Roadbot

Dual Line Laser Benchmark Road Profiler

Paul Toom P. Eng. MBA
ICC, Cherry Systems

Glenn Hennin
LMI3D

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Presentation Overview

- Introduction of new Roadbot robotic profiler
  - Development Goals
  - Technology Features
  - Designing & Building Roadbot
- Performance capabilities
- Self-guided computer vision steering
- Initial results
- What we learned at MnRoad 2015
- Next steps
- Computer vision steering demo

Roadbot Development Goals

- Achieve Benchmark performance compliant with draft ASTM E-950-15
  - 0.97 CC repeatability in IRI, medium, long wavebands
- Cover the short waveband
- True unfiltered profiles (accurate end elevations)
- Autonomous, self-guided computer vision steering
- Super smooth pavement capable
- Easy to configure and operate
- Obtain Benchmark results independent of operator's skill & training

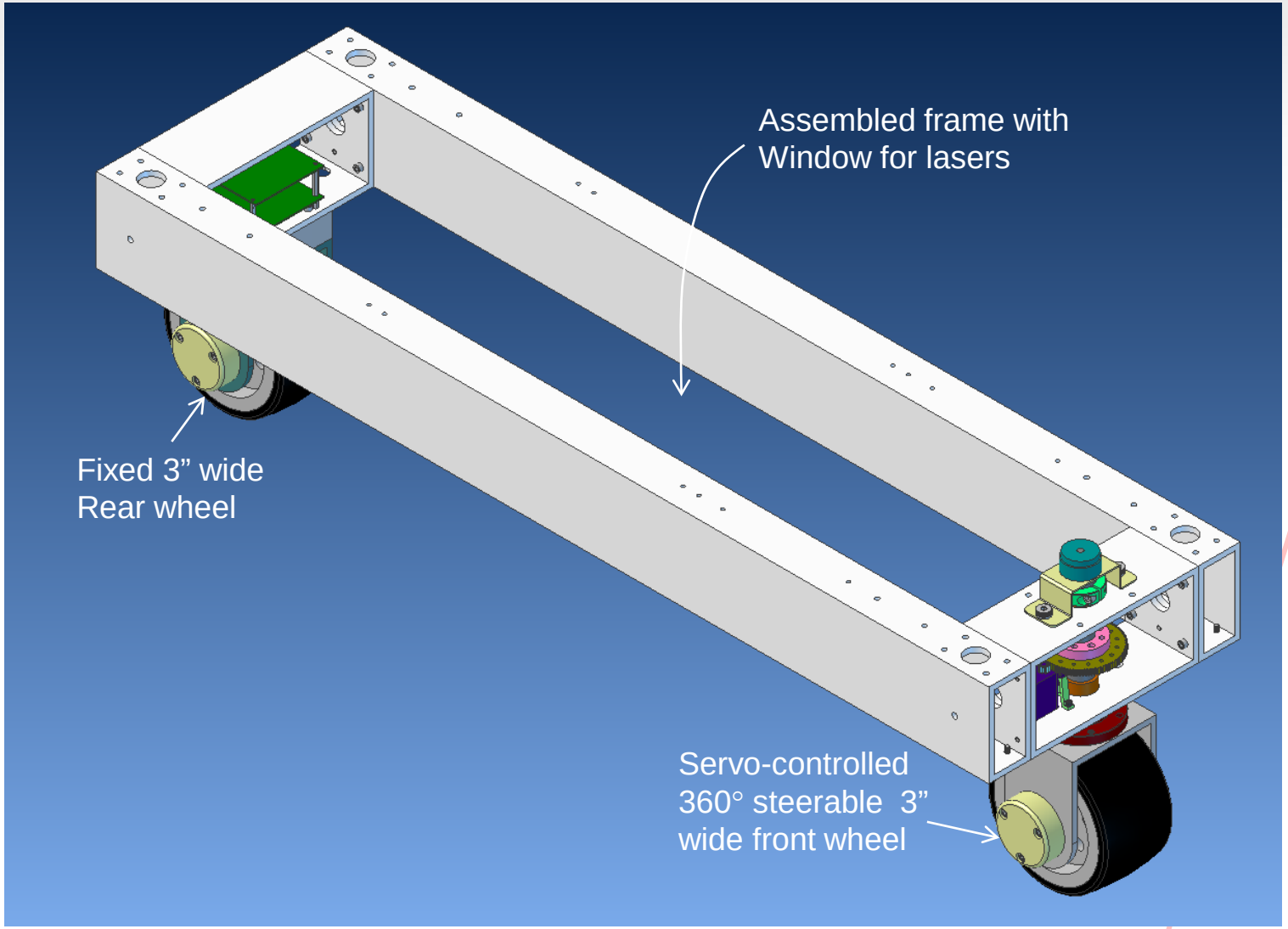
Benefits & Advantages

- Benchmark class accuracy first time, every time
  - No confusion re different results from different operators
- Save operating costs
  - 1 accurate run is better than 10 bad runs averaged
- Safe, fast and easy
  - Performs multiple runs without user intervention
  - Operator supervises at a safe distance from traffic
  - No operator fatigue
- Programmable, autonomously follows paths
  - Roads, floors or any other surface

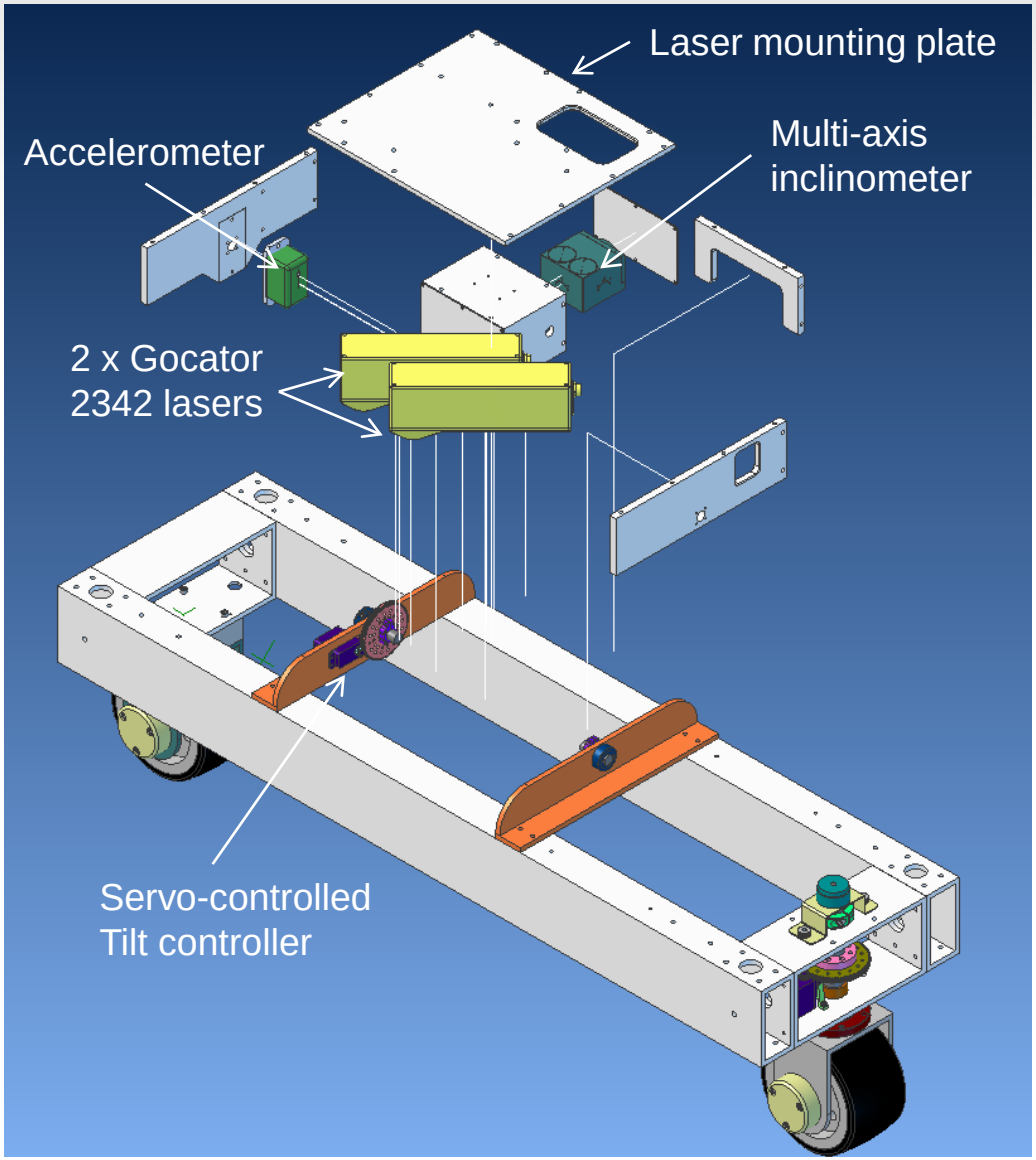
Roadbot Technology Features

- All new, Engineered from the ground up
- Dual line lasers rotated 45° for texture rejection
- Multi-axis inclinometer reference
- Autonomous, self-guided, computer vision steering
  - Servomotor actuated with PID feedback control
- Collision avoidance
- "Tilter" laser and inclinometer levelling system
  - Servomotor actuated with PID feedback control
- Precision motor drive
- Stationary 'U'-turn capability

