Mobile Survey of I15 HOV Lanes

Caltrans District 11 Brief

March 26, 2009

William J. Herr, MSEE, PE
wherr@phnx-sci.com
760.310.7469

Pavement Profile Scanner (PPS)

- Fast
- Accurate
- Available

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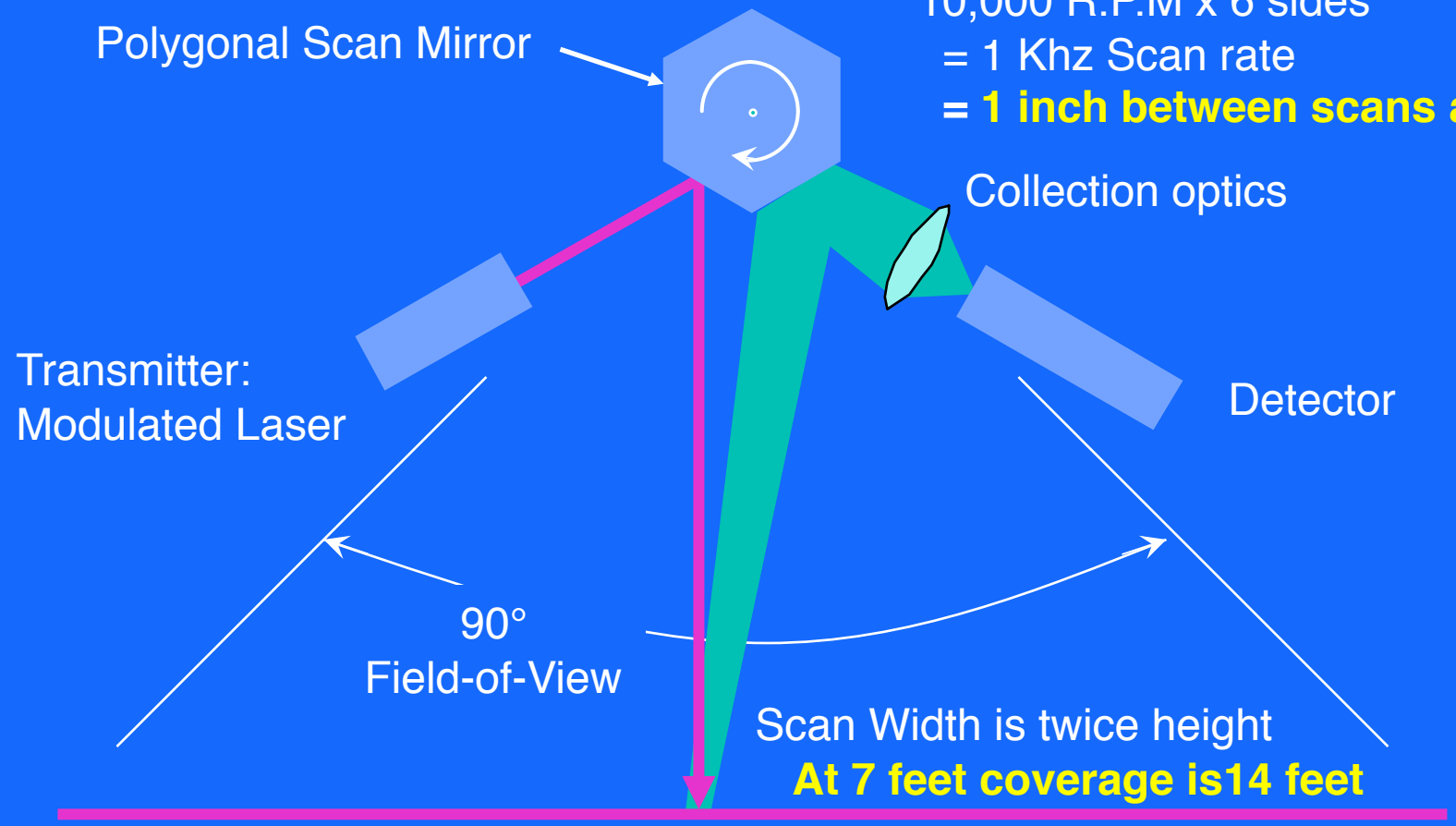
Polygon Scanner



PPS Performance Spec

- Phase Laser Radar (Class IIIB)
  - Developed for high speed pavement survey
- 1.258 Million Points per Second
  - 950 Points per scan
    - 0.15 to 0.28 inches between points
  - ±0.02 inch Accuracy at 1.258 MSPS
    - Precision + Bias
    - Peak to peak, not rms.

Applications

- Rolling Wheel Deflection
  - Technology Driver
- Rut and Ride
  - Rut Bar Replacement (IRI)
  - Texture, Distress Correlation, Shoulder
- Mobile Mapping
  - Precision DTM
  - Road Design, Vehicle Dynamics

Development Prototypes for RWD

USACE-WES SBIR funded development.

PSI Patented RWD

Rutting for LTPP

Roll-by Deflection Demonstrated

FHWA(ARA) SBIR – Rolling Wheel Deflectometer (RWD)

Single Scanner Used

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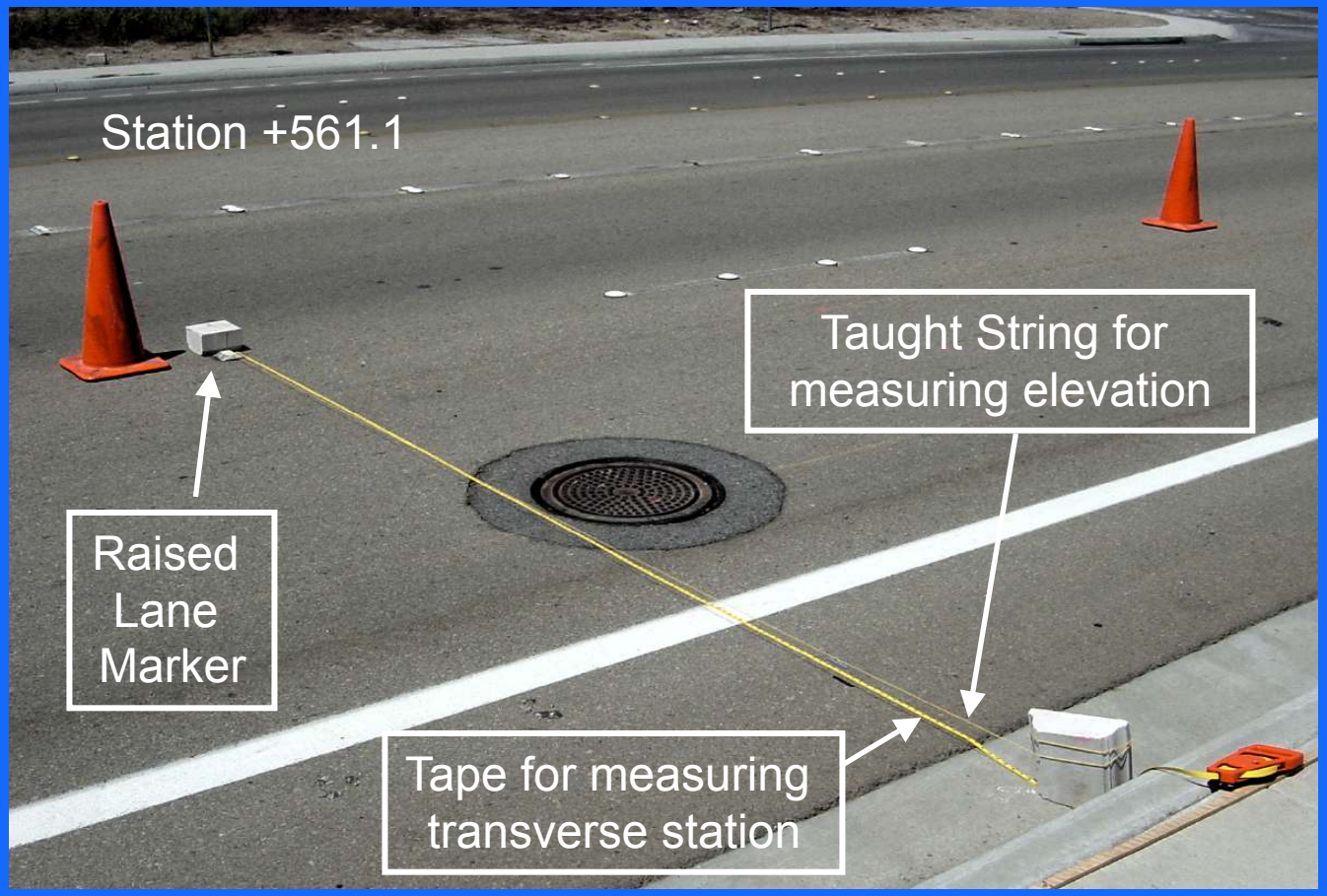
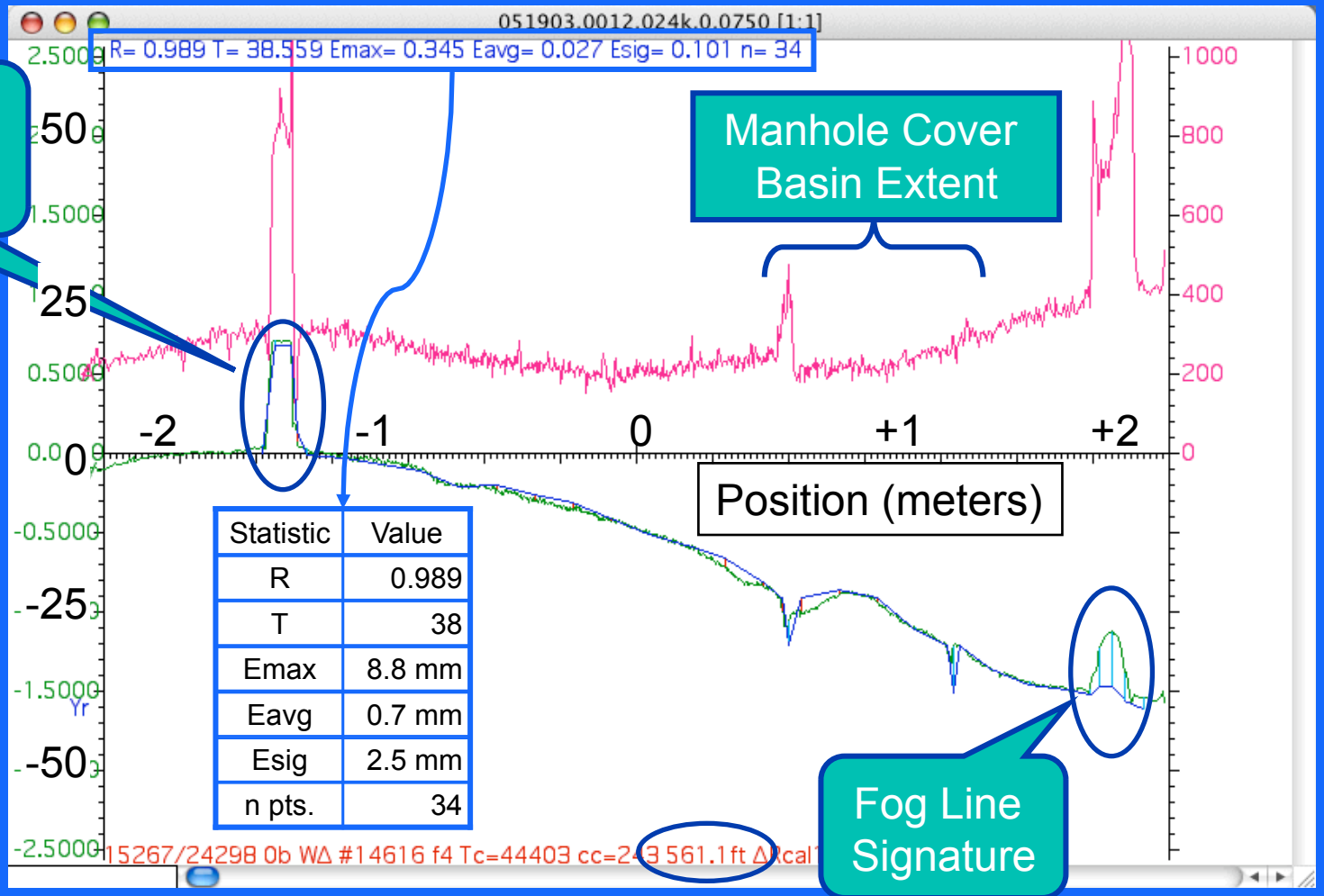
Road Condition Testing Units

In-service since October 2002

Transverse Profile Detail



Transverse Profile Scan



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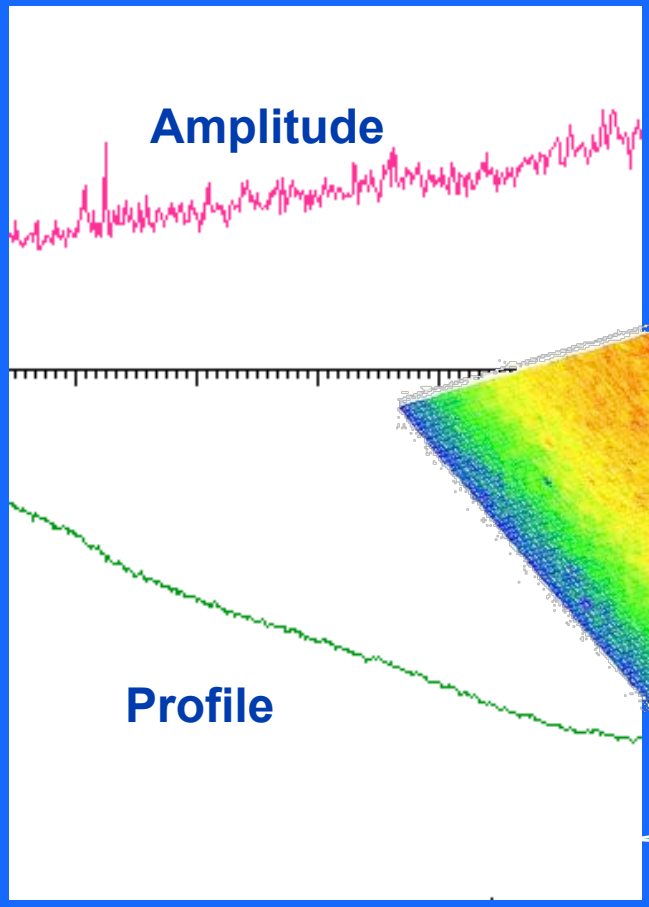
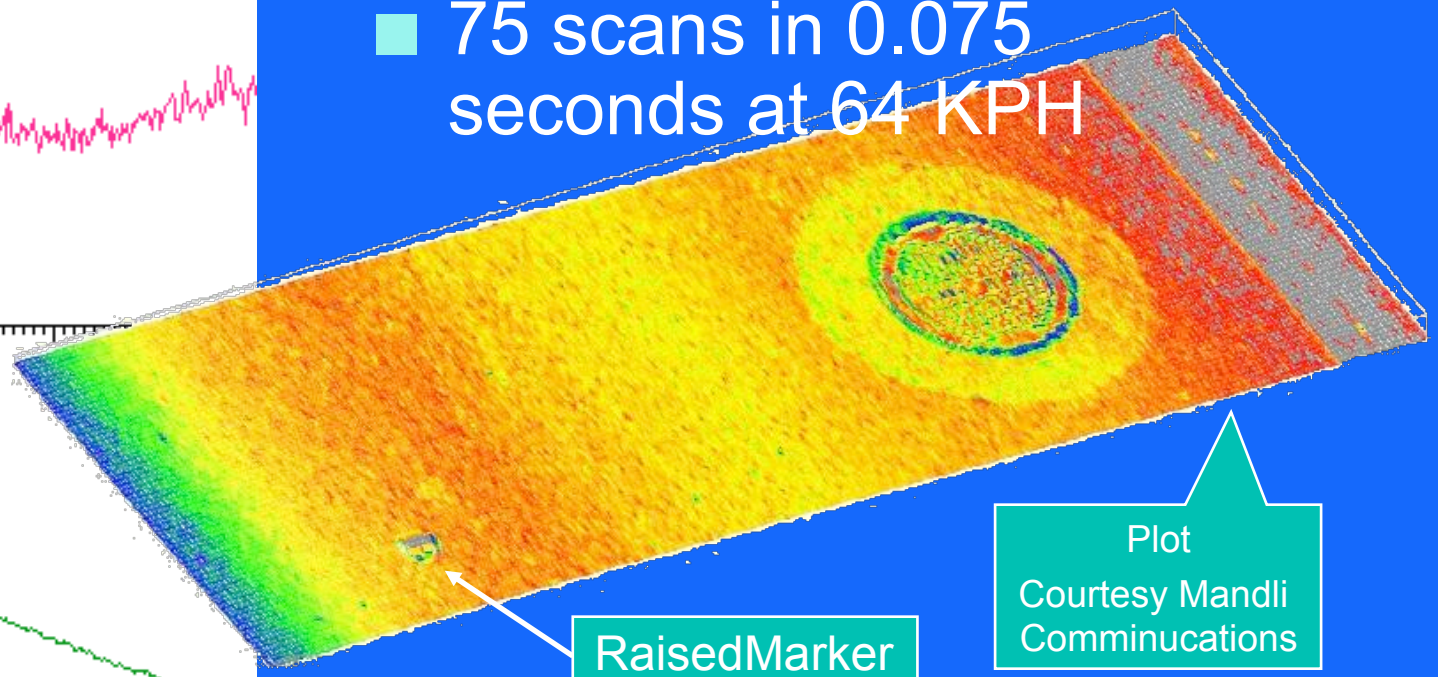
Manhole Sequence



