dump can be terminated by any key.

Log Open.
Activates the built-in log for storing measuring and calibration data. Measuring number, date, time, R', mode and sequence id are logged. Only valid measurements and calibrations are logged.

Log Reset.
Deletes all stored data. Log must be open. Confirm with <Y>.

Log Stop.
Closes log. Measuring data is no longer logged.

R' Measurement.
Executes measurement cycle. Returns R'. Same as using instrument trigger.

Read R'.
Returns result of last R'M-command.
**Sequence id**
RetroSign has a built in function to mark each measurement with a user defined name (sequence id) and a unique sequence number automatic generated by the instrument. The sequence id and the sequence number will also be stored in the log. The length of the sequence id text is 6 characters. See *Menu system*.

**Keyboard functions**

<table>
<thead>
<tr>
<th>Button</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON/C</td>
<td>Push shortly to switch on instrument. When switched on it clears the current operations. Redisplays the last measuring result.</td>
</tr>
<tr>
<td>OFF</td>
<td>Turn off RetroSign.</td>
</tr>
<tr>
<td>↑</td>
<td>Activate menu system. Scroll key when in menu system. Parameter and value increment / decrement.</td>
</tr>
<tr>
<td>↓</td>
<td>Activate menu for instrument calibration.</td>
</tr>
<tr>
<td>← Enter</td>
<td>Activate selected function or accept changed settings.</td>
</tr>
<tr>
<td>Trig</td>
<td>Start R’ measurement. Start fast calibration.</td>
</tr>
</tbody>
</table>

**Log Dump**
Returns measuring number, date, time, R’, mode and sequence id. Each value are separated by comma. Data can easily be imported in a spreadsheet e.g. Microsoft Excel.

*LD without parameters will respond like this:*
1, 1996-07-30 08:22:53, 200, 0, Roadxy, 1
2, 1996-07-30 08:23:42, 385, 0, Roadxy, 2
3, 1996-07-30 08:26:58, 210, 2
4, 1996-07-30 08:27:58, 296, 0, Roadxy, 3
End of Log File

Column 1 = measurement number, 2 = date/time of measurement, 3 = measured value, 4 = mode, 5 = sequence id (if any).

Mode indicates what kind of measurement was executed:
0 = normal measurement, 1 = fast calibration, 2 = full calibration, 3 = calibration via communication port (RC command).

Including parameters to the *LD* command specify the log start number and the length (numbers of lines). If n2 and n1 are omitted data starts from log position n1 and to the end of the log file.

**Initialise Instrument settings. Confirm with <Y>.**
Sets instrument to factory settings. Calibration is necessary.

**L.A**
Lamp current Alarm.
Returns set point for low lamp current alarm.

**L.C**
LampCurrent.
Returns the lamp current measurement from the last *R* measurement.

**Calibration**
RetroSign features two levels of calibration: *fast* and *full*.
*Fast* calibration is an "everyday" calibration using factory zero calibration and default reference value. Default reference value can be changed only when
RetroSign can respond to a command in two ways: data mode or text mode. RetroSign always powers up in the data mode. This mode is used by the RSCad Sensor Control program.

Special command, TXT, is used to set RetroSign to respond in text mode. The user should set RetroSign to respond in text mode if a simple communication program is used instead of the RSC program.

Example: The user wants to set the automatic off timer to 120 seconds. The command should look like this:

OT 120 <CR> or OT120<CR>

The RetroSign accepts the command it responds:

120

text mode it responds with the message:
Automatic Off Timer = 120 sec.

For some reason the communication fails or the command is rejected RetroSign responds with a question mark <?>

The parameter exceeds the defined range for that parameter, RetroSign returns the present setting without any change.

Command set
The following command action are all:

Command: Action:
L [T/F] Display Backlight True/False.
True enables display light. False disables light.
A [yyyy mm dd] Set year, month, date in real time watch.
DA without parameter returns current date and time from watch.
V Returns Firmware Version.

Using the full calibration mode.
Full calibration is used for high accuracy calibration of zero and reference.