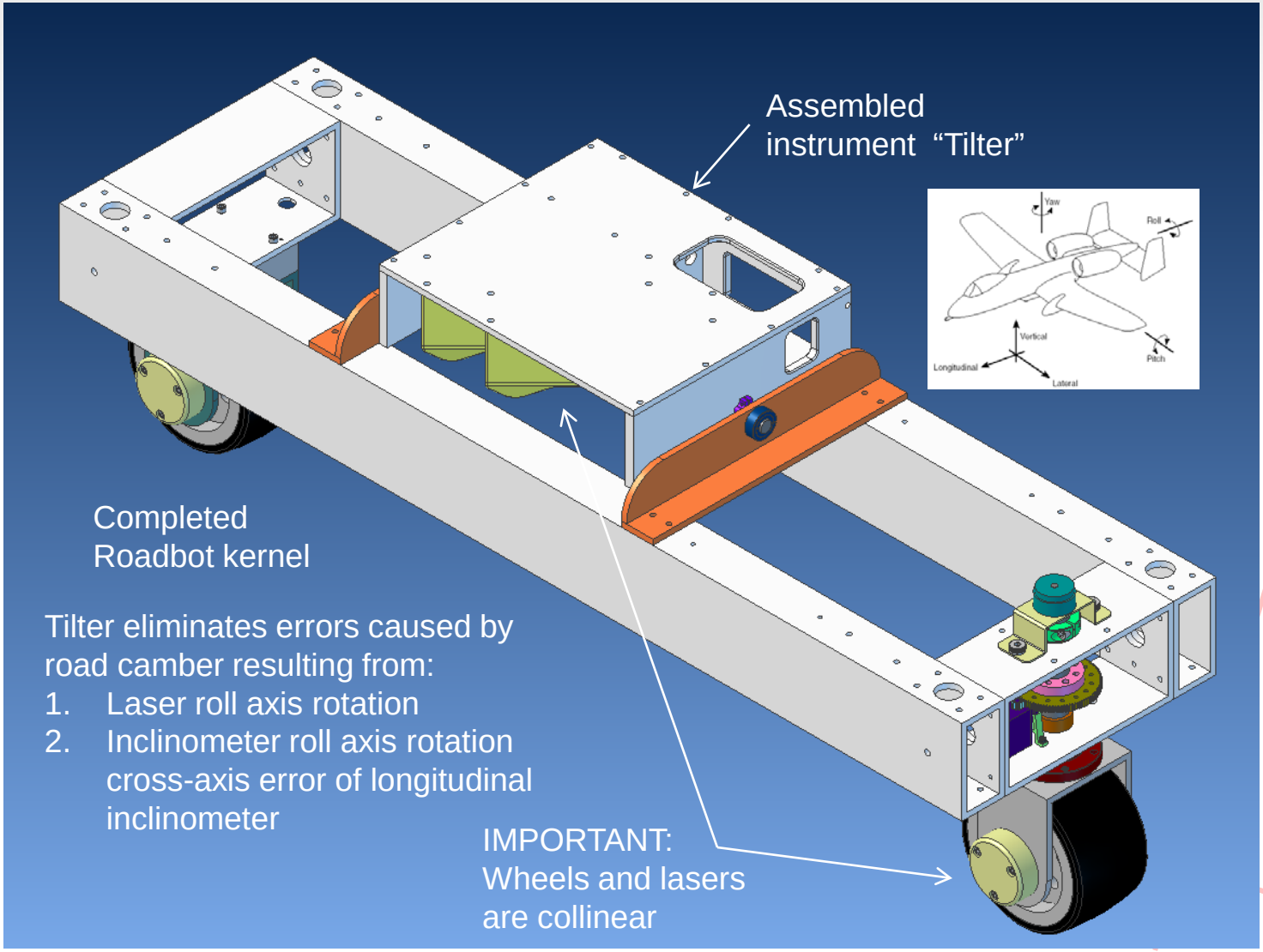
Designing & Building Roadbot



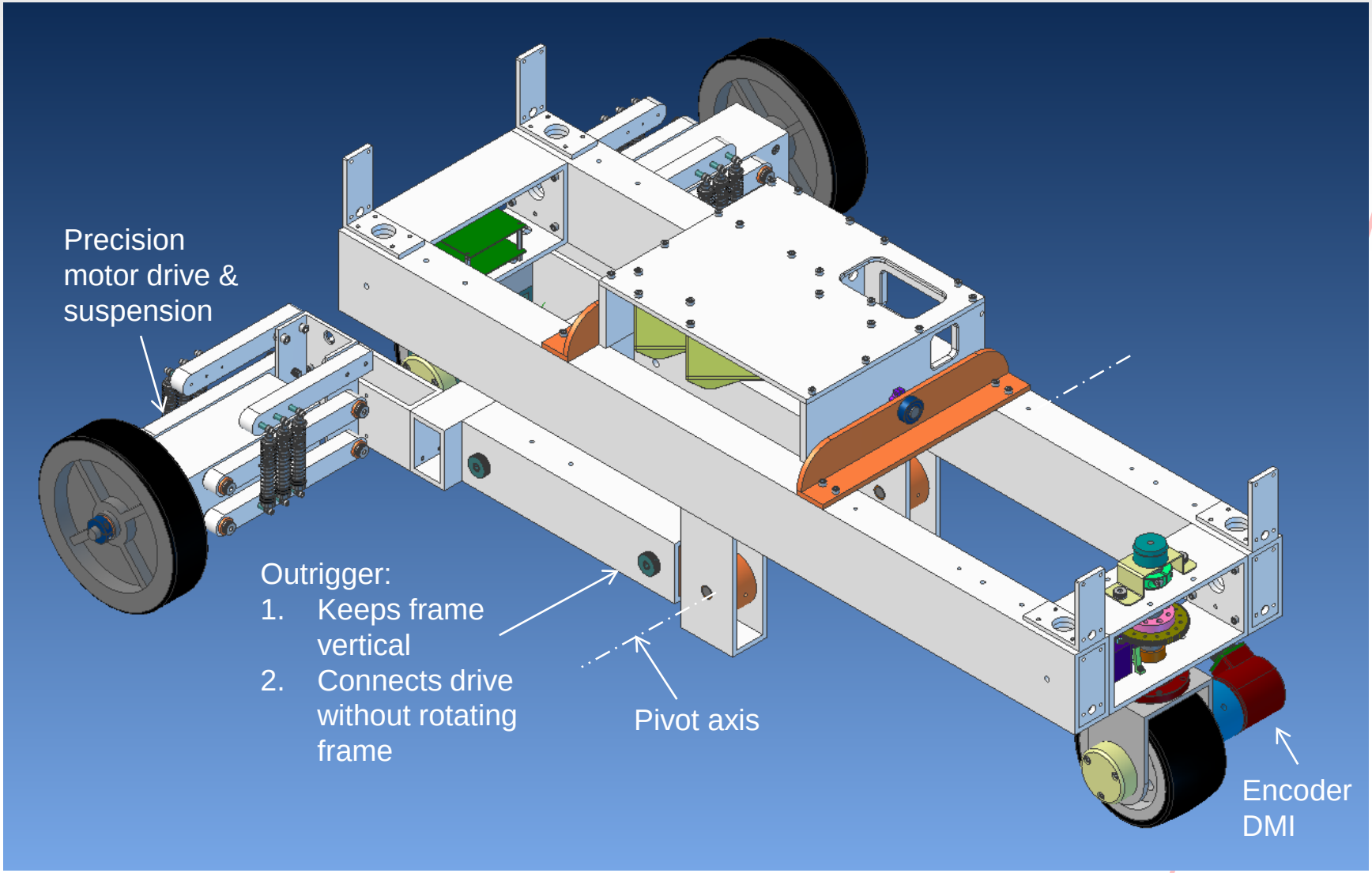
Designing & Building Roadbot



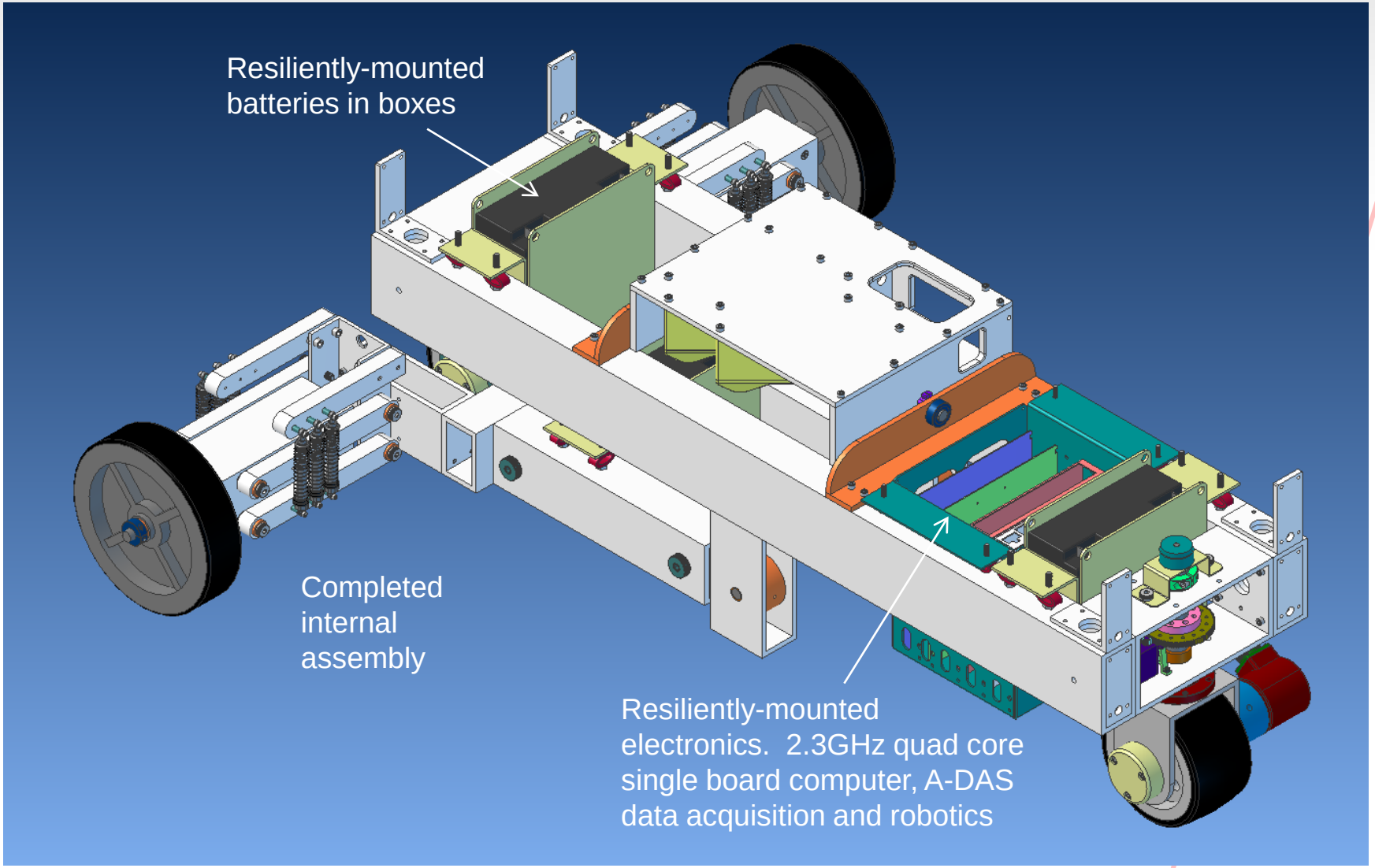
Designing & Building Roadbot



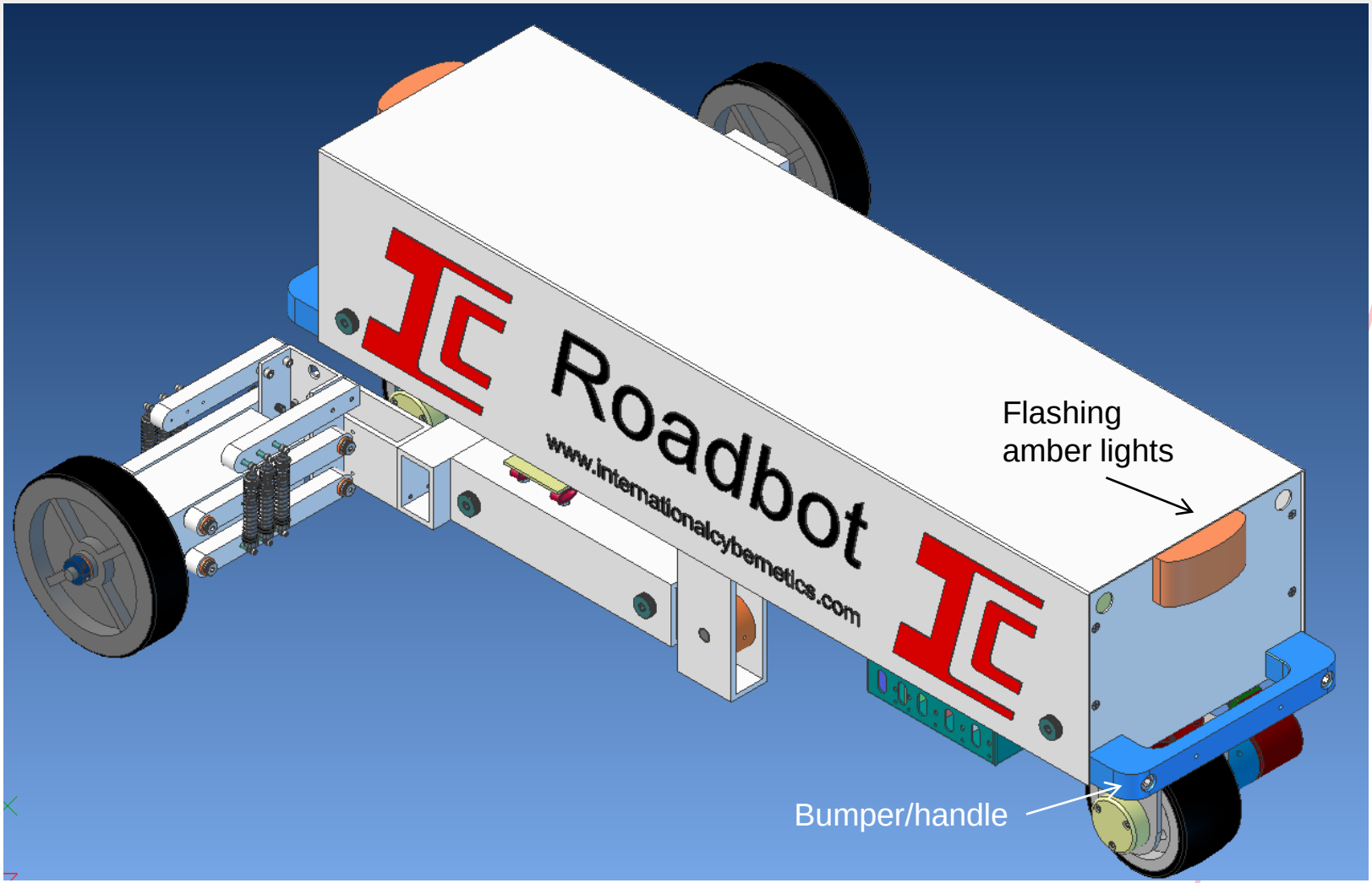
Designing & Building Roadbot



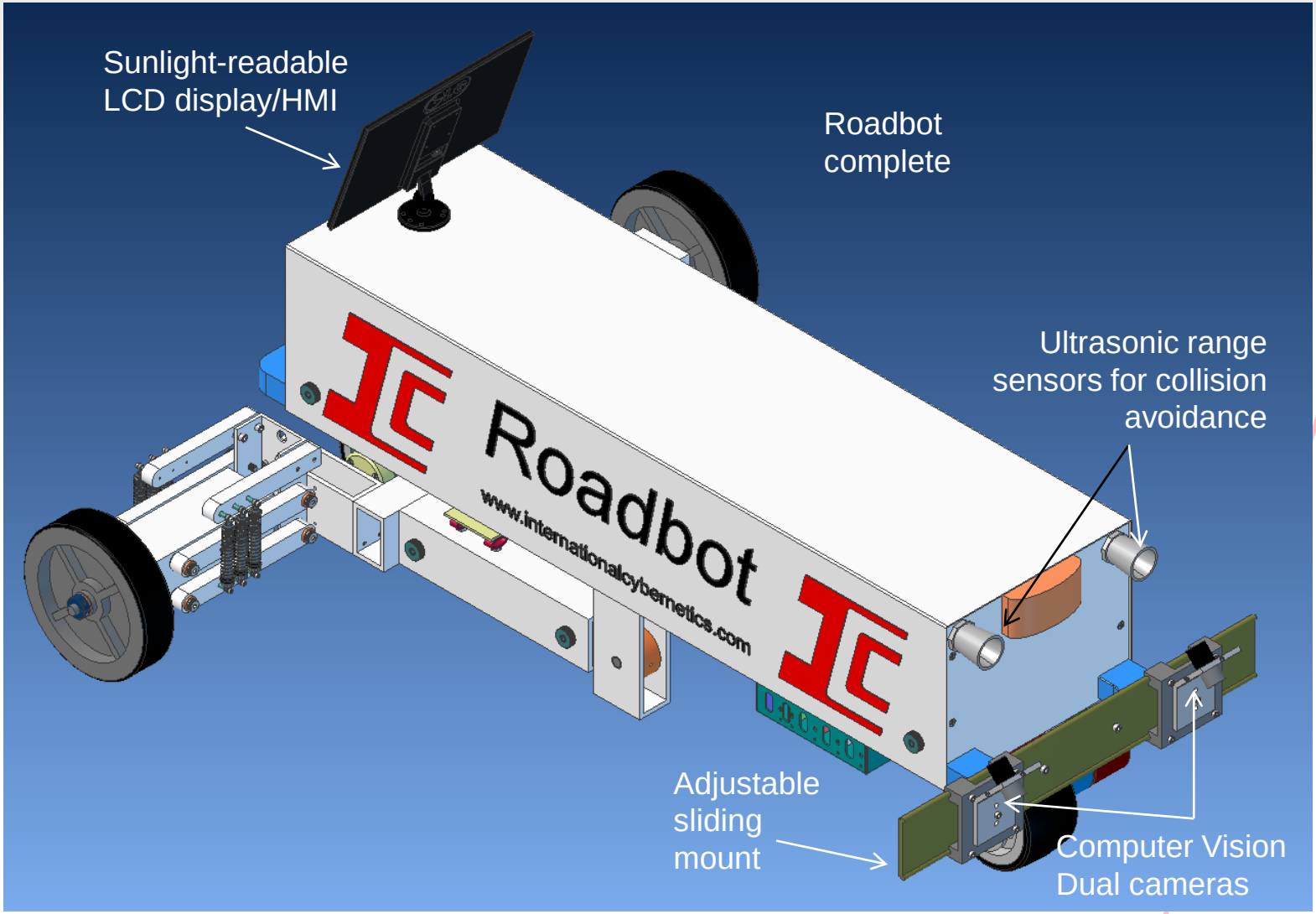
Designing & Building Roadbot