Screen Capture

- 75 scans in 0.075 seconds at 64 KPH



RaisedMarker

Plot
Courtesy Mandli Comminucations

Screen Capture of Scan Display
Cropped to zoom on manhole

Scanner Functional Overview

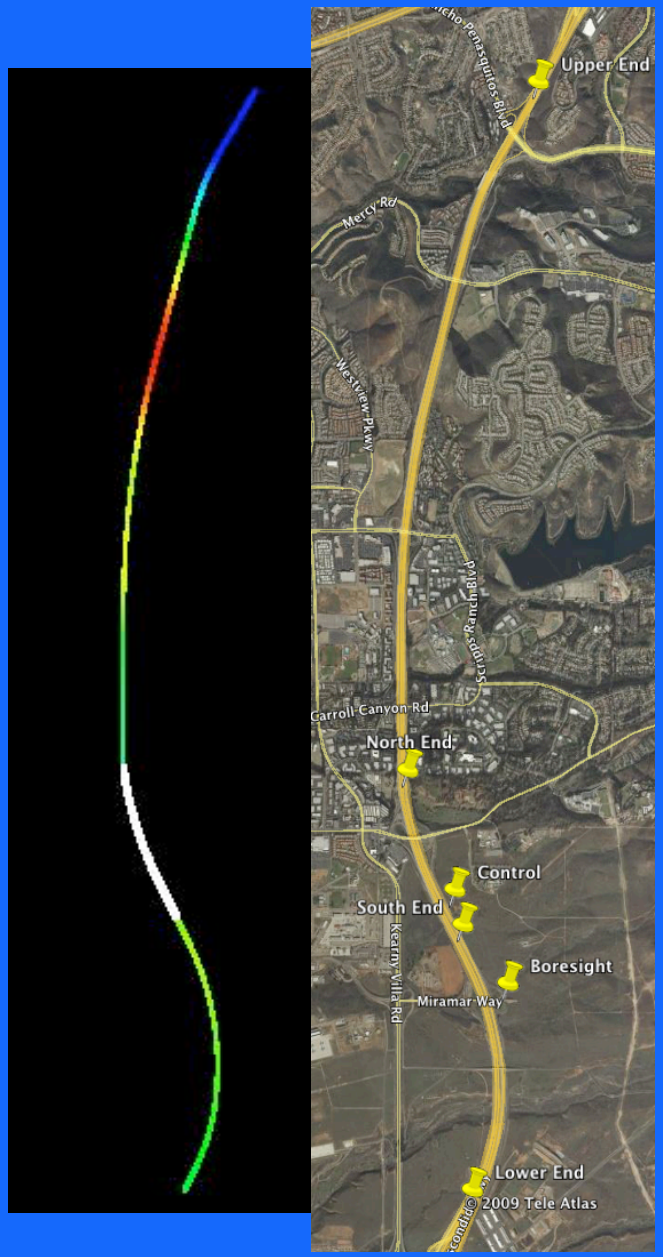
- Data Rich
  - 4MB/sec
  - 15 GB typical for 6 miles of 4 lanes + shoulders
- Multidimensional
  - Shape
  - Reflectivity
- Feature Recognition
  - Edge of pavement
  - Lane boundaries
  - Lane markings
  - Slope changes
- Optimal Decimation
  - Uniform DTM grid
  - Match Control Points

2005 Road Survey

- Road Reproduction for Ride Testing (BMW)
- LA Area (405)
- Impossible to close road
- Fine Grain DTM
  - Joints
  - Faults
  - Slab angles
  - Distress

I15 Project Overview

- Dave Olander
  District 11 Survey
- Reversible HOV Lanes
- 6 mile loop
- 0.9 mile (1.4 Km)
  Length surveyed by
  Caltrans District 11



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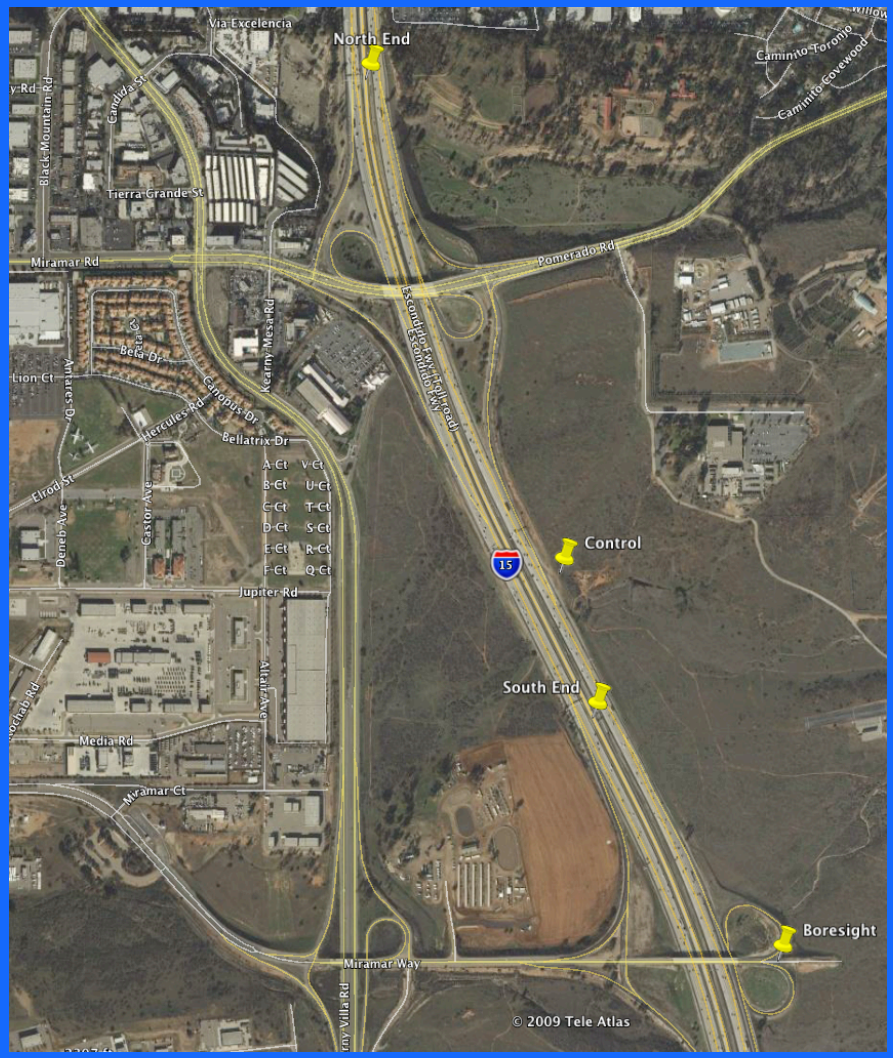
Surveyed Test Section

Two HOV Lanes

- 0.9 miles (1.4 Km)
- Overpass provides GPS outage

- Extensive Controls
  - Surveyed during midday direction reversal
  - 1,700 points
  - Cross section every 5 meters
  - 5-10 points per cross section



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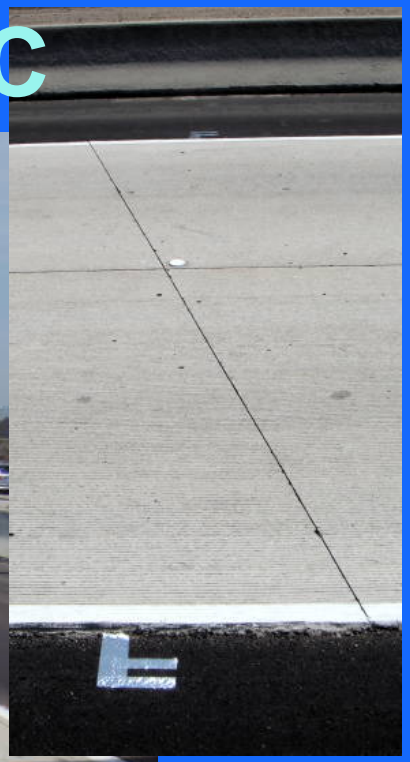
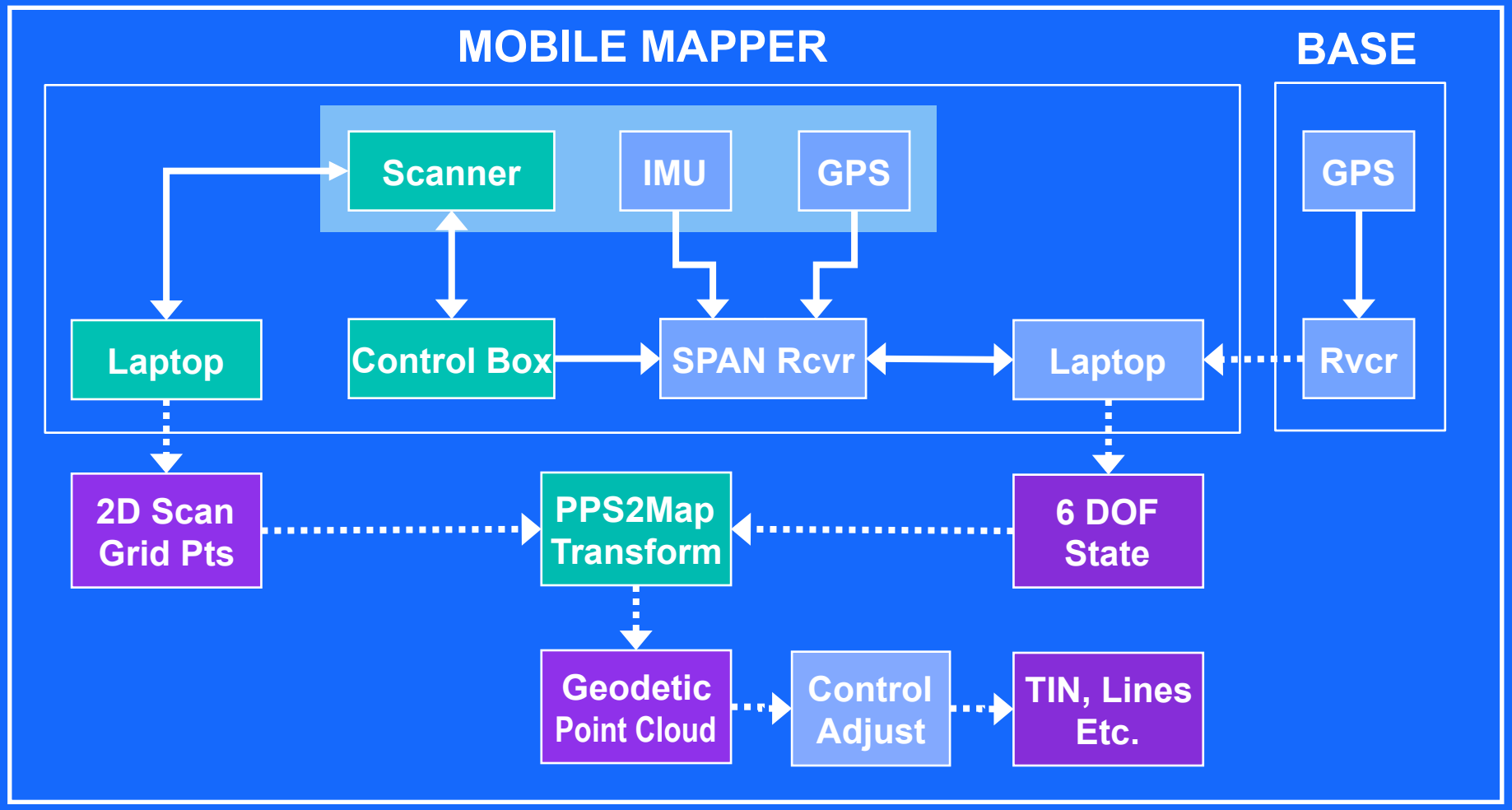
I-15 Survey Control