- Fast calibration.  
Fast calibration is initiated by pressing and then trigger. Mount reference cap (reflective bottom) before triggering. Calibration is executed immediately. Default instrument zero (factory setting) is used.

- Full calibration.  
Full calibration is initiated by pressing and .
Follow the procedure displayed.

Zero.  
Mount the zero cap (dark bottom) on the instrument. Press when ready. When hourglass disappears instrument is ready for next step in the calibration procedure.

Reference.  
Mount the reference cap (reflective bottom). Edit reference value using until correct.
Press when ready.
When the hourglass disappears confirm with when ready. Cancel with ON/C.

After a successful calibration the icon is active.
If for some reason the calibration fails, values from the previous successful calibration are used. This information is given immediately after calibration.

Reduced Aperture option.
When the instrument is configured for measurements with reduced aperture the calibration monitor should be disabled to avoid the “Error in Calibration” condition, the display icons reflects the status for this option.

Menu system
Press or to activate the menu system from top or bottom end respectively. When menu is selected use and to scroll through function. To select the shown function press .
Menu points are:

- **Remove top data in log.**
  This function allows the user to delete the top level in the data log. The deletion restores the Sequence ID text string and measurement counter from the log. The deletion process can be continued until the log is empty. Deleted data cannot be recalled.

- **Data log enable / disable.** (Log Open).
  Switches on / off the built-in data logger. Press ← to toggle selection. When the log is enabled the \( \mathcal{Q} \) is shown and the bottom display line will show the number of measurements stored in the log and date / time for the last log entry. When the log is full the \( \mathcal{Q} \) is shown and log stops.

- **Data log clearing.** (Free data log).
  Clears built in data log. Also shows the remaining space in the log in percent. Press ← to clear data log.

- **Off time (power save).**
  Settings for automatic instrument power off. When selected use ↑ and ↓ to edit off time. Off time less than 60 sec. will disable automatic power off!

- **Initialize instrument.**
  Initialize the instrument to factory default settings. The instrument has to be calibrated afterwards. The log data and sequence id are not affected but the log is closed afterwards.

- **Display light.**
  Enables or disables the display back light. Press ← to toggle operation. When display light is enabled the \( \mathcal{X} \) is shown. The back light will light for a moment when any key or measurement trigger are pushed.

- **Clear Seq_ID.**
  Clears the sequence id as if all 6 positions were set to space. Press ← to clear. See also Sequence ID.

- **Sequence ID.** (Old Seq_ID)
  If any sequence id is defined, the id text and a sequence number is shown

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**APPENDIX A**

**COMMUNICATION FACILITIES**

**RS-232C specification**
The RetroSign is equipped with a communication facility that enables the use of a simple terminal or an ordinary PC type computer for control of the RetroSign functions and for dump of data from the internal data log.

The computer or terminal connects to the RetroSign using the connector on the rear and a special communication cable. The cable is mounted with a 9 pin female connector for computer connection. Use of a 9 to 25 pin adaptor may be necessary on some computers.

The electrical connections meet the normal standard for serial communication.

**Data protocol**
The communication between the RetroSign and the computer equipment takes place using the following settings:

- Baudrate: 9600 bit/sec
- Number of databit: 8 bit
- Parity: none
- Stopbit: 1 bit

**Command format**
All RetroSign commands are built using the following template.

<table>
<thead>
<tr>
<th>Command</th>
<th>Letters (not case sensitive) or &lt;?&gt;.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delimiter</td>
<td>One or more spaces, optional.</td>
</tr>
<tr>
<td>Parameter</td>
<td>One or more integer or real numbers seperated by space, optional. Parameters in square brackets are optional. If no parameters are entered the actual value is returned.</td>
</tr>
<tr>
<td>Delimiter</td>
<td>One or more spaces, optional.</td>
</tr>
<tr>
<td>Command end</td>
<td>Carriage Return (&lt;CR&gt;), mandatory.</td>
</tr>
</tbody>
</table>
in the display. To edit the sequence id press the \( \text{↵} \) button. The \( \text{↵} \) cursor is placed to the right of the first character position. Use the \( \uparrow \) button to scroll through the alphabet in direction 0..9,A..Z starting with the space character. The \( \downarrow \) button will scroll through the alphabet in opposite direction. When the wanted character is shown press the \( \text{↵} \) button to advance to the next position. You have to step through all 6 positions before the sequence id function can be accepted.