Designing & Building Roadbot



Designing & Building Roadbot



Precision Profiling Methods
Rolling Profilers vs Physics

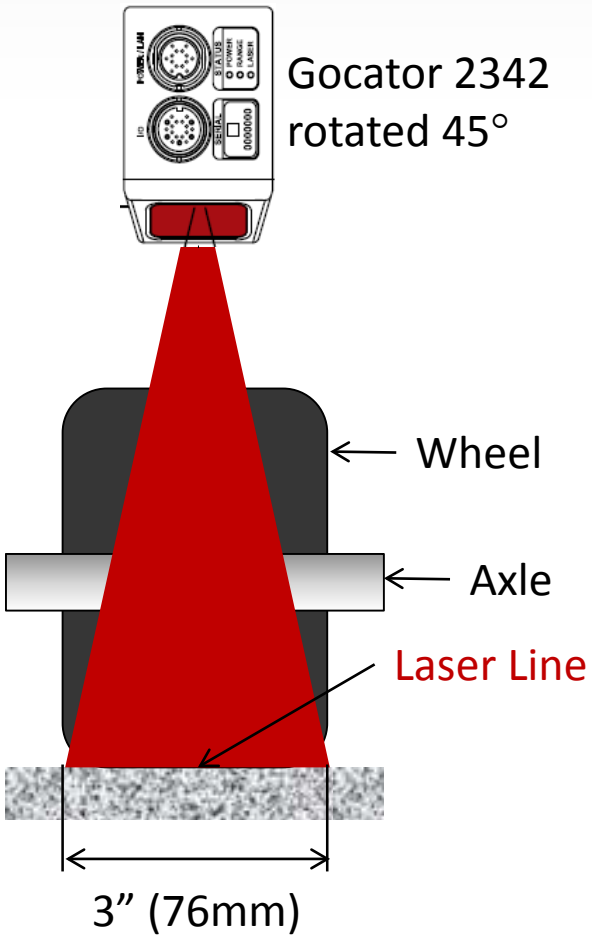
- Conventional rod & level, optical level reference
- Auto rod & level, spinning laser level reference
- Rolling auto rod & level, spinning laser level reference (BMP)
- Rolling inclinometer, gravity reference (SurPRO)