- Permanent Control
  - Used for conventional and mobile survey

Tinned and Jointed PCC



Survey System Diagram



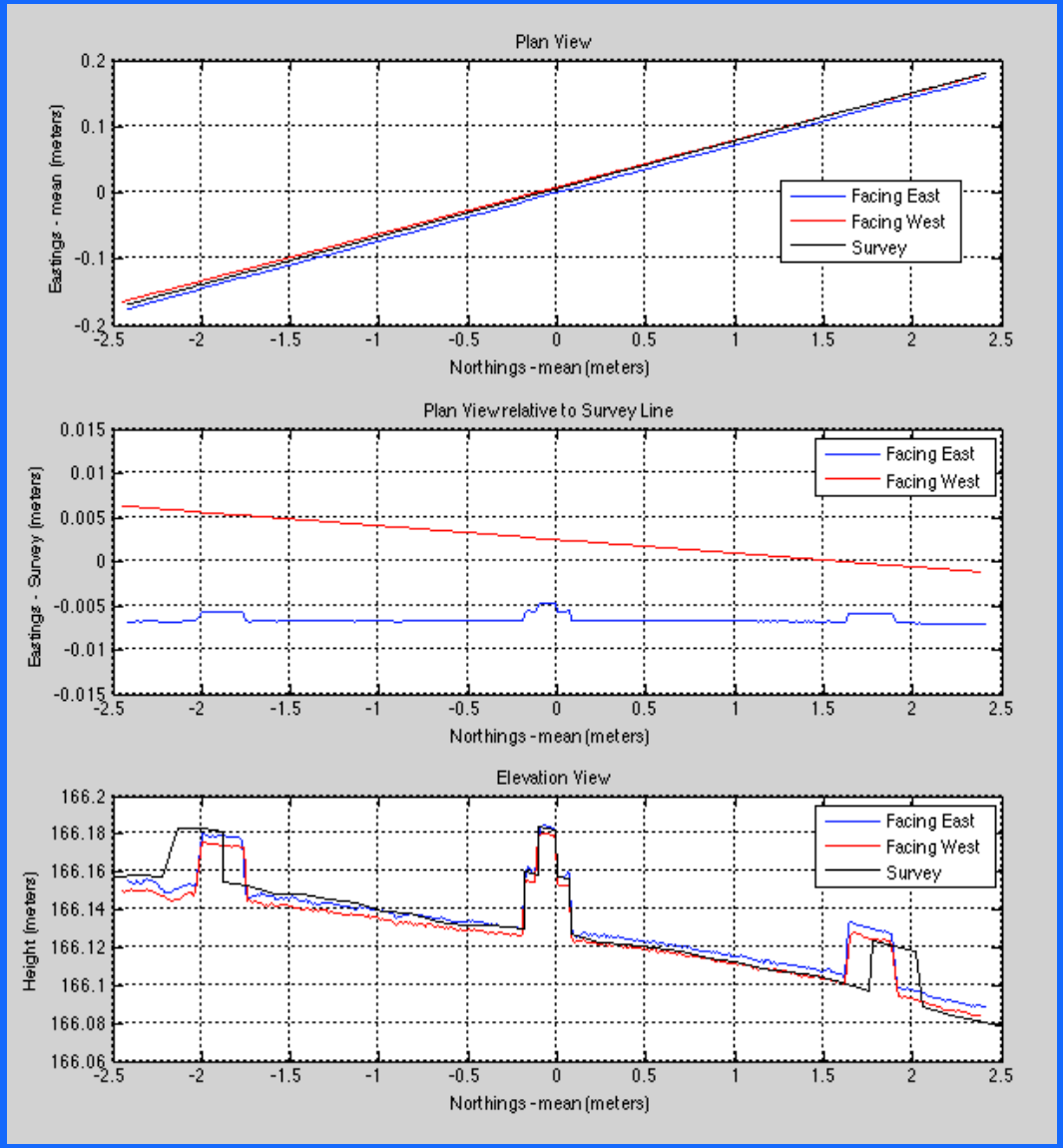
Data Processing

- Raw Scanner Data
  - 1 scan per inch – 944 points per scan
- LAS Files Analyzed
  - 1 scan per 6 inches – 32 points per scan
- Quantity of Data Analyzed
  - Reduced to 95% of raw (bin averaging)
  - 2 Million Points per Run – 16 Million Total

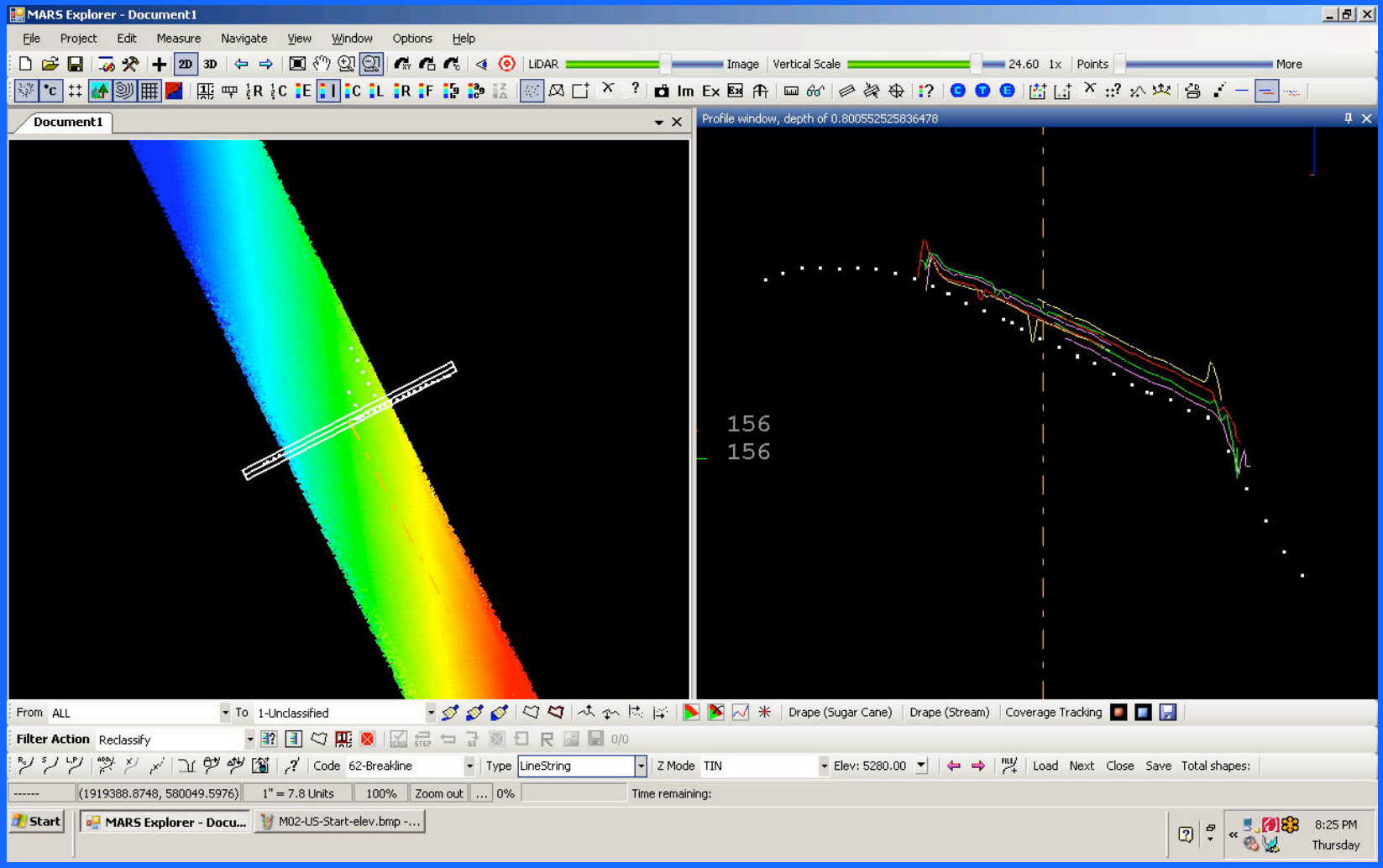
I15 Boresight

Boresight Results

- Process
  - 12 min static
  - East and West
- Results
  - Roll -1.25°
  - Pitch -0.25°
  - Yaw -0.01°



South End - Unshifted



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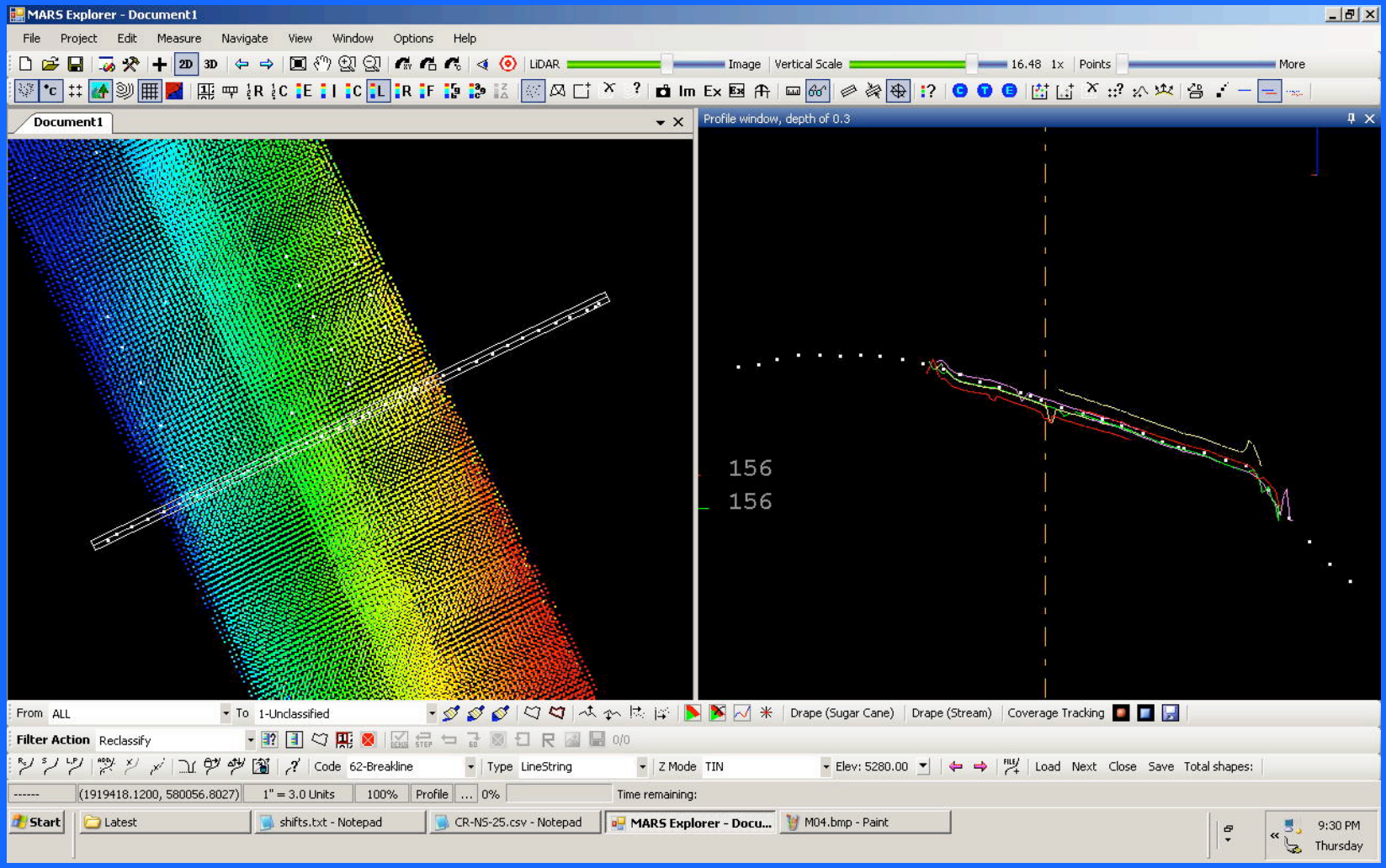
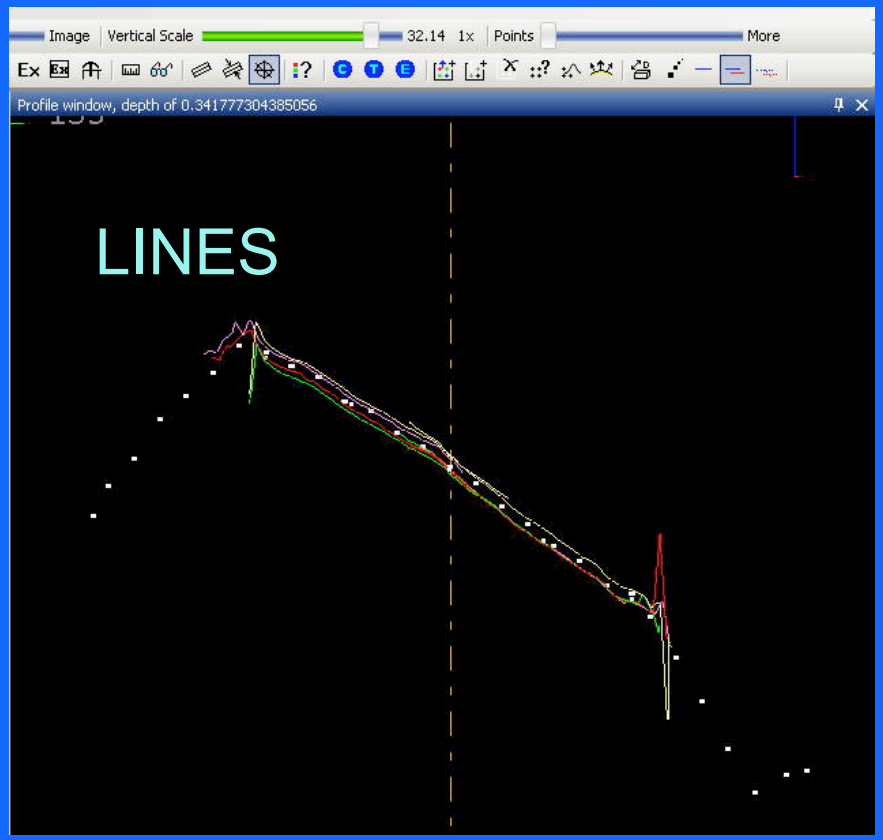
South End - Shifted