When typing a new sequence id text or editing an old one, the sequence number is reset to 0. When all 6 positions are set to space the sequence id function is undefined and no longer included in the log nor shown in the display.

**Battery / charging**

Temperatures in excess of 50°C (122°F) will damage the battery. Do not short circuit. Do not dispose with household waste.

To remove battery swing over battery retaining spring and pull out battery from handle. *See Section 4 - Battery* for further information on charging.

**Remote control**

*External trigger.*

By use of the connector on the rear of the instrument, it is possible to remote trigger the instrument.

**Serial communication.**

The instrument is equipped with a serial communication port. This allows complete instrument control and data collection.

Use a simple terminal or PC with communication software to control the RetroSign.

Serial communication setup (RS232 interface):

- 9600 baud, No parity, 8 bit, 1 stop bit

**Selected commands.**

- \( \text{L} \) (Log Open): Enables log for input.
- \( \text{L} \) (Log Dump): Number, date, time, \text{R}', mode.
- \( \text{R} \) (R'Measurement): Start \text{R}' measurement.
- \( \text{S} \) (Status Dump): Returns instrument settings and status.
On-line help.

RetroSign will return a brief help page of command set.

See also Appendix A - Communication facilities.

Aperture Reduction.

For special measurement requirements on small targets, the RetroSign can be mounted with a special Aperture Reducer Unit, this reduces the field of measurement to either $\phi$ 15 mm (0.6 in) or $\phi$ 10 mm (0.4 in) depending on the unit used.

To achieve the smaller aperture, the reduction unit is simply mounted in front of the lens barrel.

There is however one drawback in using the aperture reduction unit! The signal values obtained during the calibration procedure will be much smaller than originally anticipated, this and the fact that the instrument default is set to interpret low signal values during calibration as an error condition, will render the calibration useless and not allowing the user to make any measurements.

To avoid this situation, instrument with firmware version 1.28 and higher have a new menu feature that controls the error monitor function. Disable the Calibration Monitor when using the Reducer!

Calibration

The RetroSign is factory calibrated, but a calibration should always be carried out before starting a series of measurements.

After compensation of zero signal, leakage and other known "errors" the calibration factor is easily calculated. This is done automatically by the instrument if the calibration routine is followed. After a calibration the retrometer will display "true" $R$.

Store the reference cap in a dry and clean environment.

See also Section 2 - Getting started and Section 3 - General information.
SECTION 4

MAINTENANCE

General care
The retrometer is constructed for outdoor use in ordinary good weather conditions. It will withstand moist weather, but caution must be taken against rain or splashes and dirt from traffic. The RetroSign retrometer is an optical instrument and shall be handled as such. Avoid shock and vibration if possible.

Front lens
The lens does not need special maintenance. If dirty carefully moist the lens with ordinary window cleaning liquid and clean it with a soft cloth.

Battery
The instrument is powered by a Ni-Cd battery, which under normal use requires no maintenance.
A battery charger is provided as a standard accessory for charging the battery from mains.

To recharge the battery swing over battery retaining spring and remove battery from the handle.
Please refer to enclosed charger instructions for operation and for details of the charging process.
A new battery or one which has not been used for an extended period achieves full performance only after approx. 5 charging and discharging cycles.

The battery is equipped with a temperature monitor which allows charging only within a range between 0°C and 45°C (32°F and 113°F). This ensures long battery life. When used properly, the battery can be recharged up to 100 times.
A substantial drop in operation period per charge indicates that the battery is worn out and must be renewed.

Battery and charger are specifically designed for use in conjunction with other
other. Charging should be performed exclusively with the charger delivered with the instrument.