- *Rolling inclinometer with dual laser slope for short waveband, gravity reference (Roadbot)*
- Rolling single laser, inertial reference (inertial profiler, long wavelengths filtered out)

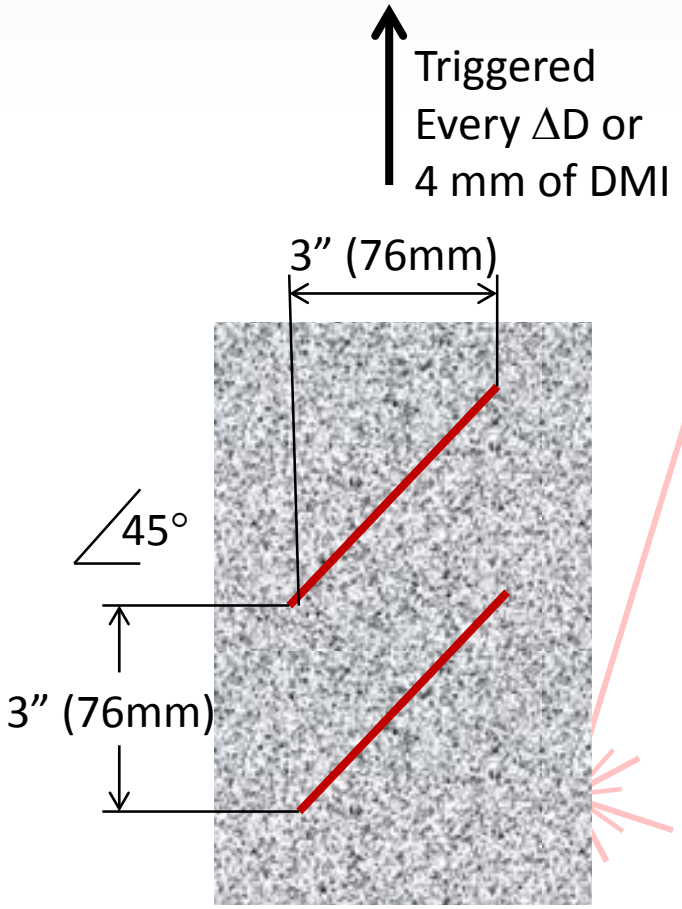
Gocator 2342 Line Lasers

- Roadbot uses two line lasers with bridging

Roadbot End View (along longitudinal axis)