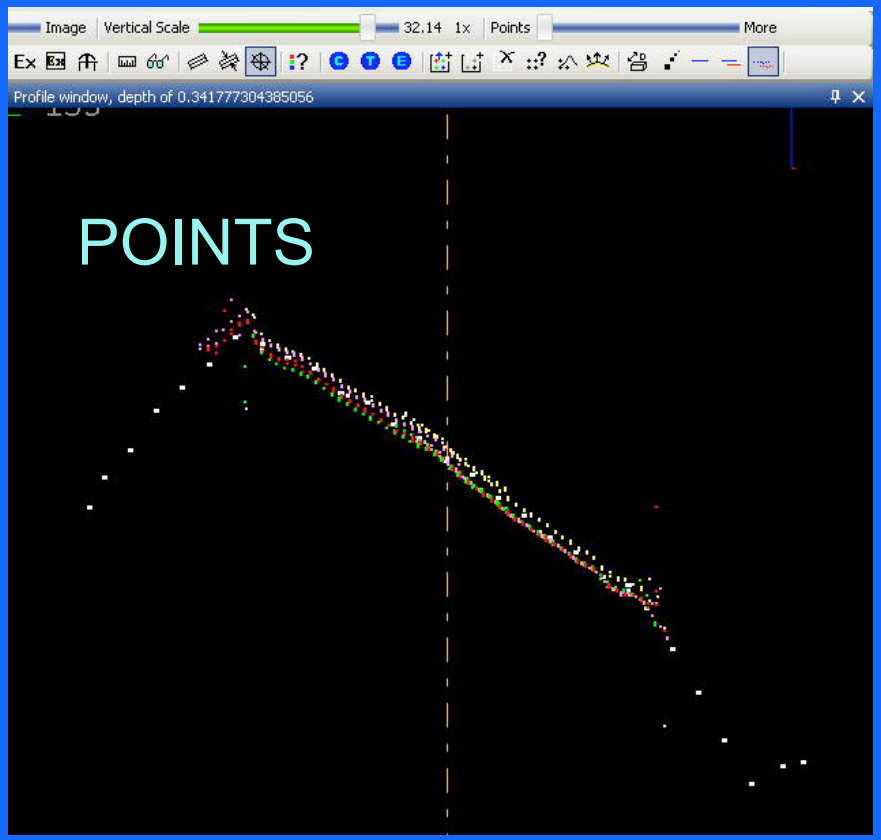


Run Summary

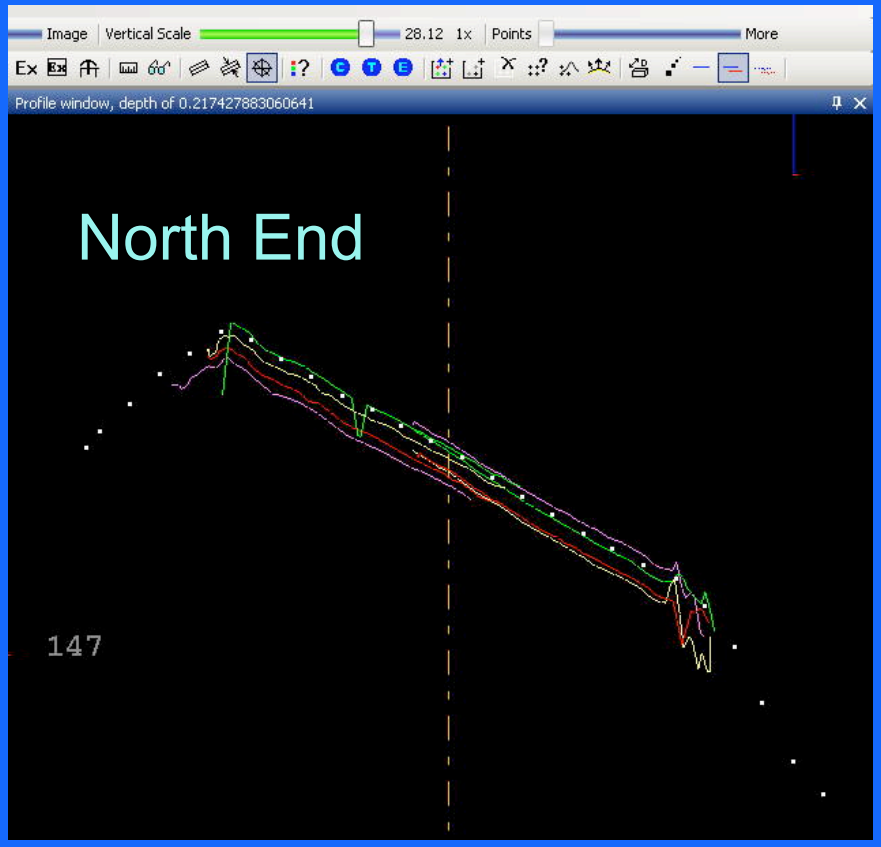
Run #	Drive Direction	Lane	Run Elevation Bias (cm)
10	South	West	1.7
11		East	2.5
12		West	2.8
13		East	4.0
22	North	East	2.5
23		West	1.8
24		East	3.9
25		West	2.5
Overall Average Elevation Bias (cm)			**2.7**

One Third North - Shifted

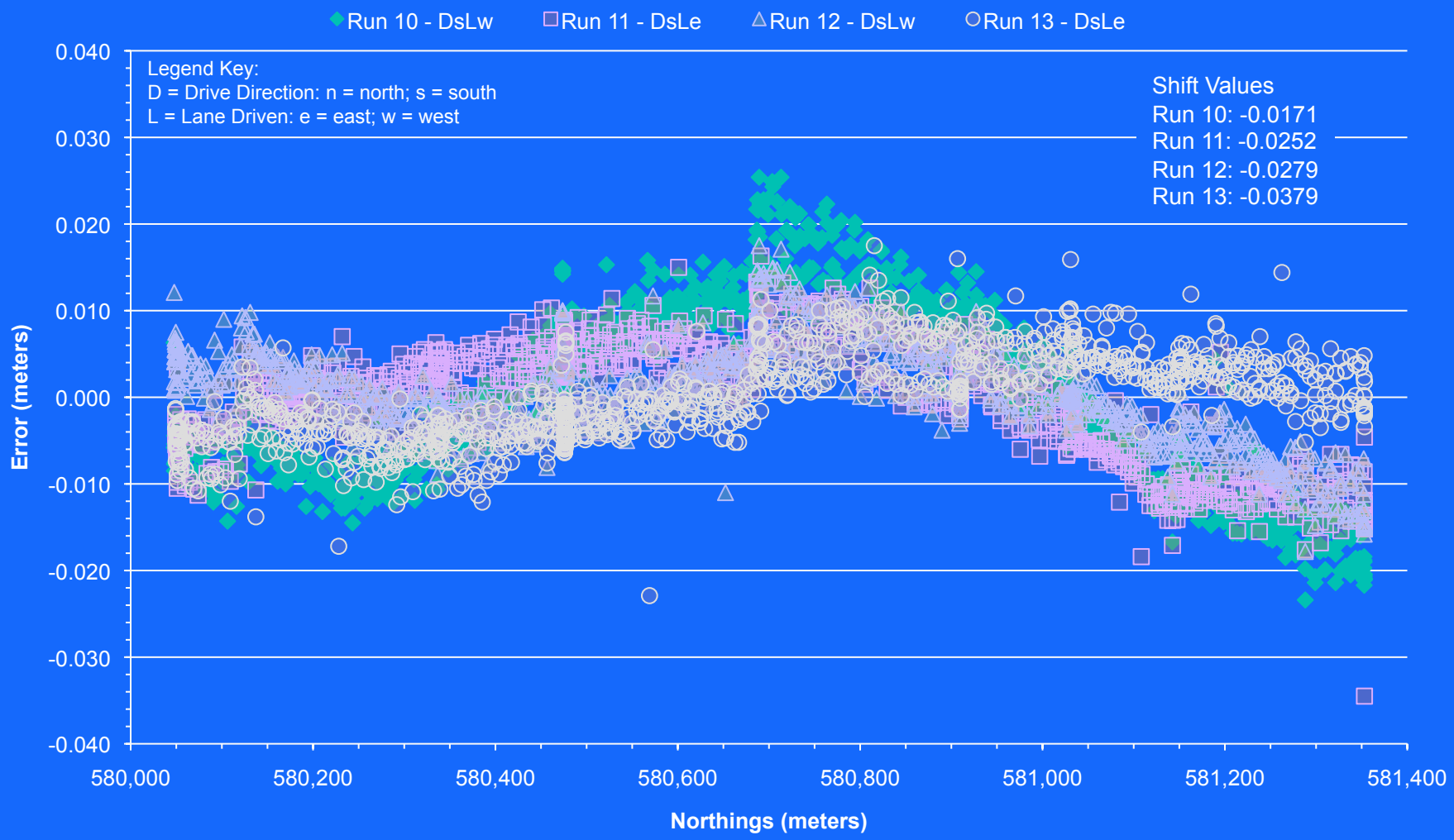




Two Thirds North & North End - Shifted



Runs Driving South



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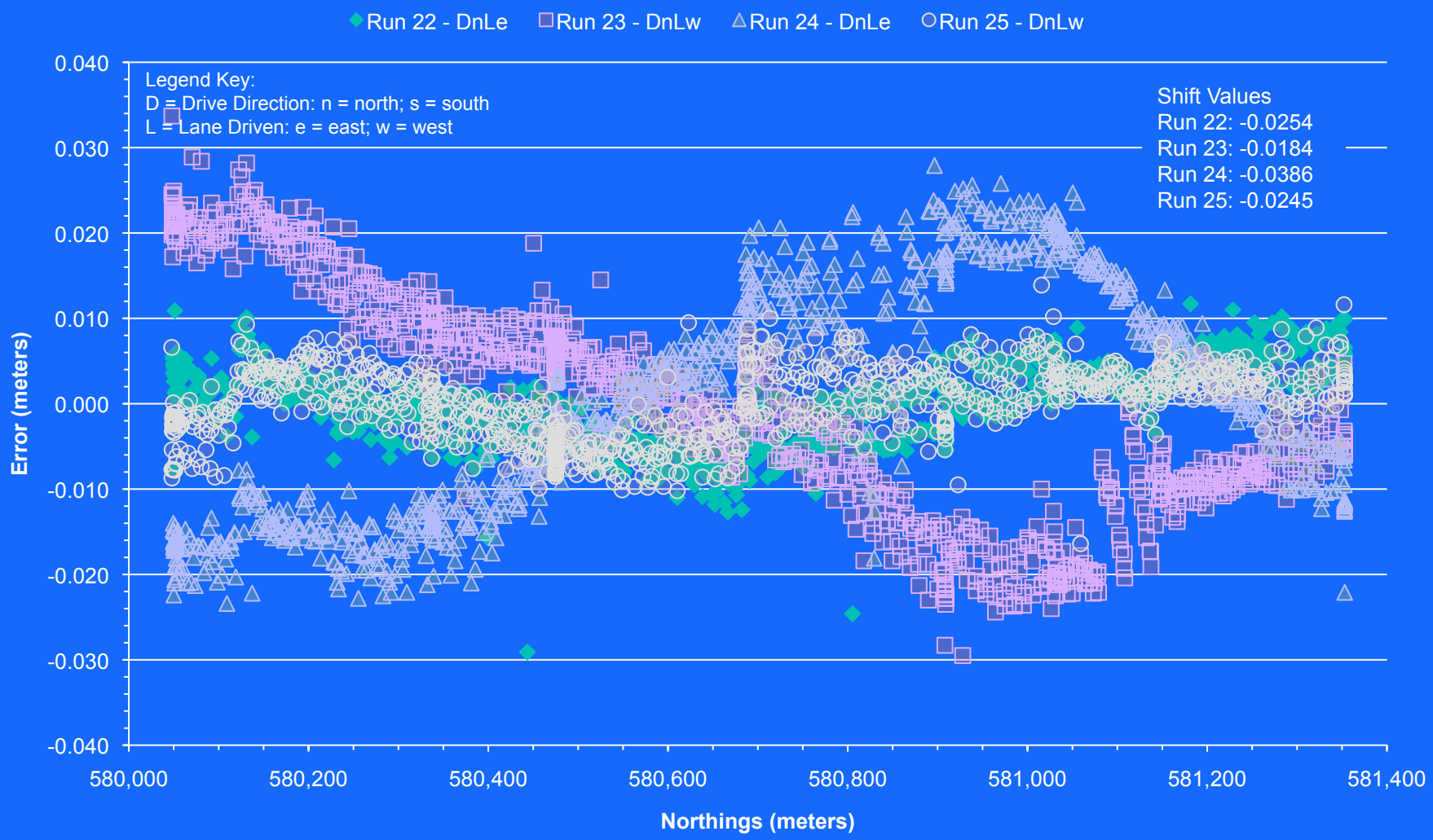
Runs Driving North



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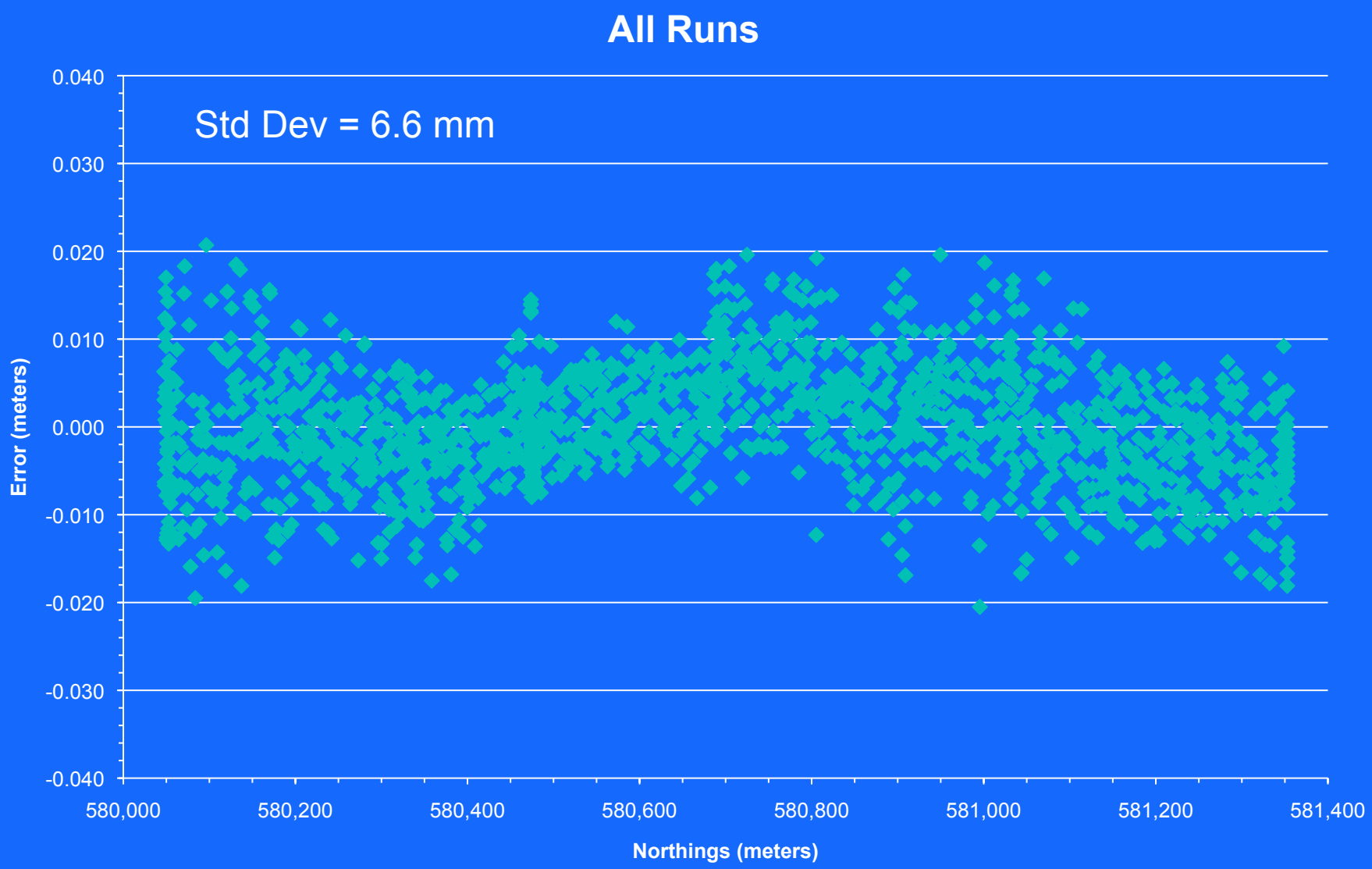