Do not expose battery to heat or flames: **Danger of explosion.** Do not place battery on a heater or expose to direct sunlight for long periods. Temperatures excess of 50°C (122°F) will damage the battery. Allow warm battery to cool before charging. When battery is outside the instrument, cover the contacts to void short circuits.

void repeated consecutive rapid charges of the battery. Do not recharge after ing only briefly.

**Note**

Battery should be protected against impact. Do not open battery. Store battery in a dry place where it is protected against freezing. Due to environmental protection do not dispose battery with household waste.

**Lamp**

The lamp requires no maintenance. At life end the instrument will display a lamp error and the lamp must be renewed. It is recommended that renewing is done by trained personnel.

**Reference cap**

To make sure that the calibration of the retrometer is correct it is important that the surface on the reference cap is clean and undamaged. Keep the cap protected, and be aware of that you don't touch the reference cap (reflective bottom).

If the surface is stained, scratched or broken the reference cap has to be placed.

If case of dust on the surface, clean it gently by use of a soft cloth with a mild household detergent. Wipe carefully with dry cloth afterwards.

To ensure reliable measurements, it is recommended that the reference cap is

**Disabling the Calibration Monitor:**

Press the ↑ or ↓ until the display shows Calibration Monitor ON

Disable Now

Press ⬅ to Disable.

**Enabling the Calibration Monitor:**

Press the ↑ or ↓ until the display shows Calibration Monitor OFF

Enable Now

Press ⬅ to Enable.

Be aware that the state of the Calibration Monitor normally cannot be seen in the display!

**Sequence ID**

From firmware version 1.28 the valid range for the Sequence ID has been reduced to only allow for the space character, numbers and the capital letters A to Z.
Battery

The RetroSign is powered by a replaceable rechargeable battery, which under normal operation will keep the retrometer operating a day. The battery must be charged by an external charger. See also Section 4 - Battery.

Note on error sources

The RetroSign is factory calibrated. Nevertheless, begin important measurements sessions with a calibration. See also Section 4 - Maintenance.

When stringing measurements RetroSign must be in close contact with the surface of the sign.

Daylight can enter the instrument between front-end and the sign. Leakage may under normal conditions not be significant. Nevertheless, it may occur. During each measurement the RetroSign automatically evaluates the leakage. The result is compensated before read out.

Instrument leak, drift and offset errors are compensated by means of data taken during the calibration procedure, so perform calibration procedure carefully. It is very important to keep front lens and surface on reference cap clean.

Values from measurements on wet signs are not reliable.

The RetroSign retrometer is a rugged instrument, but it is an optical instrument and must be handled as such. Store instrument in a clean and dry environment.

SECTION 3

GENERAL INFORMATION

RetroSign®

RetroSign retrometer measures the R' (coefficient of retroreflected luminance) parameter. The R' parameter represents the retroreflection of the road signs seen by drivers of motor vehicles by headlight illumination.

Physically the retrometer is a small hand held instrument. It is constructed in aluminum housings, containing electronics and the optical system. The measurement trigger button and the replaceable battery are housed in the handle.

The RetroSign is controlled by a microcontroller. The microcontroller executes a measurement automatically when the trigger is activated and the result is shown on the display. The result is automatically transferred to the internal non-volatile memory if logging is enabled. The RetroSign is operated from a small keyboard on the lefthand side of the retrometer. Retrometer control is also possible by a serial communication link (RS 232). Stored data can be transferred to a PC for further processing.

Factory calibrations

The RetroSign retrometer is factory calibrated. This calibration is carried out by using a special reference. The reference's R' value is measured in the laboratory using traceable methods and equipment.

The enclosed reference cap can be used for verification or recalibration of the retrometer.
Type 4000
In the RetroSign the illumination angle is +5° and the offset between observation and illumination angle is 0.33°. The measurement area is approx. ø30 mm.

Type 4500
In the RetroSign the illumination angle is -4° and the offset between observation and illumination angle is 0.2°. The measurement area is approx. ø30 mm. Or ø15mm/ø10mm when using the reduced aperture adaptor. According to ASTM R° it is named RA.