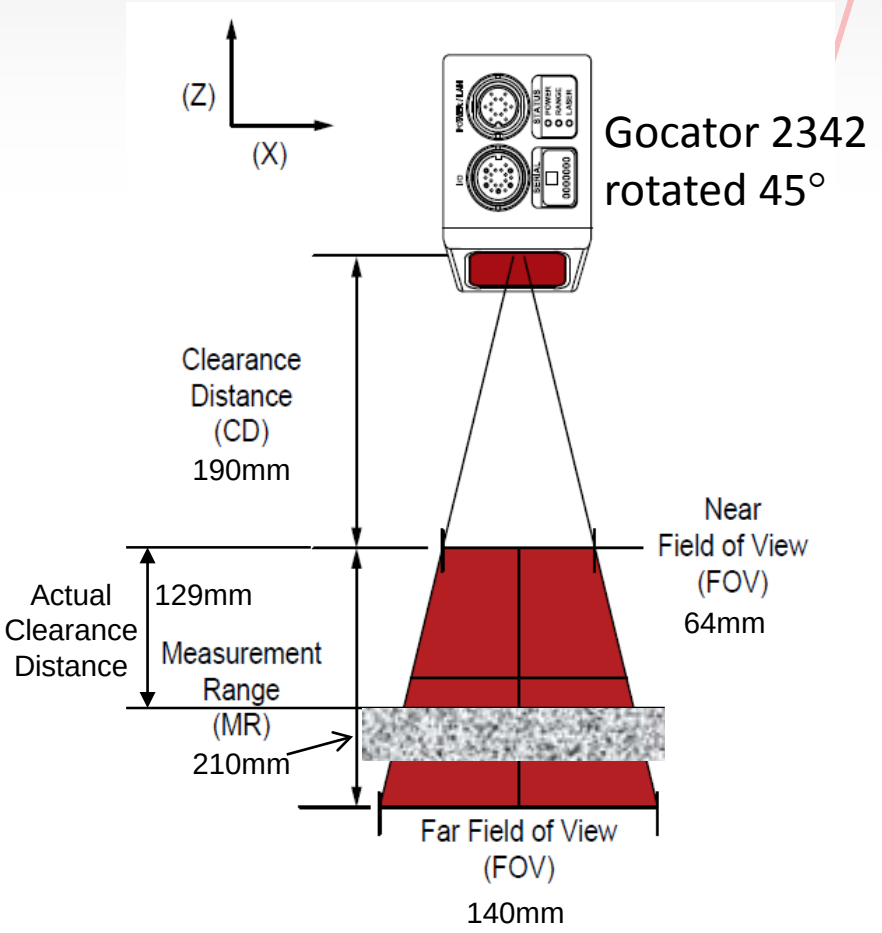
IMPORTANT: Wheels and lasers are collinear





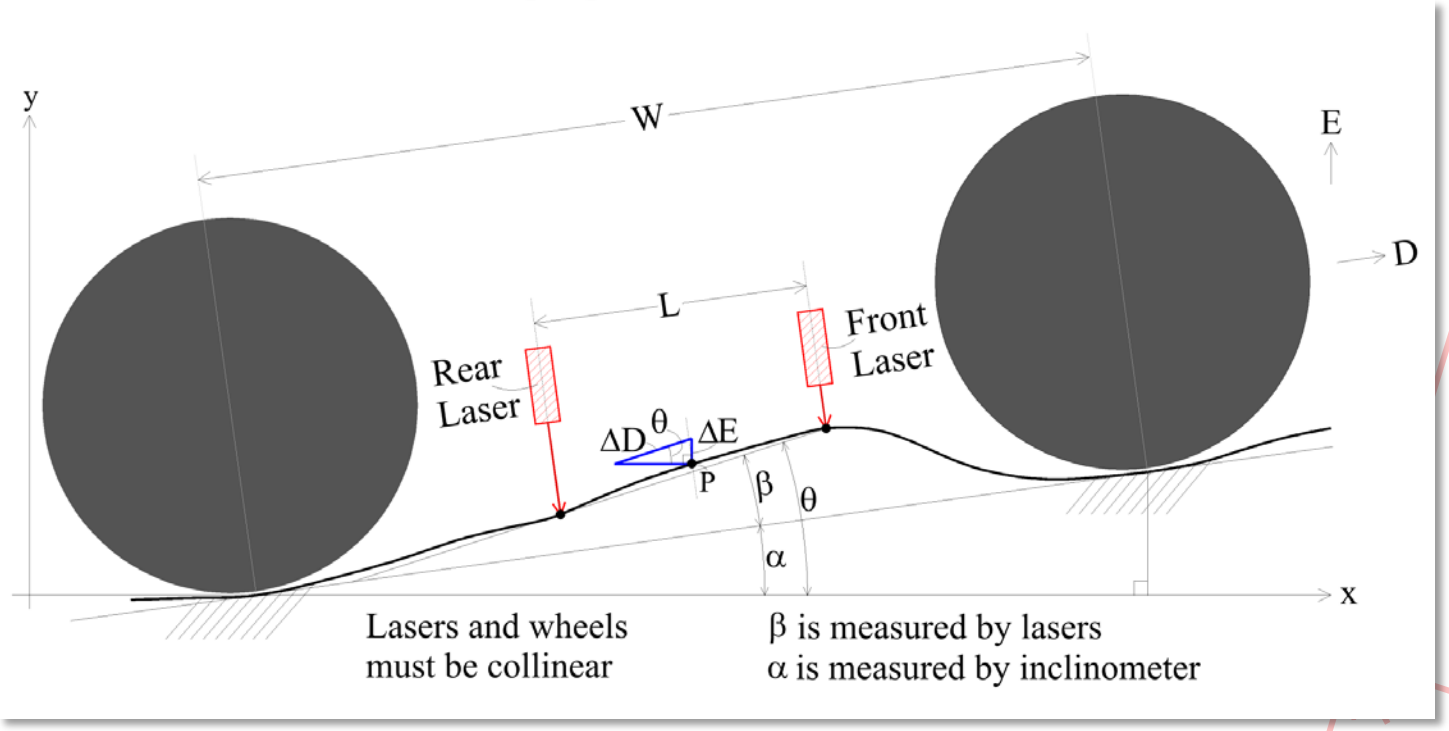
Gocator 2342 Line Lasers

- Both lasers are triggered every ΔD or 4mm of DMI
- Measurements from the lasers give local slope angle β
- Data acquired via both:
  - Serial for single bridged point
  - Ethernet LAN for all points on line



Dual Line Laser Profiler Method

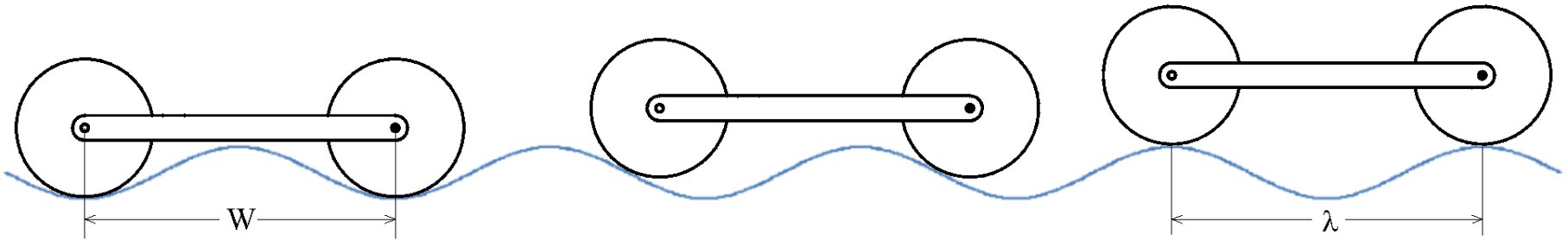
- Incremental changes in elevation are computed from distance encoder (ΔD), dual line lasers (β) and inclinometer (α)