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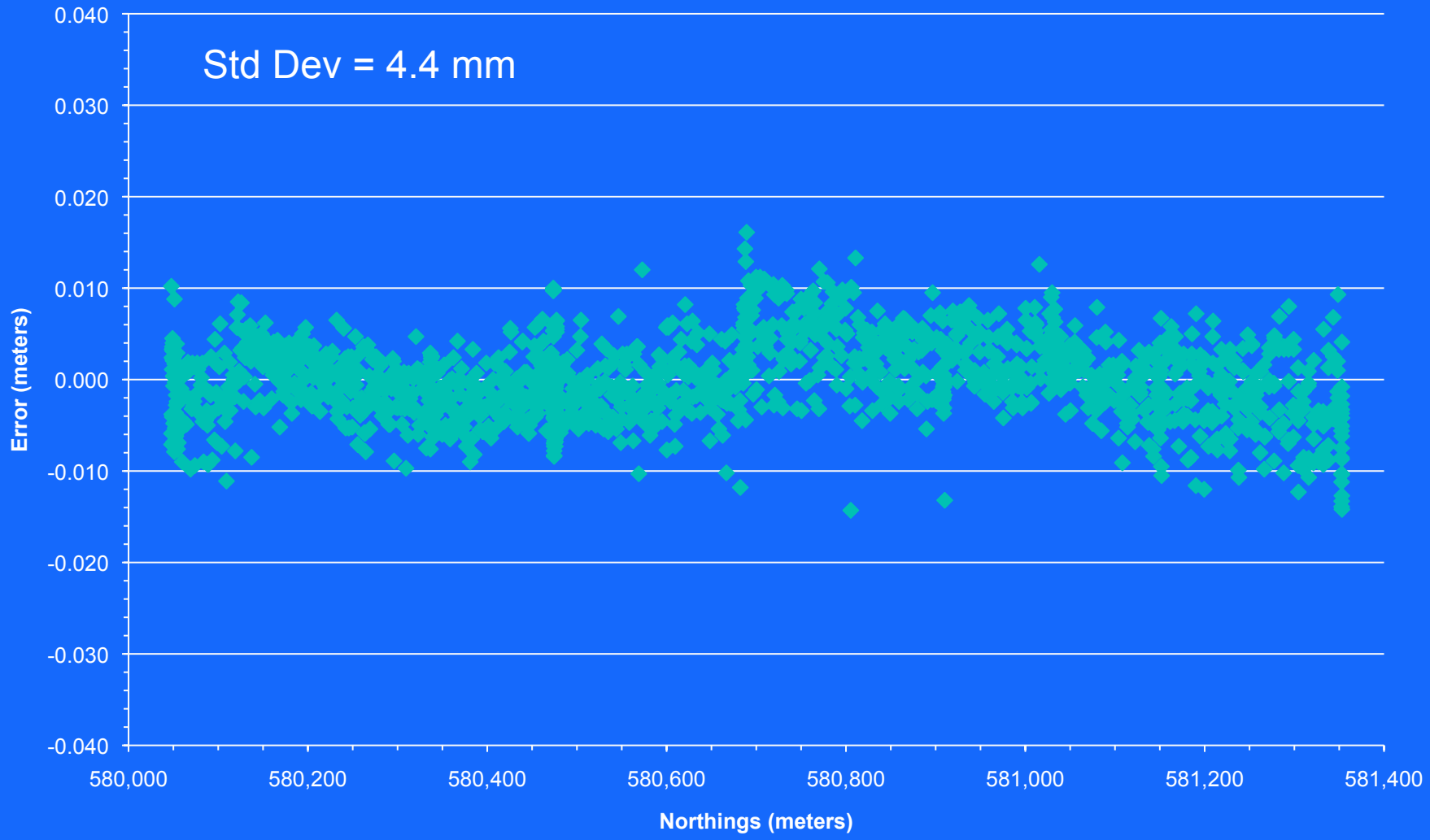
Best 5 of 8 Runs (11-13, 22, 25)



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Surveyed Region Statistics

Run Number	10	11	12	13	22	23	24	25	All	6 of 8	5 of 8
Direction	South				North				Both	Both	Both
Lane	West	East	West	East	East	West	East	West	Both	Both	Both
Time (sec)											
Start	414447	415468	416459	417503	424372	425433	426453	427523	n/a	n/a	n/a
End	414497	415518	416509	417547	424417	425482	426504	427572	n/a	n/a	n/a
Duration	50	50	50	44	45	49	51	49	n/a	n/a	n/a
Control Points, Total	1702										
No. with Coverage	940	957	958	956	956	958	956	957	1606	1606	1604
% of Total	55.2%	56.2%	56.3%	56.2%	56.2%	56.3%	56.2%	56.2%	94.4%	94.4%	94.2%
Error Statistics											
Average Offset	0.0171	0.0252	0.0279	0.0379	0.0254	0.0184	0.0386	0.0245	0.0000	0.0000	-0.0001
Maximum	0.0254	0.0163	0.0175	0.0175	0.0117	0.0337	0.0279	0.0139	0.0207	0.0214	0.0161
Minimum	-0.0234	-0.0345	-0.0178	-0.0229	-0.0291	-0.0295	-0.0234	-0.0164	-0.0205	-0.0184	-0.0143
Range	0.0488	0.0508	0.0353	0.0404	0.0408	0.0632	0.0513	0.0303	0.0412	0.0398	0.0304
Standard deviation	0.0104	0.0069	0.0056	0.0052	0.0047	0.0129	0.0129	0.0043	0.0066	0.0054	0.0044

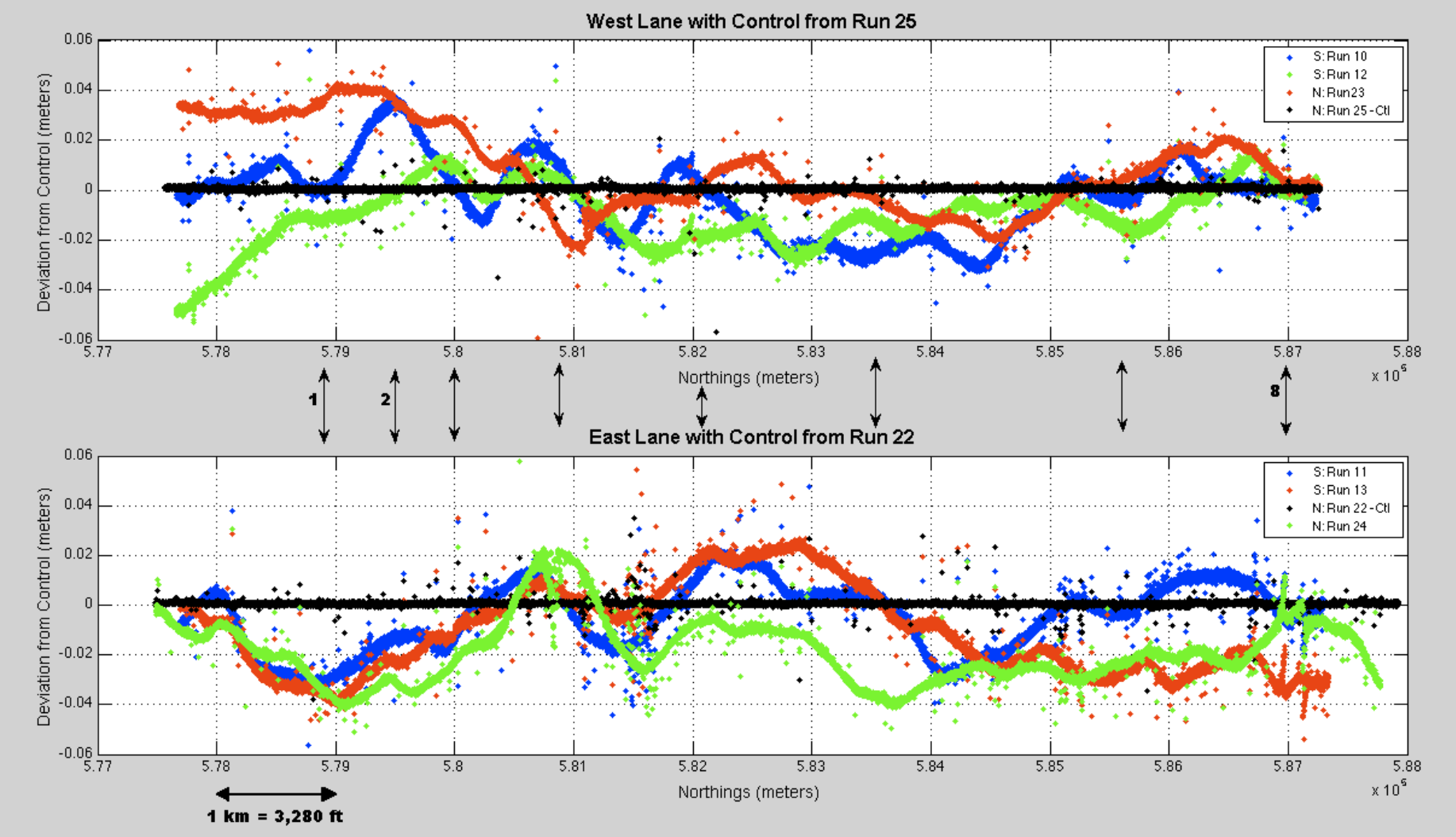
Full Length Analysis

- Selected best run in each lane: 22 and 25
- Reprocessed and edited to create Control
  - 7 points per scan:
    0, ±0.5, ±1.0 and ±1.5 meters
    0, ±1.6, ±3.2 and ±4.9 feet
  - 1 scan per 5 meters (16 feet)
- Quantity of Control Points
  - 13,860 Control Points per 6 miles per lane

GPS Outage Locations

Index	Overpass or Structure	Latitude	Longitude	Eastings (m)	Northings (m)
8	Ranch Penesquito Blvd / Poway Rd	32° 56" 53.53'	117° 6" 21.40'	1919965	587003
7	Mercy Rd / Scripps Poway Pkwy	32° 56" 12.27'	117° 6" 40.55'	1919457	585736
6	Mira Mesa Blvd	32° 55" 01.44'	117° 6" 57.70'	1918994	583558
5	Carol Canyon Road	32° 54" 12.35'	117° 6" 58.53'	1918960	582046
4	Miramar Road	32° 53" 35.44'	117° 6" 54.57'	1919053	580908
3	HOV Toll Bridges	32° 53" 06.35'	117° 6" 39.81'	1919429	580009
2	Miramar Way	32° 52" 49.99'	117° 6" 30.45'	1919668	579503
1	NCSA Miramar Minor Road	32° 52" 30.86'	117° 6" 25.93'	1919781	578921

Full Length Results - Relative to Best Run



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Full Length Statistics

Run Number	10	12	23	25	11	13	22	24
Direction	South		North		South		North	
Lane	West				East			
Time (sec)								
Start	414249	416268	425358	427440	415271	417305	424289	426366
End	414574	416585	425673	427755	415597	417623	424634	426730
Duration	325	316	315	315	326	319	346	365
Control Points, Total	13818				15169			
No. with Coverage	13549	13548	13587	13813	13685	15164	15164	14875
% of Total	98%	98%	98%	100%	90%	100%	100%	98%
Error Statistics								
Average Offset	-0.0026	-0.0098	0.0091	0.0006	-0.0045	-0.0113	0.0006	-0.0182
Maximum	0.0838	0.0752	0.0890	0.0208	0.0659	0.0662	0.0348	0.0576
Minimum	-0.0469	-0.0655	-0.0594	-0.0567	-0.0618	-0.0539	-0.0682	-0.0764
Range	0.1307	0.1407	0.1484	0.0775	0.12770	0.1201	0.1030	0.1340
Standard deviation	0.0150	0.0162	0.0193	0.0012	0.0142	0.0210	0.0015	0.0222

Conclusions

- Mobile survey can attain survey grade
- PSI PPS Scanner exceeds requirements
- Navigation and GPS specifically is driver
- Control and QC
  - Periodic control in one or both shoulder adequate for correcting GPS
  - Control Points double as QC
  - Current tools support post-processing

Acknowledgements

Caltrans

- Dave Olander – District 11
  - Vision and drive
  - Invaluable Control Survey
- Kevin Akin – HG
  - Analytical Collaboration on original test

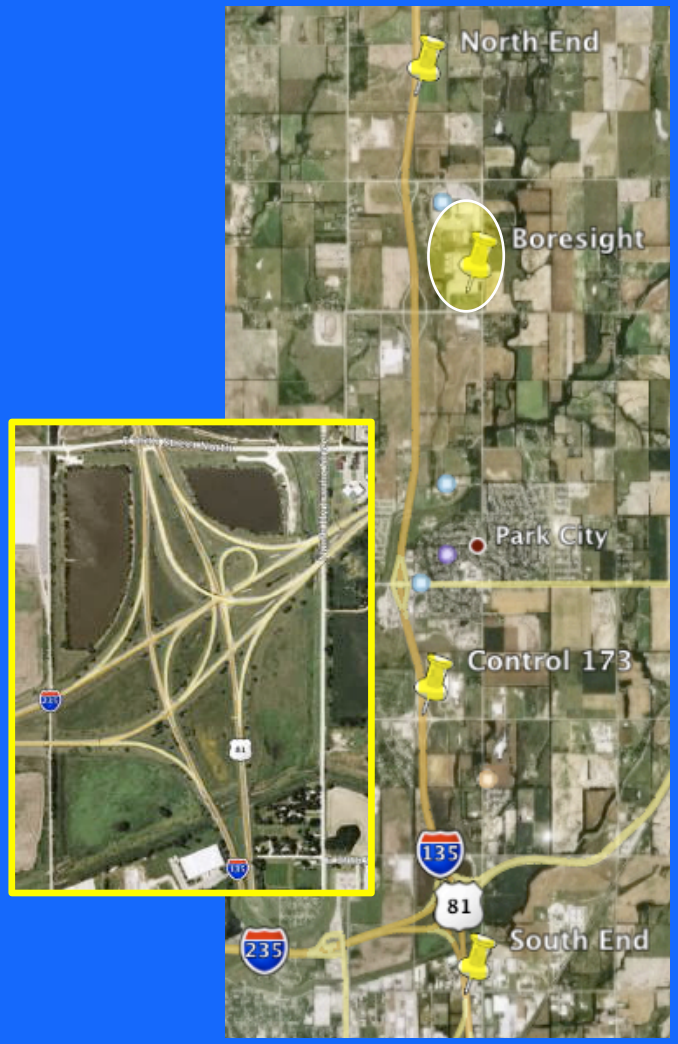
Merrick

- LAS File Export Format Test
- MARS Software
  - Visualization
  - Error Calculations
  - Efficient Corrections
  - Translation to 2D

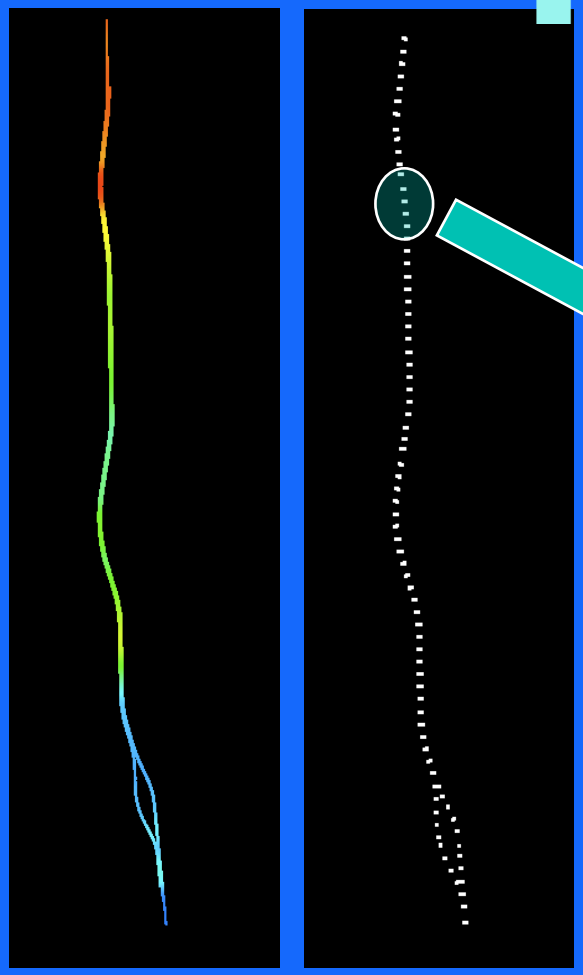
KDOT I-135 Project – August 2007

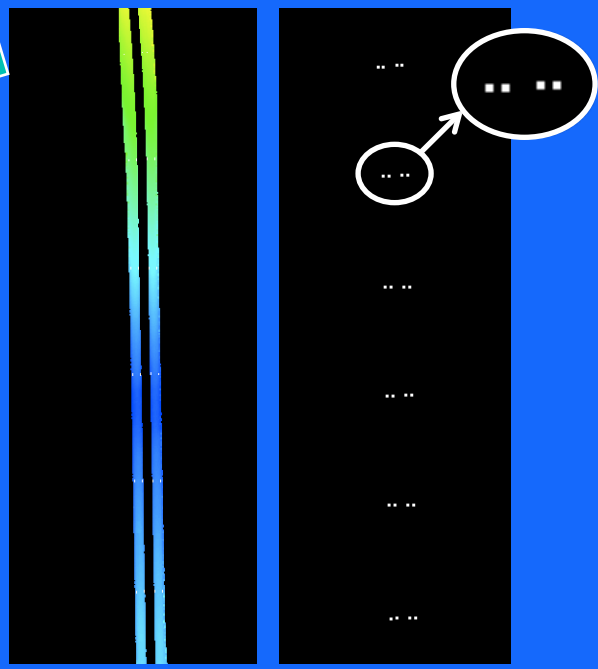
- Optira
  - Survey Expertise
  - Terrestrial scanning experience
  - Quest for mobile scanning
- PEC/Kansas DOT
  - 6.8 miles
  - 7 overpasses
  - 3/4 lanes + shoulders
  - Gore areas

