

VEHICLE **T**ERRAIN **P**ERFORMANCE **L**ABORATORY



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Research Mission
Improve vehicle performance
by studying interactions between vehicles and terrain

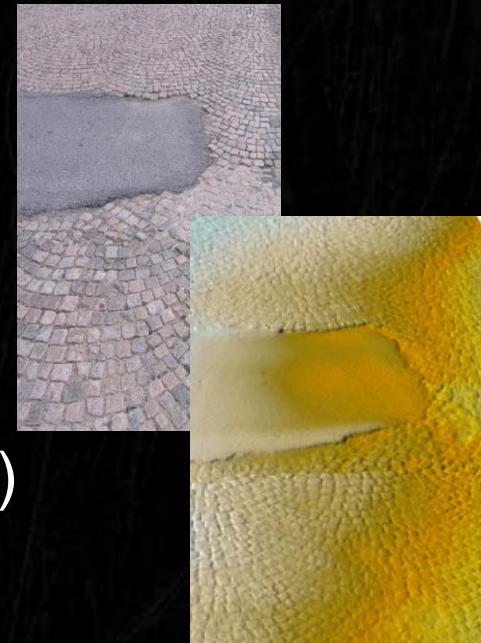
Vehicle Terrain Measurement System

- Operating Principle
 - System Hardware
 - Signal Processing
- Data acquisition procedure
- System Improvements
- System Cost
- FHWA Reference Profiler Round-up Discussion
- Conclusions

System Overview

Hardware

- Three laser measurement subsystems (relative height measurement)
- Inertial Navigation System (INS) (global positioning, motion cancellation)
- Accelerometers (high-frequency motion cancellation)



Digital Signal Processing

- Synchronization of equipment
- Conversion to global coordinates
- Cancellation of body motion





SICK LIDAR

- Resolution: 360 pts over 180° scan
- Accuracy: 10 mm
- Sample rate: 75 Hz



Phoenix Scientific

- Resolution: 941 pts over 4m scan
- Accuracy : 0.1 mm
- Sample rate: 1 kHz



RoLine Laser

- Resolution: 160 pts over 100mm scan
- Accuracy : 0.01 mm
- Sample rate: 3 kHz

Inertial Navigation System (DGPS + IMU)



- Resolution: 0.75 mm
- Horizontal Accuracy: +/- 0.01 m
- Sample rate: 100 Hz

Accelerometers



- Resolution: 0.0025 g
- Accuracy : +/- 0.2% FSO
- Sample rate: 4 kHz

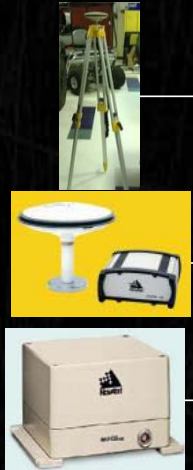
Digital Signal Processing

All Data Combined in Post-Processing

Equipment

Post Processing

Base Station



In-Vehicle



Error Correction

Kalman Filter

1

INS Solution:
Vehicle Position
& Orientation

Filter

Integrate twice

2

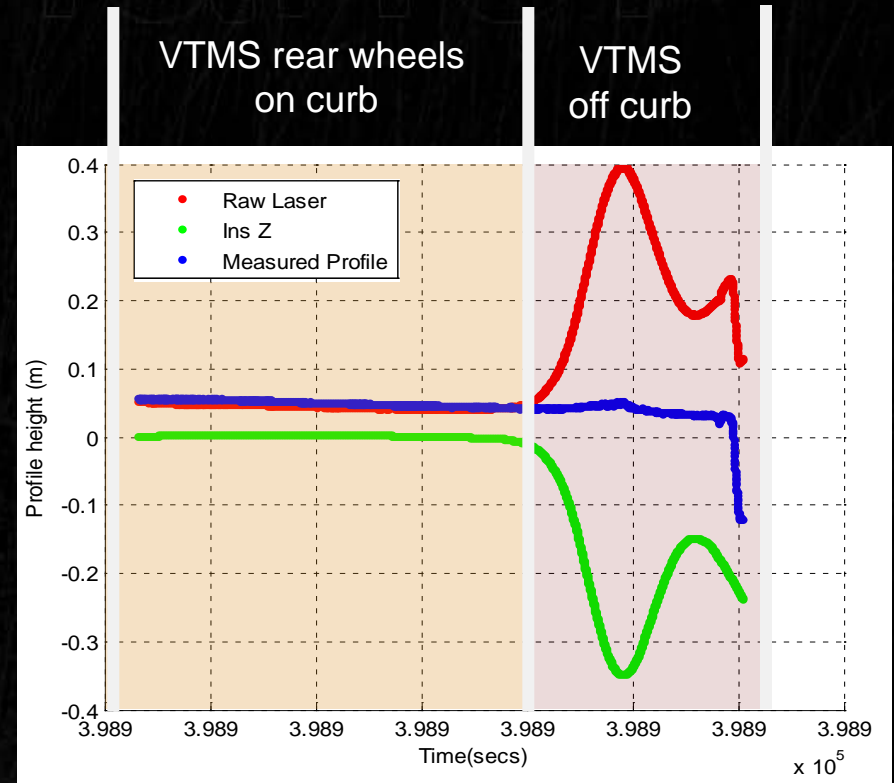
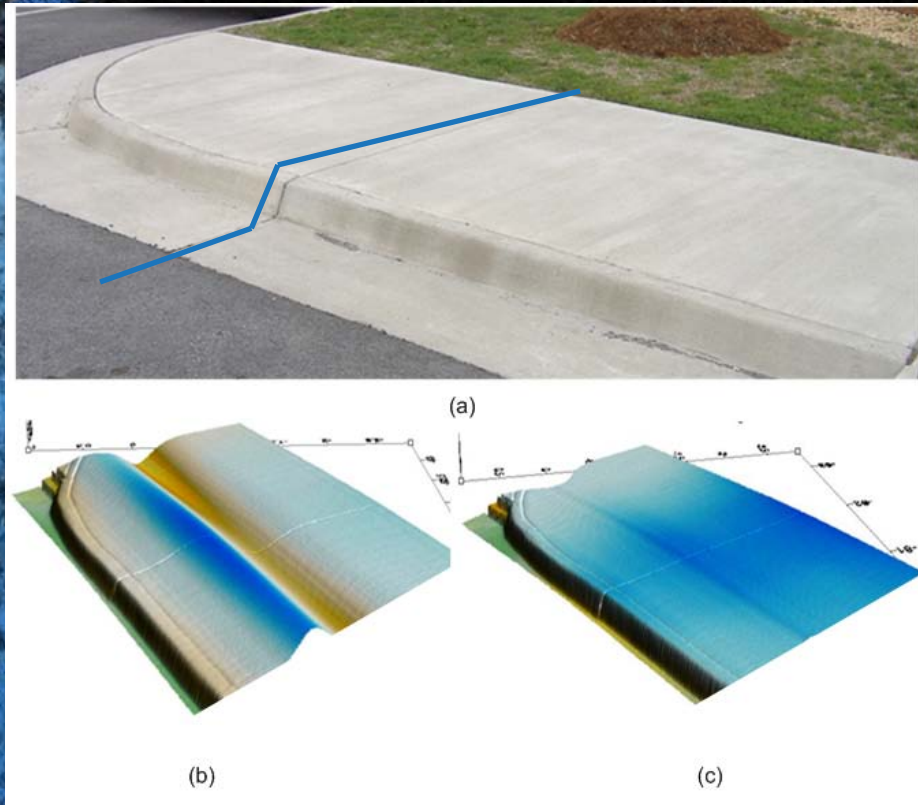
Laser Roll,
Pitch & Height