Apparatus & Method are Patent Pending

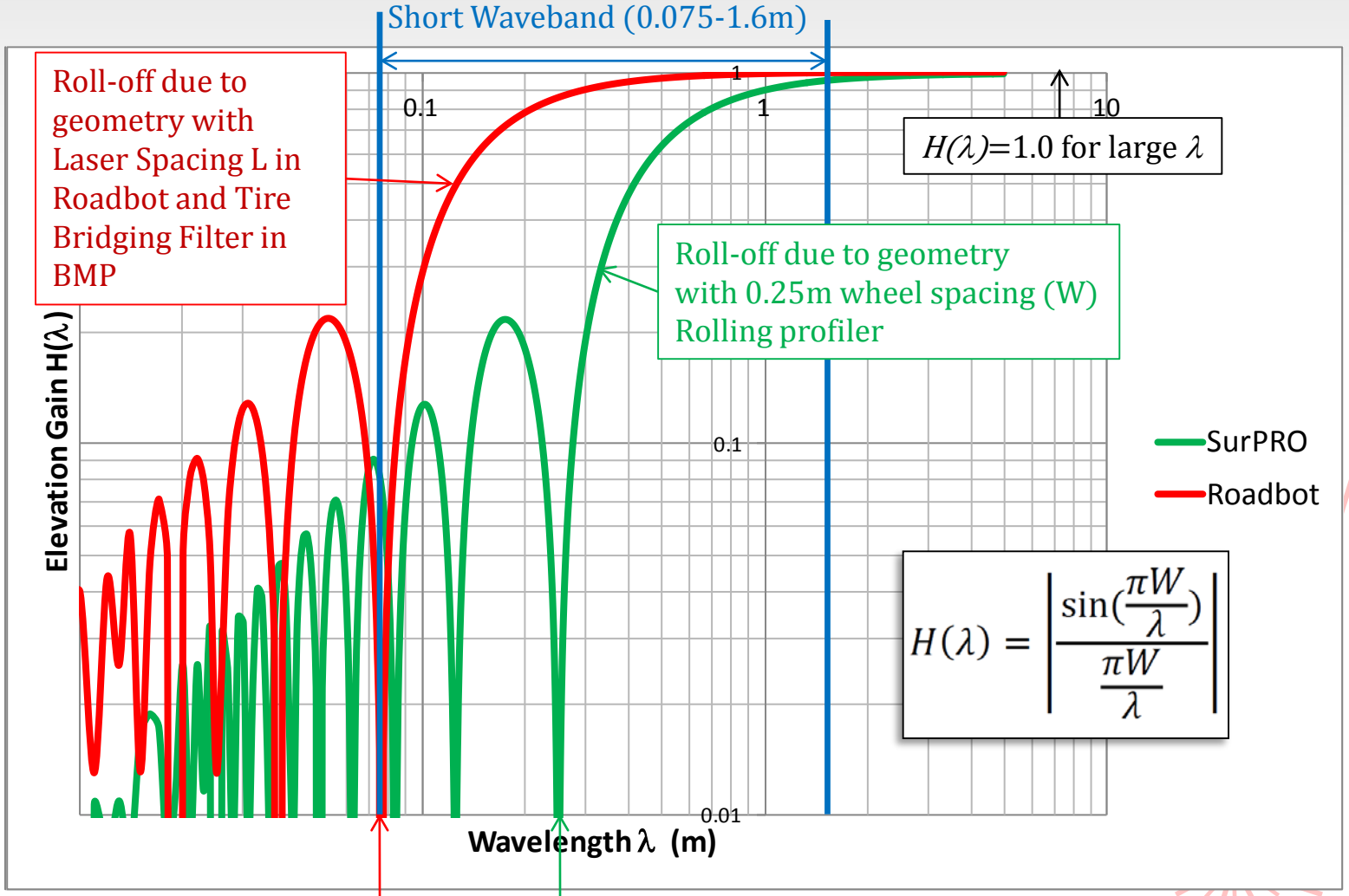
Nulls

- Nulls are wavelengths λ_N of sine wave profile input where inclinometer profiler output is zero because profiler frame always has zero tilt.



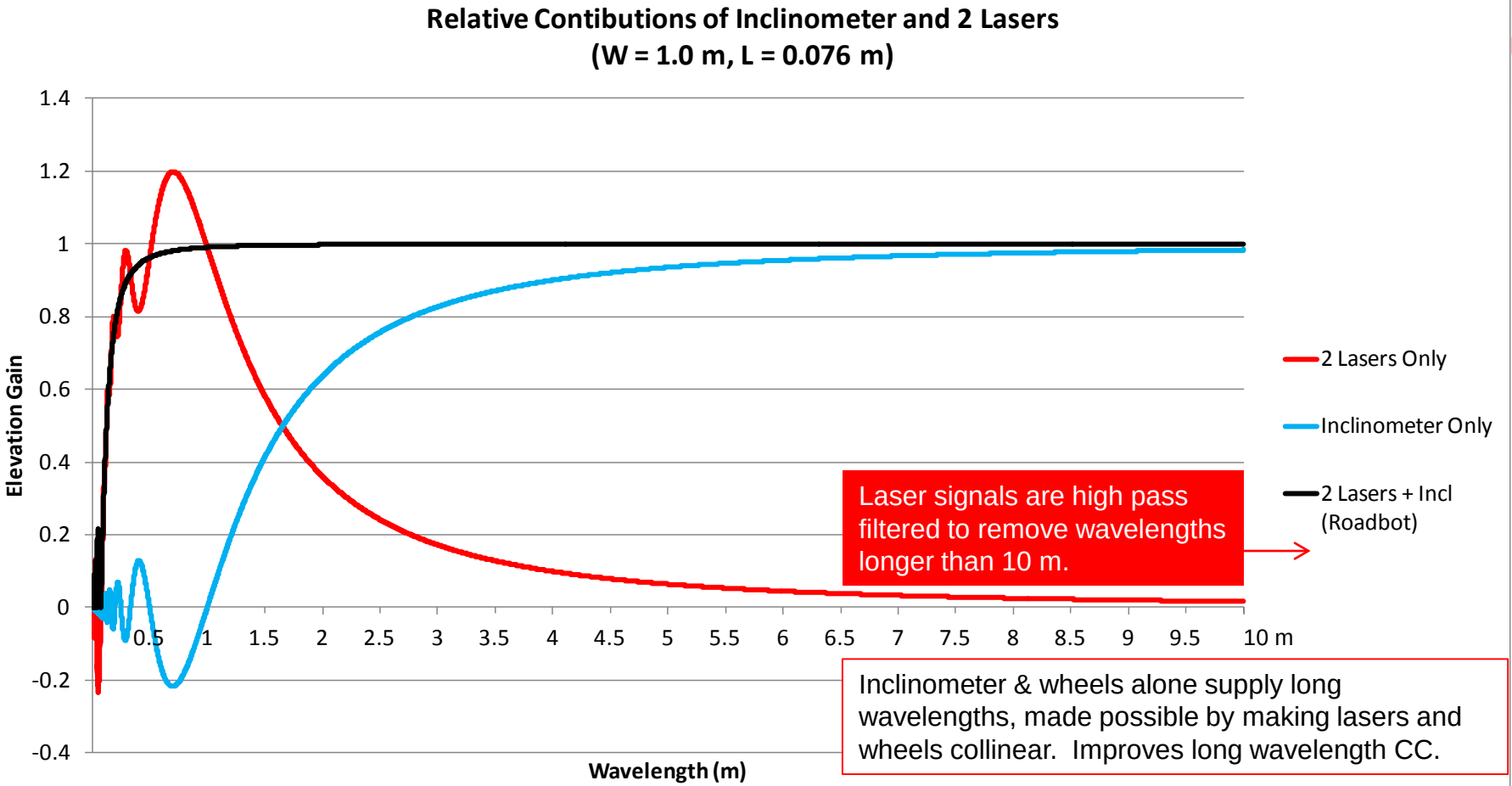
Nulls where $\lambda_N = W/n$, $n = 1,2,3 \ldots \infty$