I-135 Project Control



- 280 points
  - Inner & outer shoulders
  - North & South bound
  - Every 500 feet





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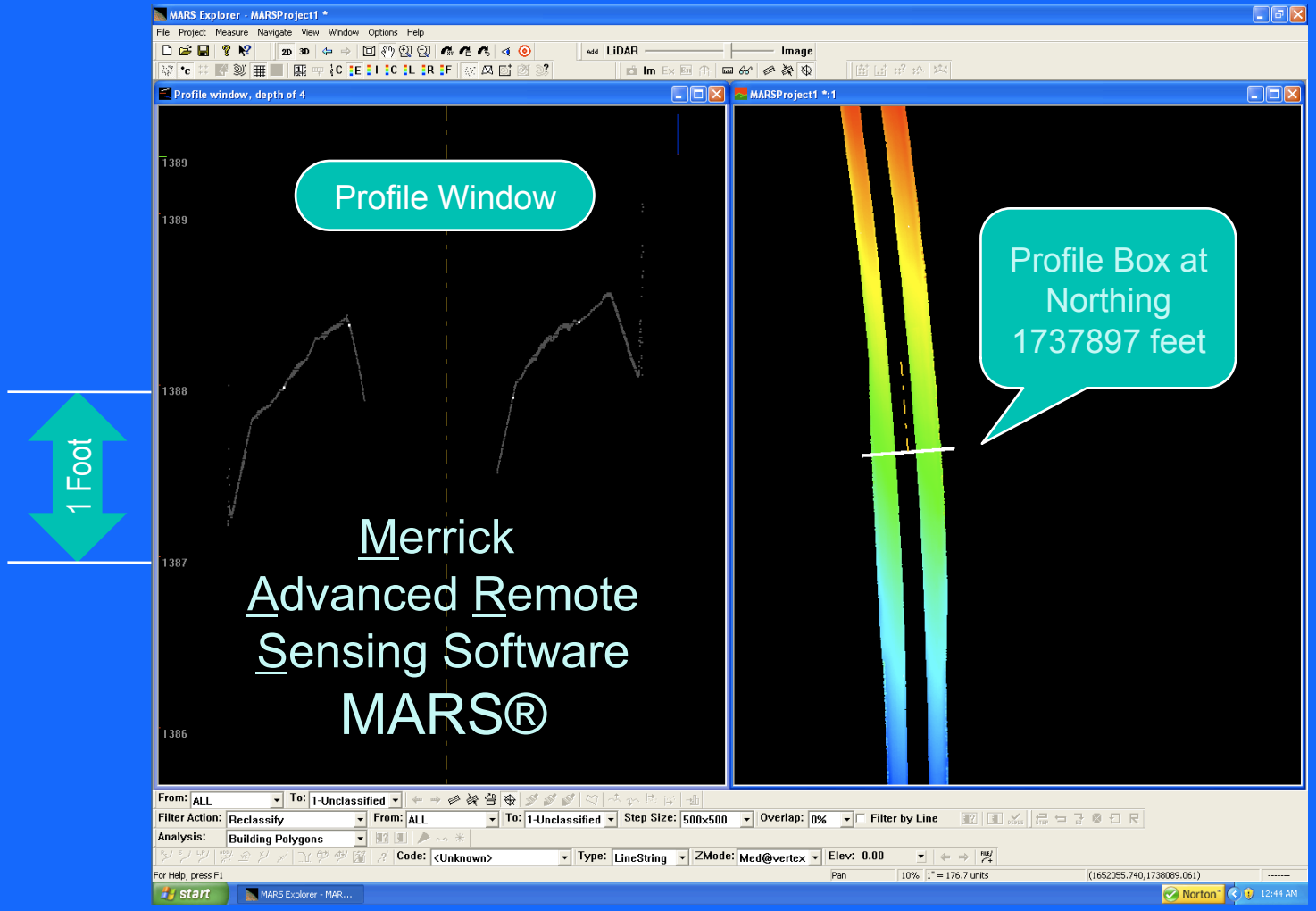
Aerial Lidar Software



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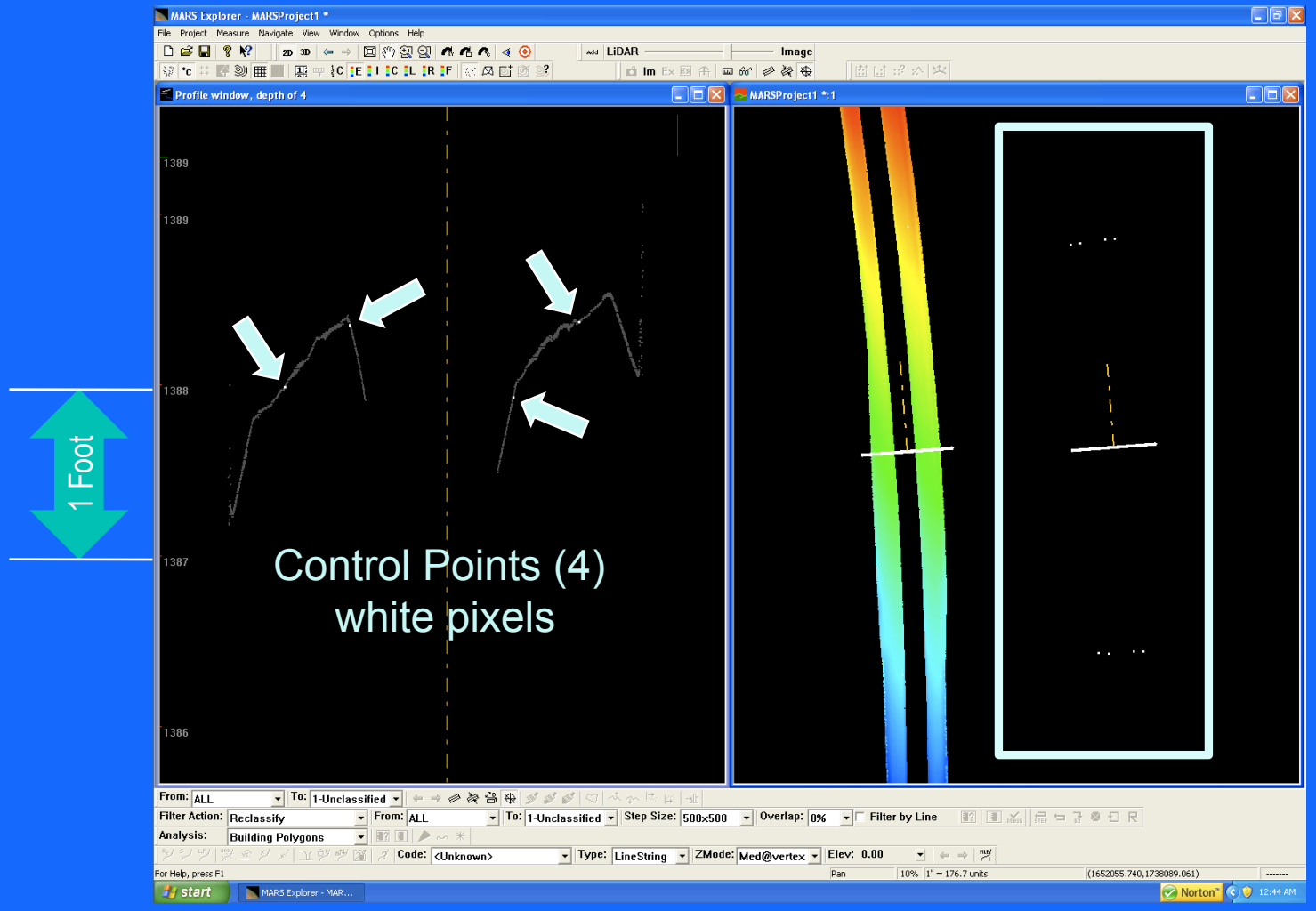
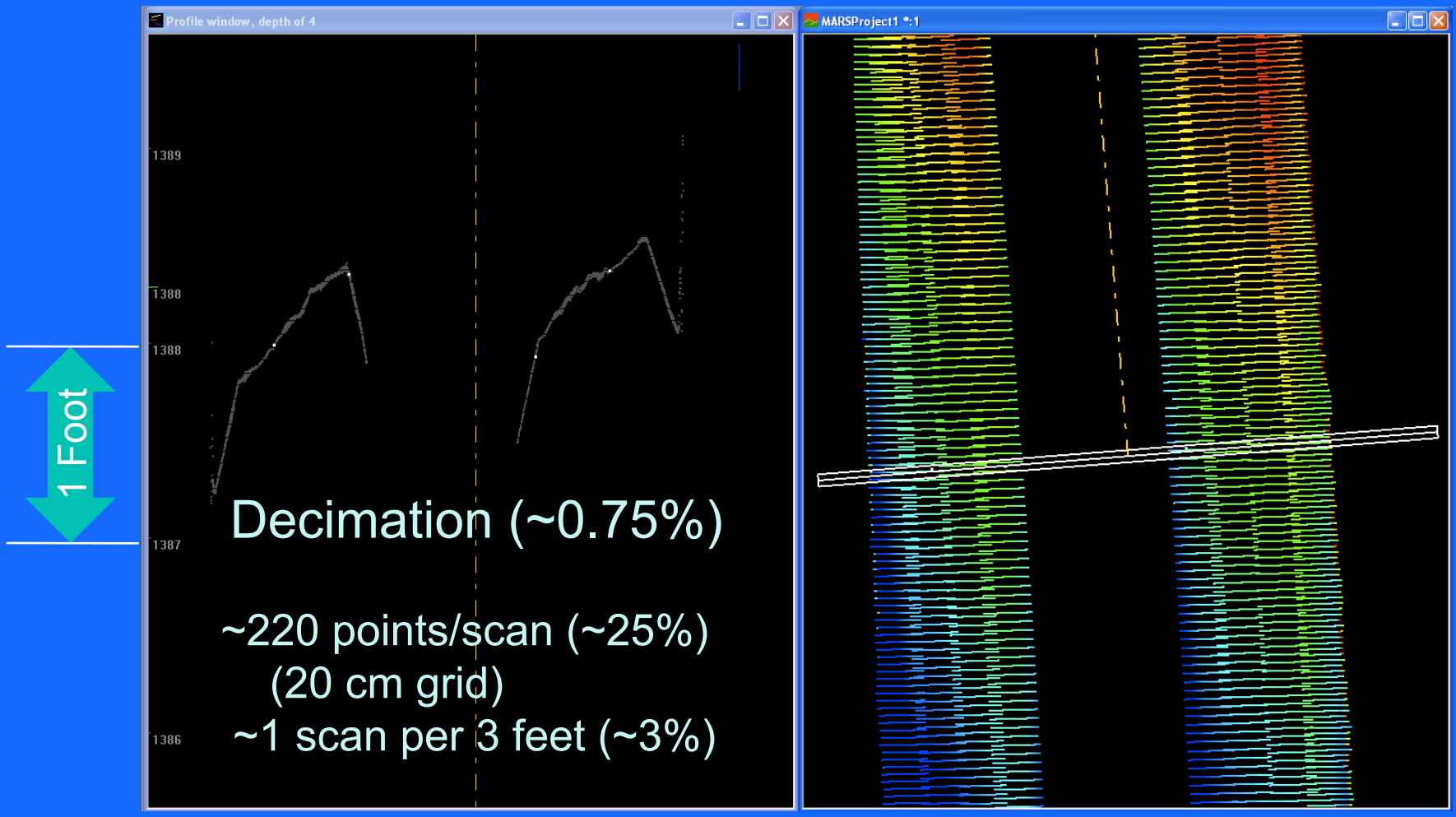
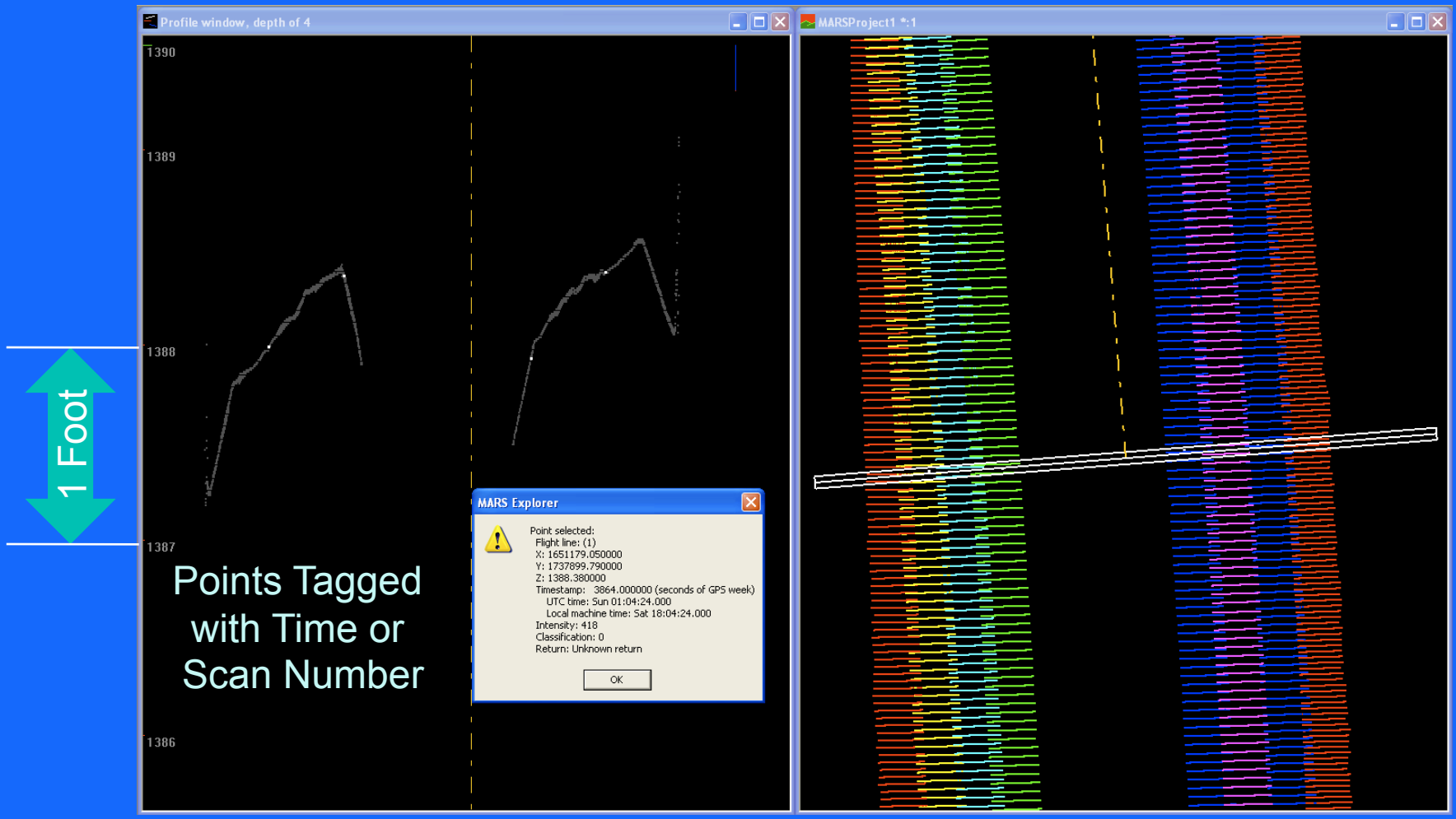
Control with Point Cloud Hidden