3

Lasers / Terrain
Vector

Digital Signal Processing

Body Motion Cancellation



Data Acquisition Procedure

- Initial Setup
 - Inertial Navigation System
 - Accelerometers
 - Log File
 - Scanning Laser
- Data Collection
 - Reference markers
 - Recommended practice

Initial Setup

- Inertial Navigation System
 - IMU Alignment
 - Static GPS/IMU Alignment Time
- Accelerometers
 - Sampling rate
 - Low-pass filter
- Log File
 - Track file naming convention
 - Describe measured terrain
- Scanning Laser
 - Spinning polygon mirror

Automated with
GPS/INS
Completion Tool

Data Collection

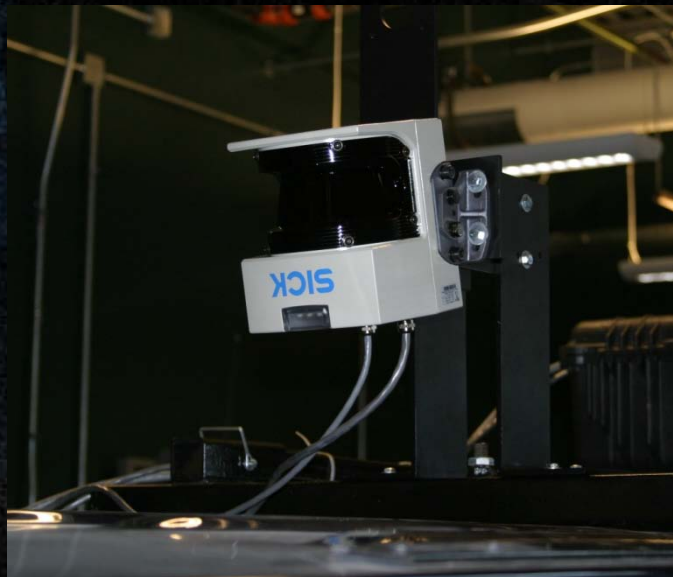
- Reference Markers
 - Aluminum plates: 10mm height
 - Corners of plates correspond to start/end of test section



- Test
 - Position host vehicle aligned with test section
 - Desired longitudinal spacing - 10mm (downsample to 25mm)
 - Toggle run marker switch corresponding to start and end of run

System Enhancements

- Multi-Scale Terrain Measurement System
 - SICK Lidar
 - LMI Selcom Roline (2x)



System Cost

Item	Cost
Host Vehicle	\$25,000
PSI PPS Scanning Laser	\$150,000
NovAtel OEM4 INS System	\$80,000
Accelerometer System	\$10,000
Power Systems and Infrastructure	\$10,000
Total System Cost	\$275,000

FHWA Reference Profiler Round-up VirginiaTech

- Data collected over 6 test sections
- Data acquisition time after setup: ~15-20 mins/section
- Processing time: ~4 hours/section
 - Process DGPS + IMU
 - Cancellation of body motion
 - Map point-cloud data to equally spaced grid
 - Removal of INS system drift
 - Creation of ERD



Conclusion

- The VTMS is the result of years of university research and the VTPL continues to develop and improve the system.
- The VTMS captures high-fidelity 3D terrain data that can be reduced to 2D profile for the area of interest.
- The VTPL can produce multiple single longitudinal profiles of the same surface.
- Minimal site closure requirements due to short data collection time.
- Measurement offered as a service