Wavelength Response



Hybrid Profiler

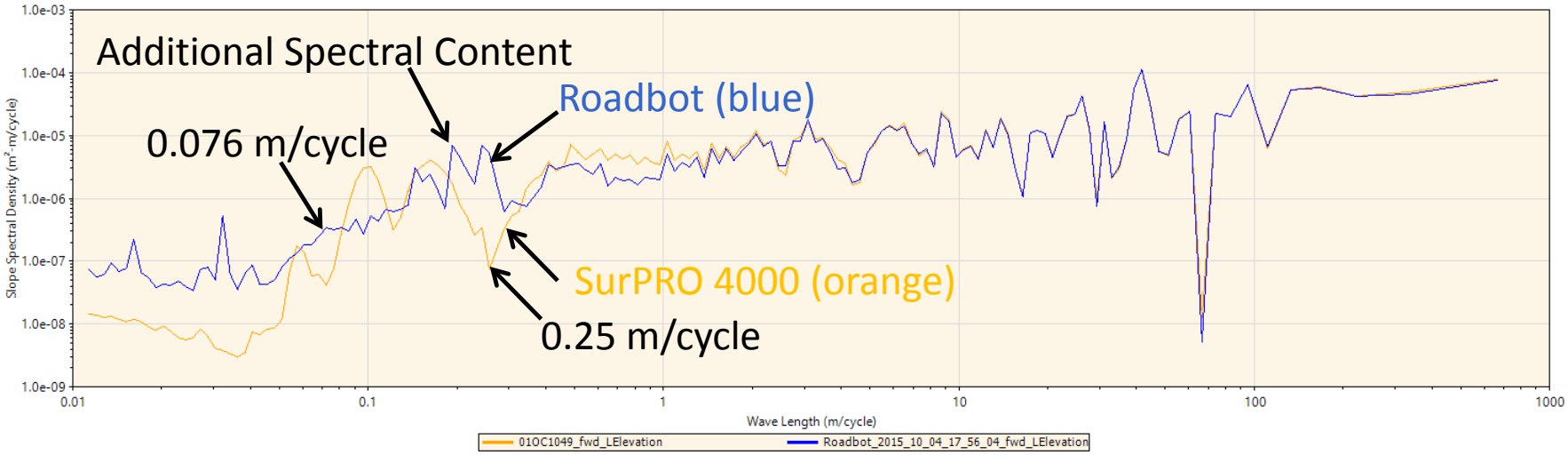
Contributions of Inclinometer & Lasers



Roadbot
Short Wavelength Extension

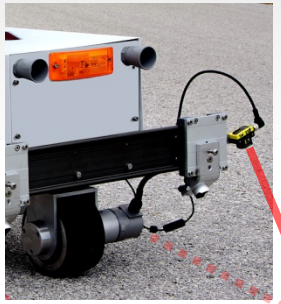
- SurPRO extends to 250 mm sufficient for IRI, medium and long wavebands
- Roadbot extends to 76 mm to add short waveband response

Roadbot uses a 0.050 m Butterworth LP filter to remove noise.



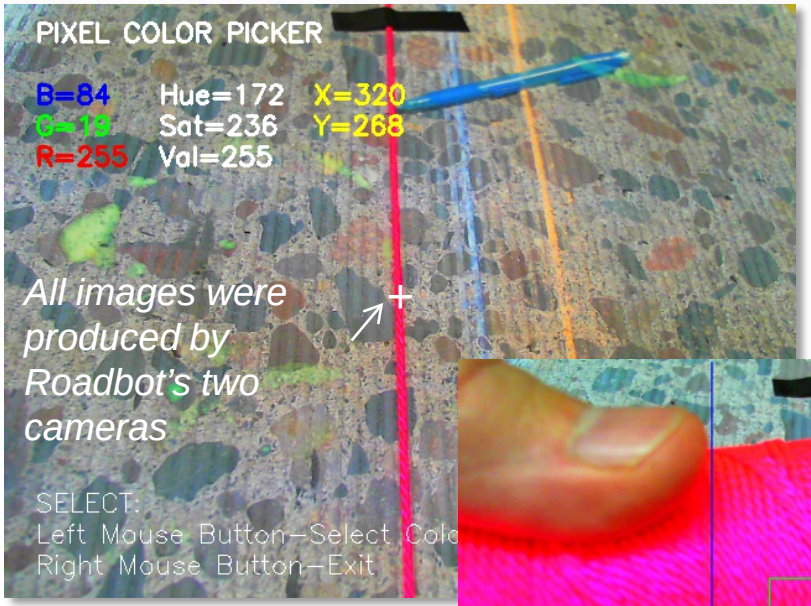
Optical Target Sensor

High Accuracy DMI Target Layout



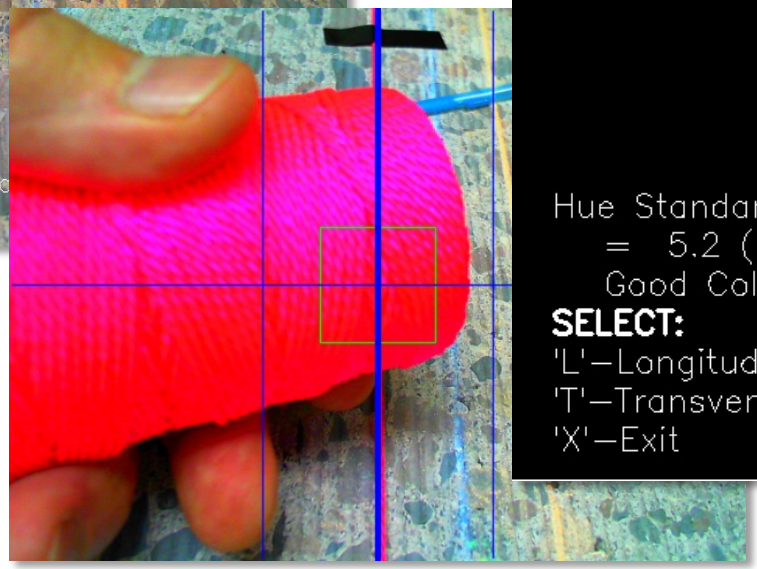
Computer Vision Steering

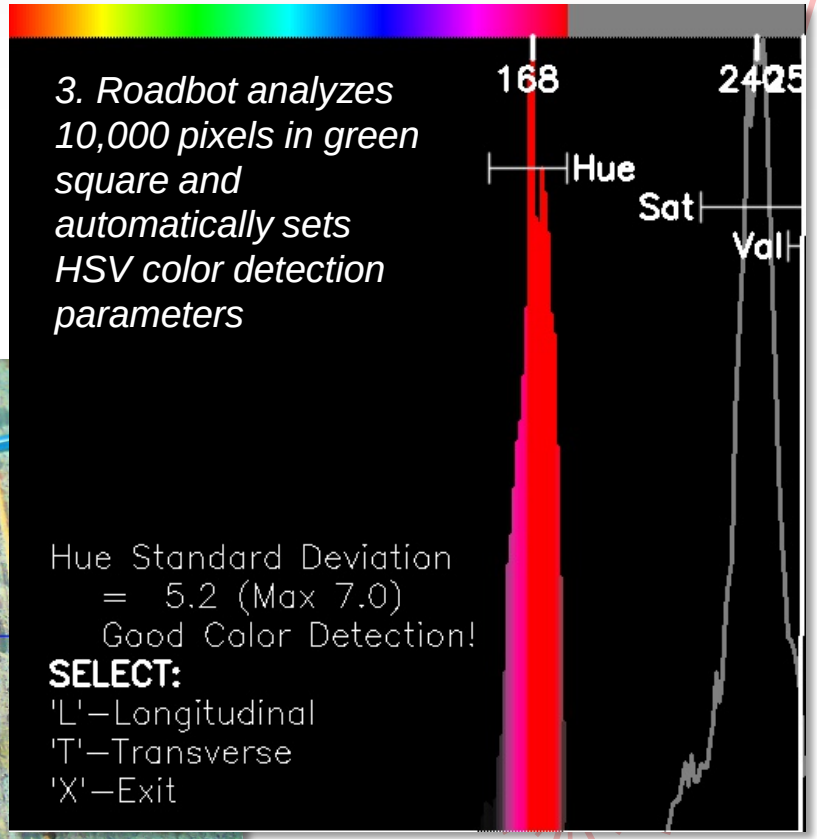
- How to train the color detection system