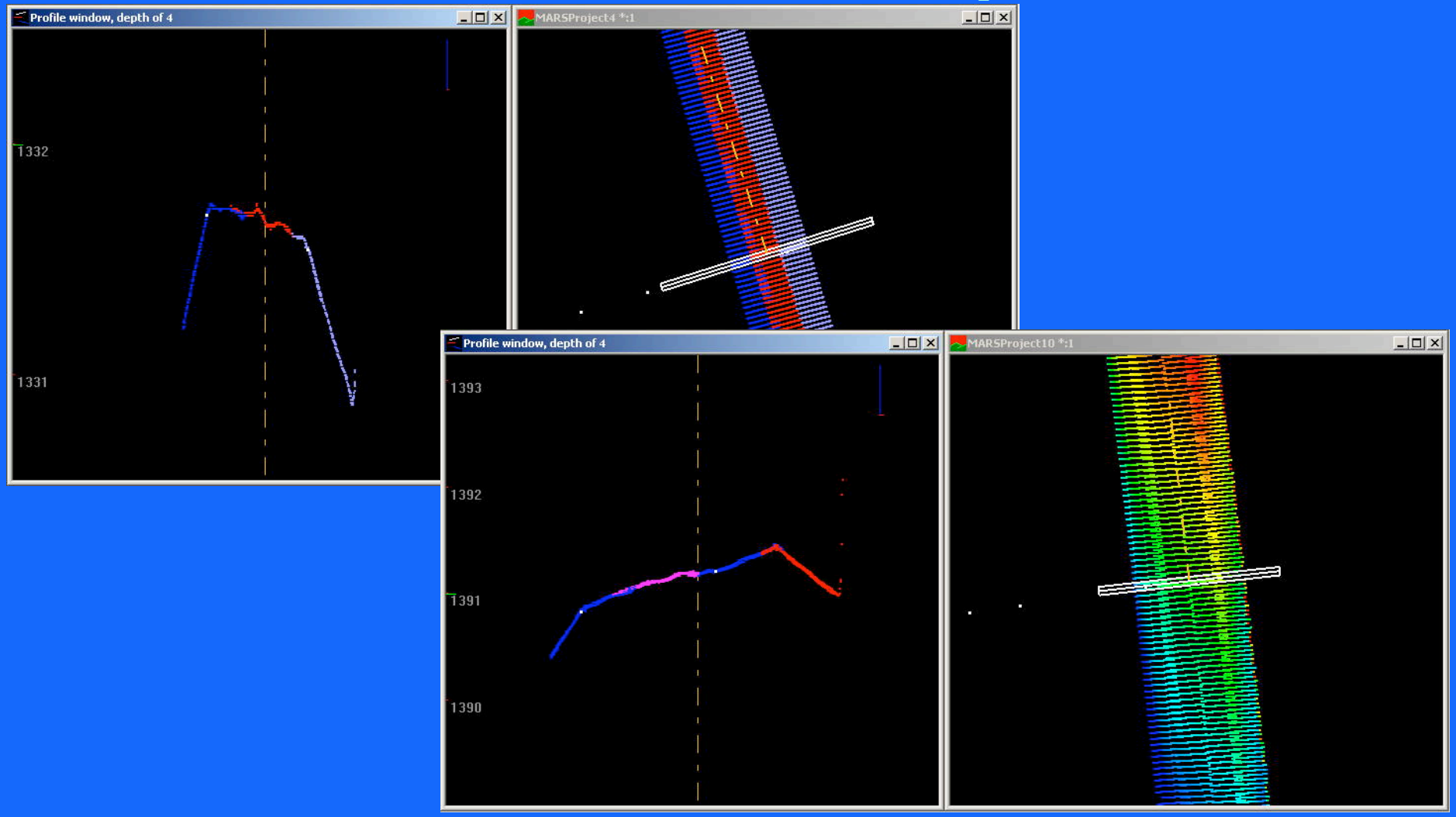
Scan Inspection



Color Coded Runs



3 and 4 Lane Samples



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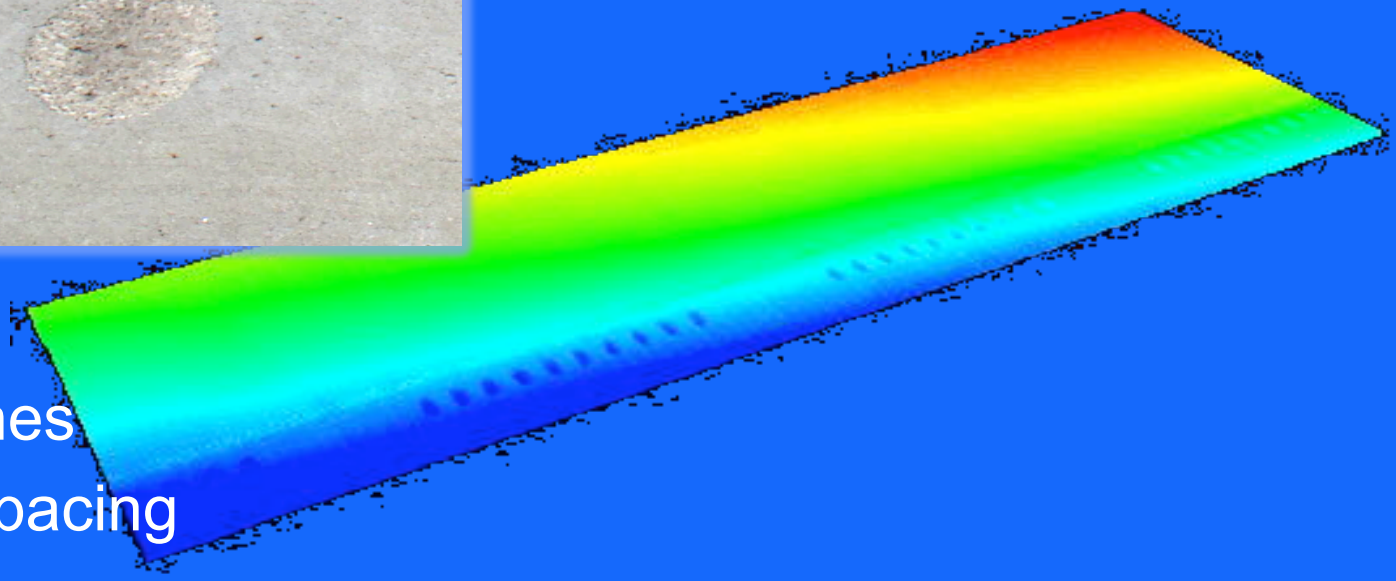
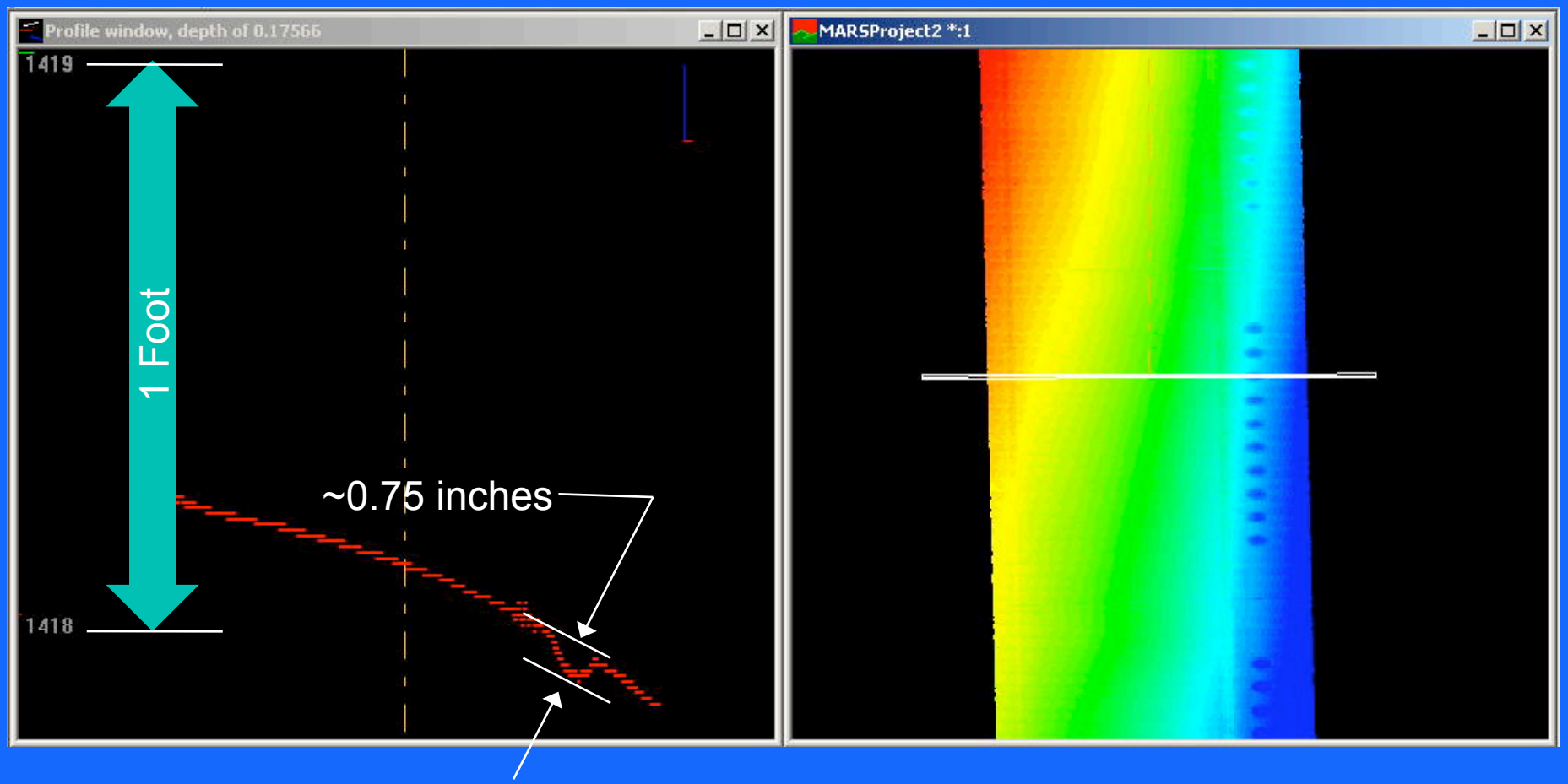
Full Resolution Example
Recessed Rumble Strip

- One Run
  - Straddling Shoulder

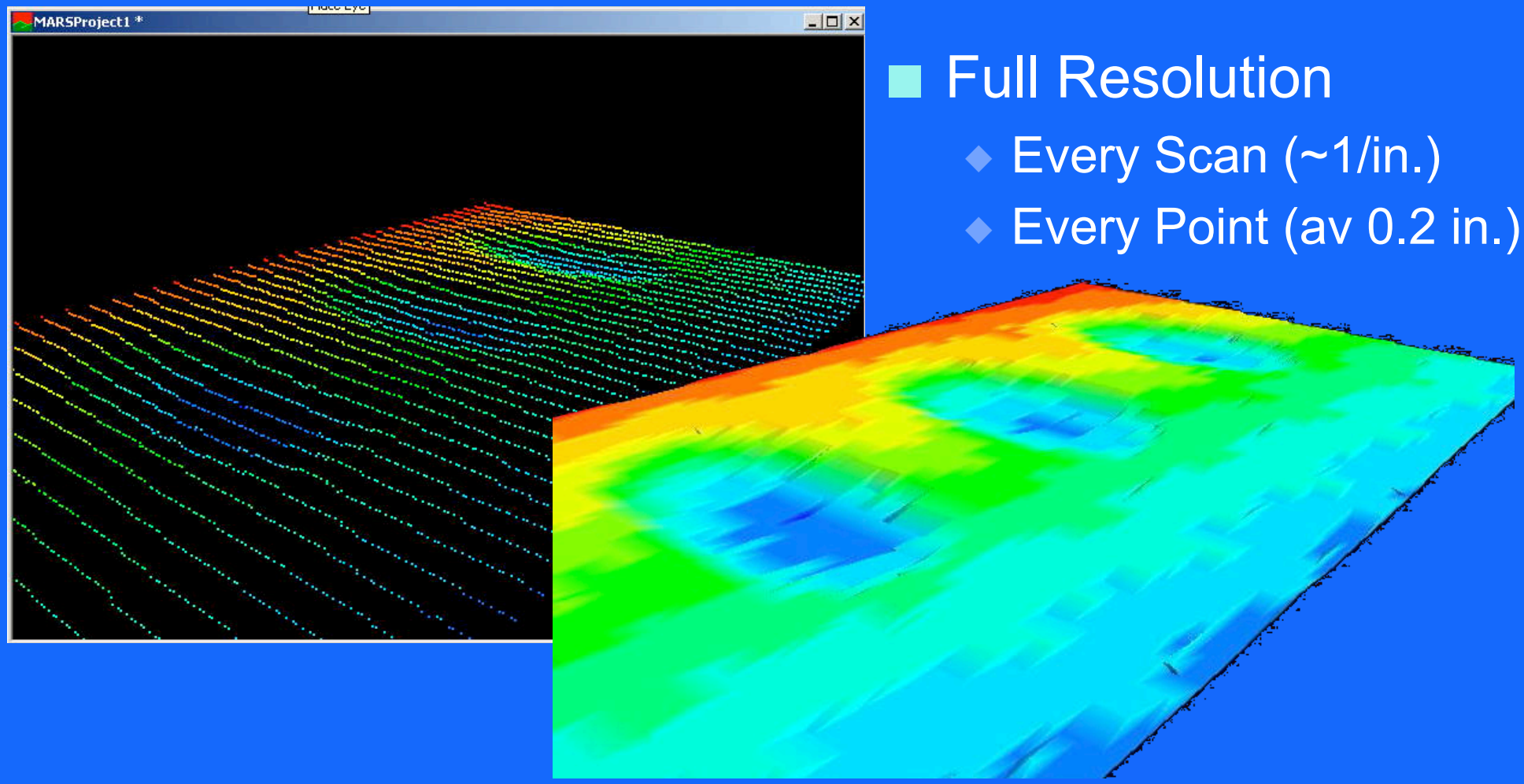


- Divots
  - ~ 6x12 inches
  - ~ 10 inch spacing

Rumble Strip Cross section



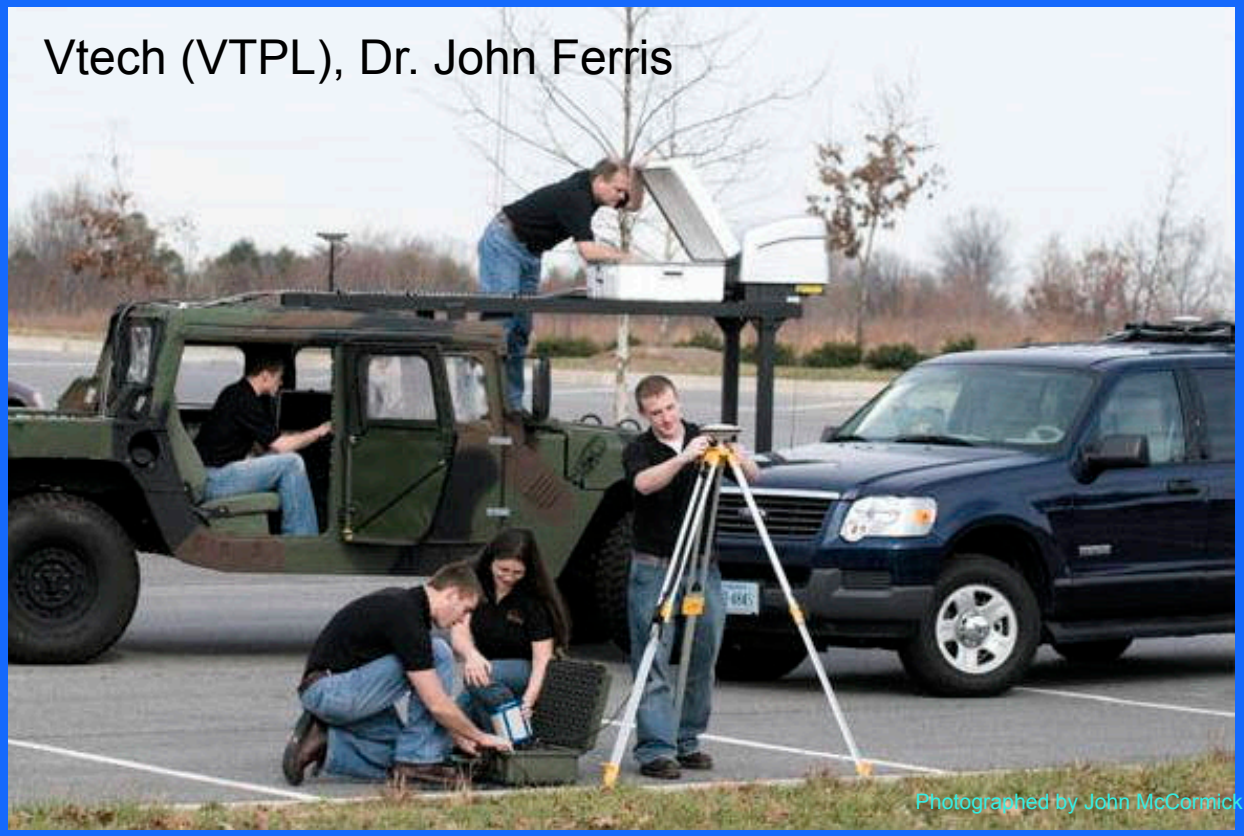
Rumble Strip Topology



- Full Resolution
  - Every Scan (~1/in.)
  - Every Point (av 0.2 in.)

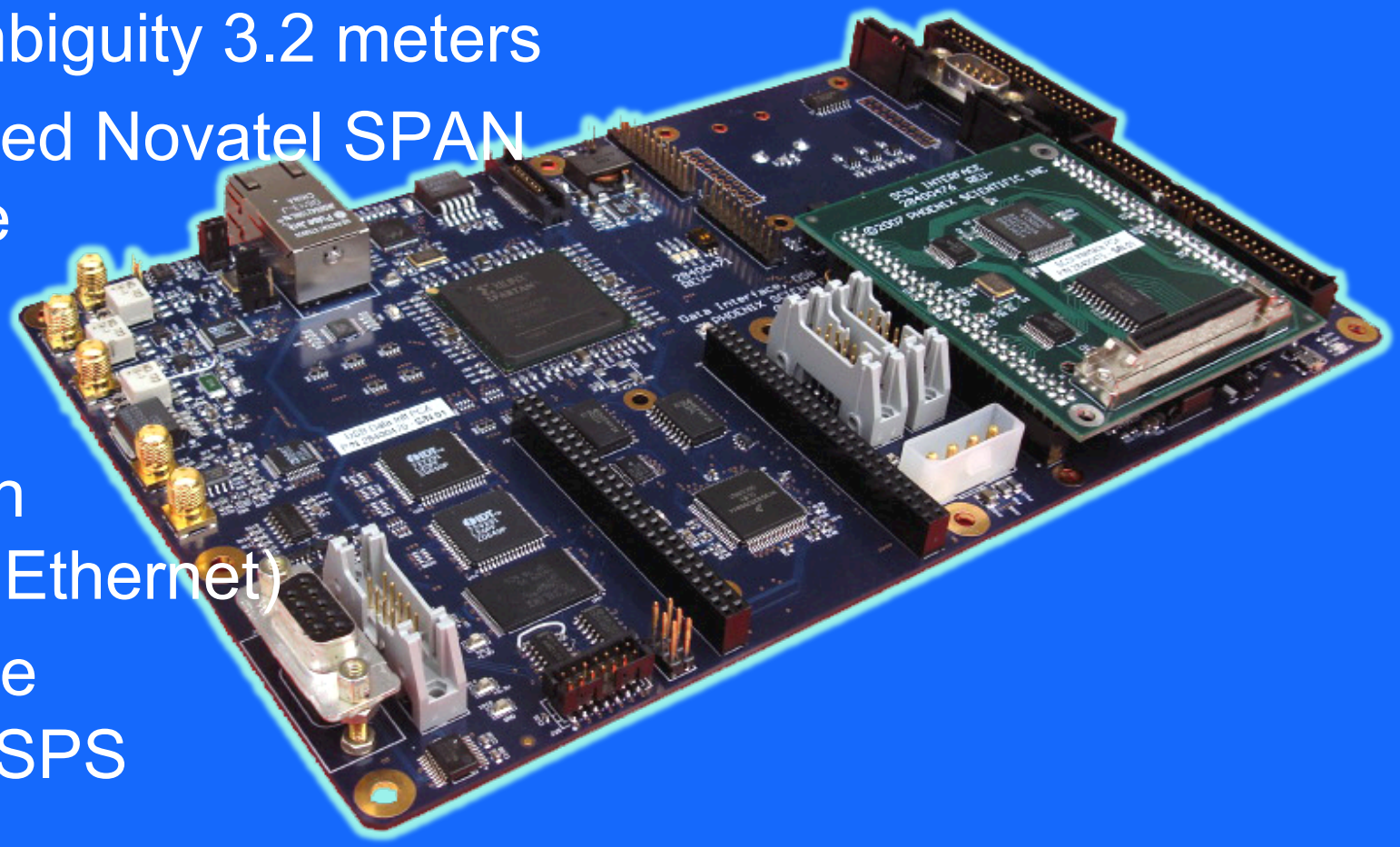
Rough Terrain

TACOM High Mobility Multipurpose Wheeled Vehicle (HMMWV)



Integrated New Design

- DSB Ambiguity 3.2 meters
- Embedded Novatel SPAN Interface
- FPGA
- Network Provision (Gigabit Ethernet)
- Max Rate 7.548 MSPS



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Summary

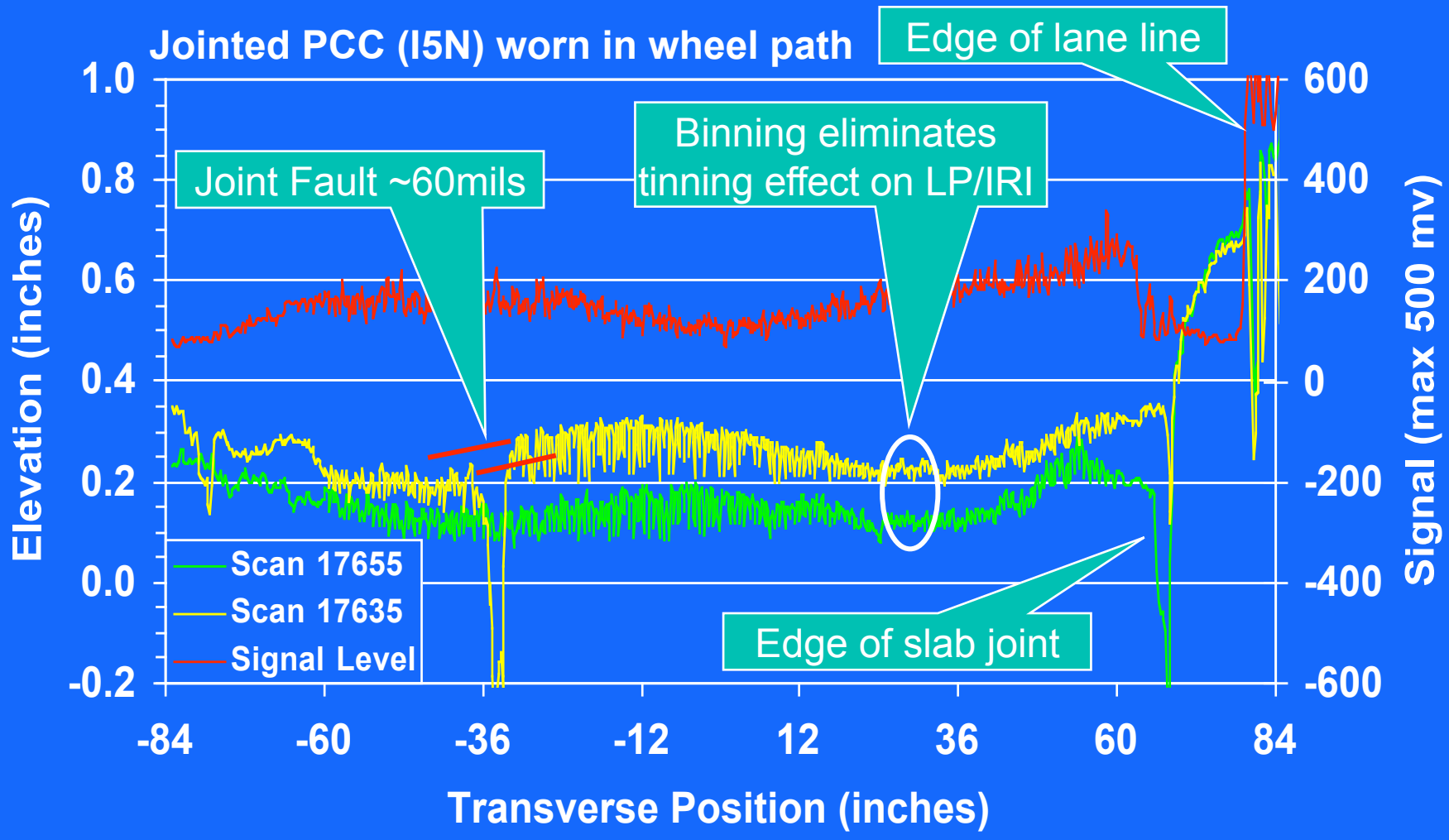
- Survey grade mobile survey a reality
  - Enabled by PSI Scanner
    - Unparalleled accuracy & speed
  - Inertial aided Differential GPS Navigation
  - Survey control tailored to requirements
- Options for Technology Deployment
  - Service
  - Sale of sensors and systems
  - Partnering, Licensing and Acquisition

Optional

Additional Information

Tinned PCC

Longitudinal Tinning and Faulting



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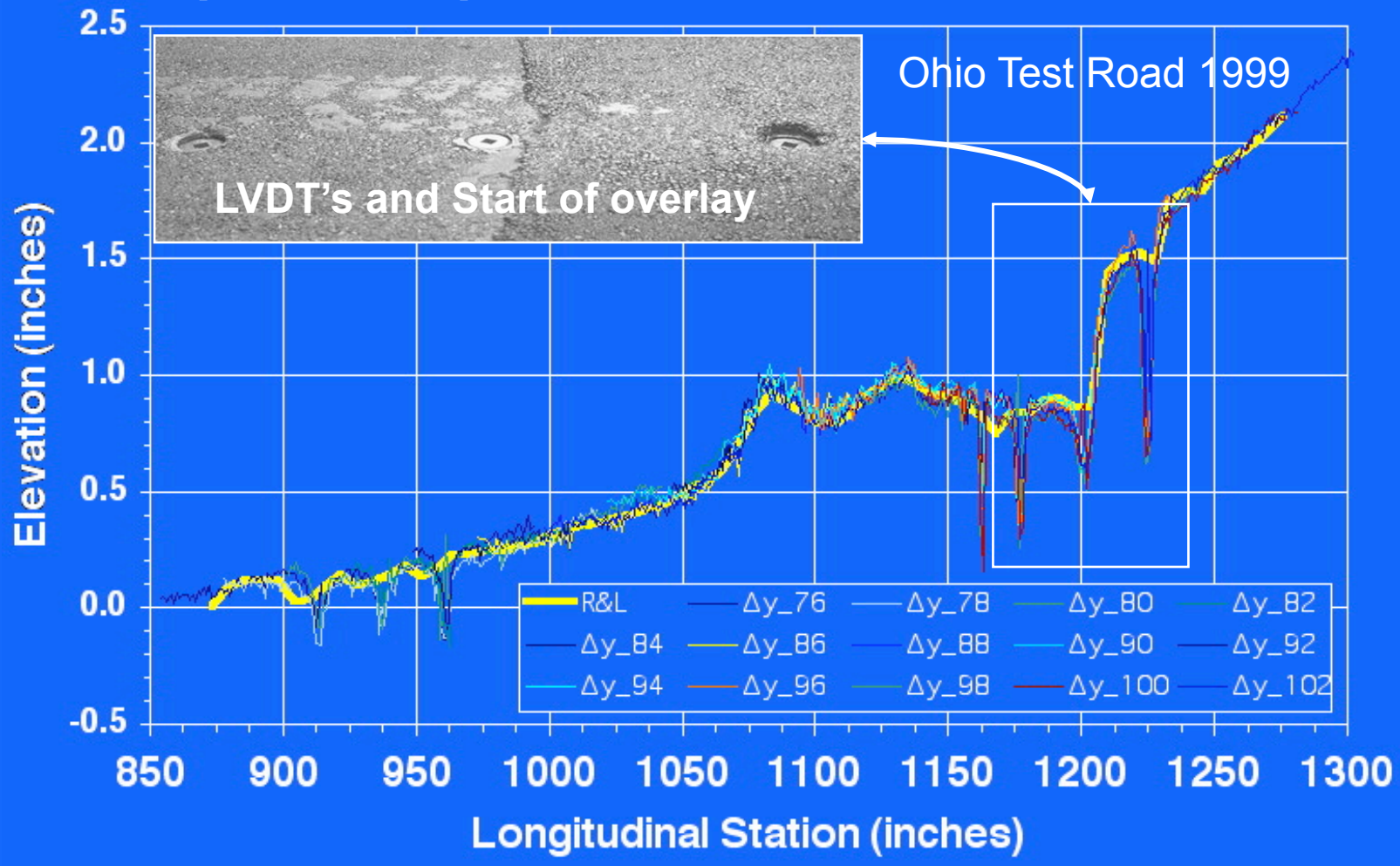
LP/Ride in Urban Stop-and-Go Traffic

Speed Independent LP w/o an accelerometer



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Longitudinal Scanning

- TRL Emulation of HRM
- Processing
  - Emulate HRM with discrete points
  - Use all points to maximize performance
- Uses
  - Urban stop & go
  - True reference profiles