1. Use mouse to pick a single pixel of desired color, or...

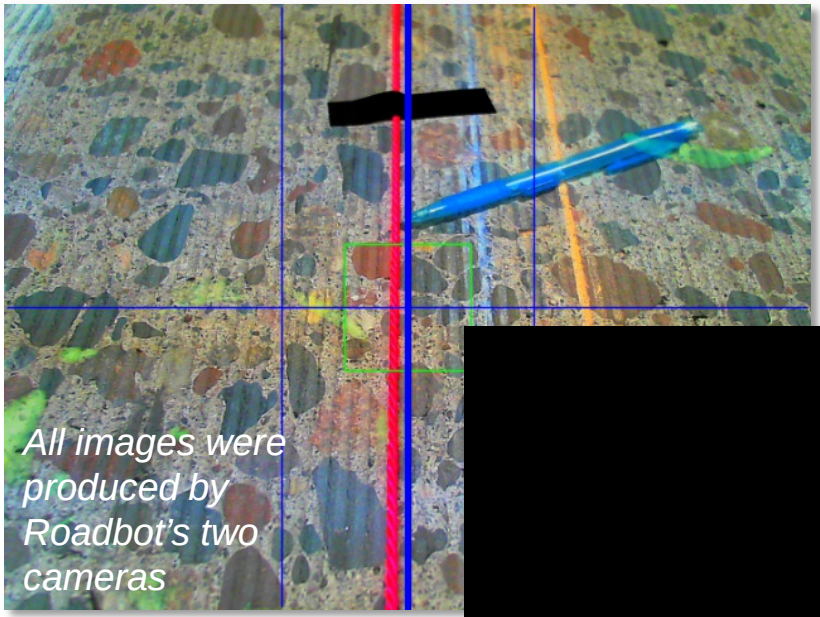
2. Better method: Fill green square with the color to be trained





Computer Vision Steering

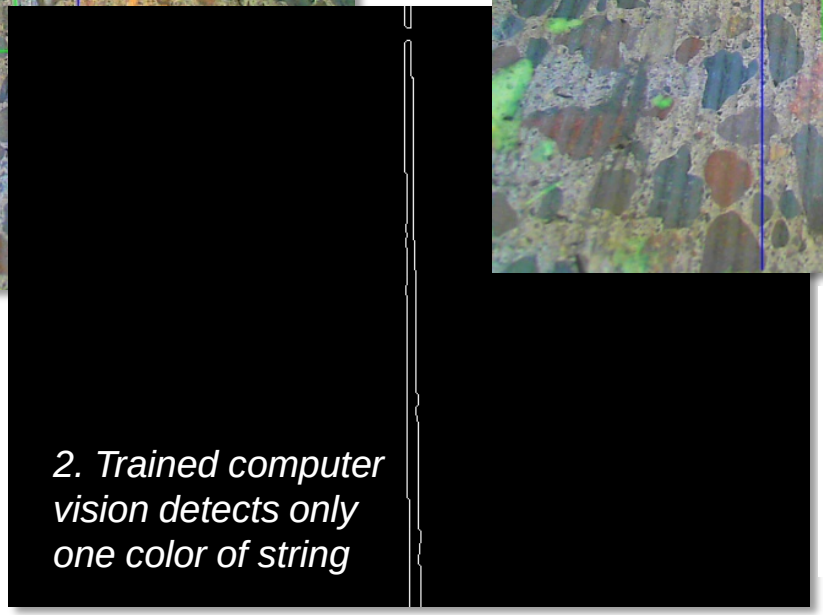
- Computer vision line detection and lock on target



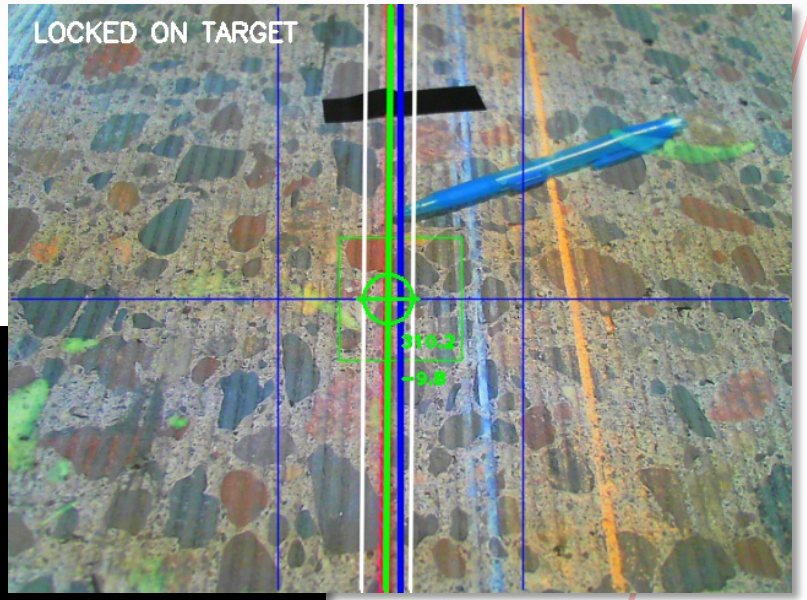
All images were produced by Roadbot's two cameras

1. Stretch out red guidance string at desired offset and tape it down.

Tape won't affect detection.



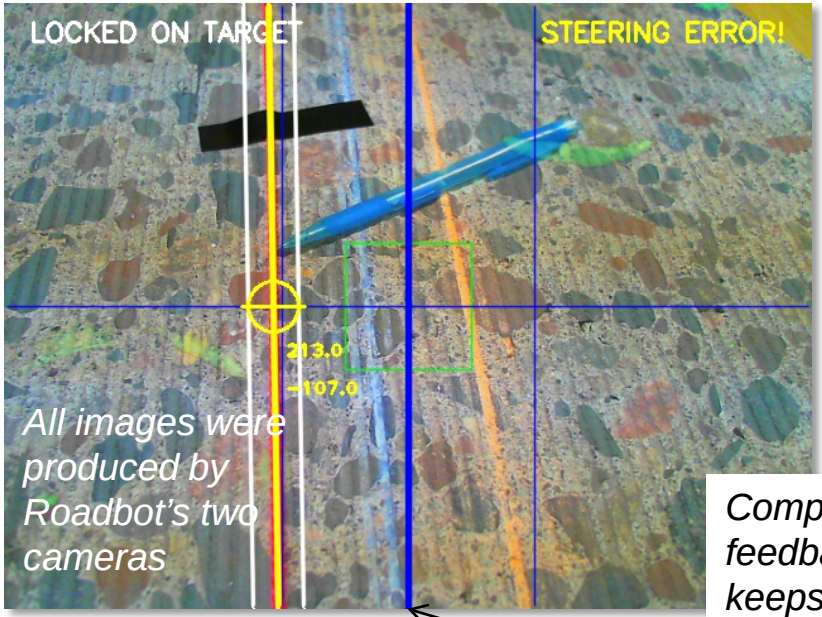
2. Trained computer vision detects only one color of string



3. Computer vision locks on string target and draws green line on top of detected string. In Lock, white lines track target line and <u>everything outside white lines is ignored.</u>

Computer Vision Steering

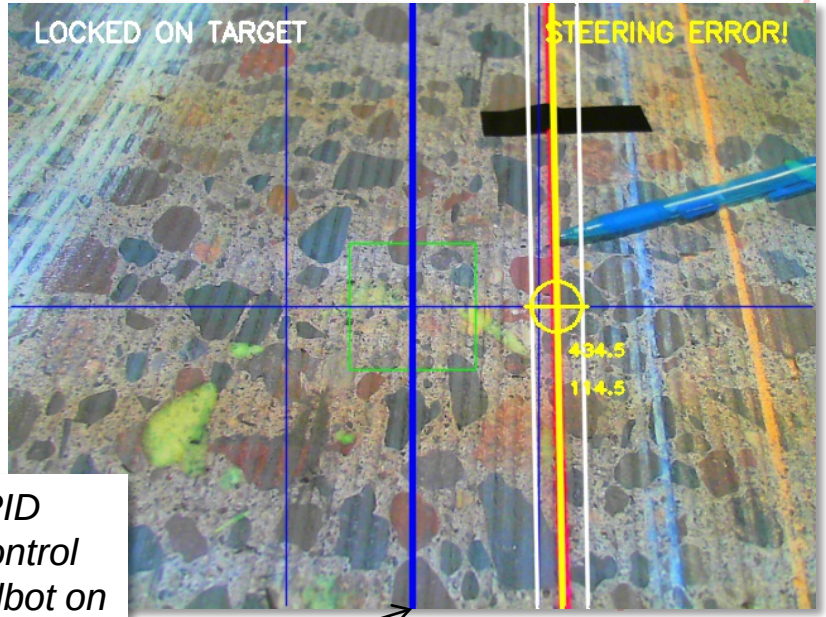
- Outside blue lines “Steering Error!” is declared and if not corrected Roadbot shuts down.



All images were produced by Roadbot’s two cameras

Steering Error declared since detected line is left of blue max allowed steering error line.

Computer PID feedback control keeps Roadbot on center blue line



Steering Error declared since detected line is right of blue max allowed steering error line.

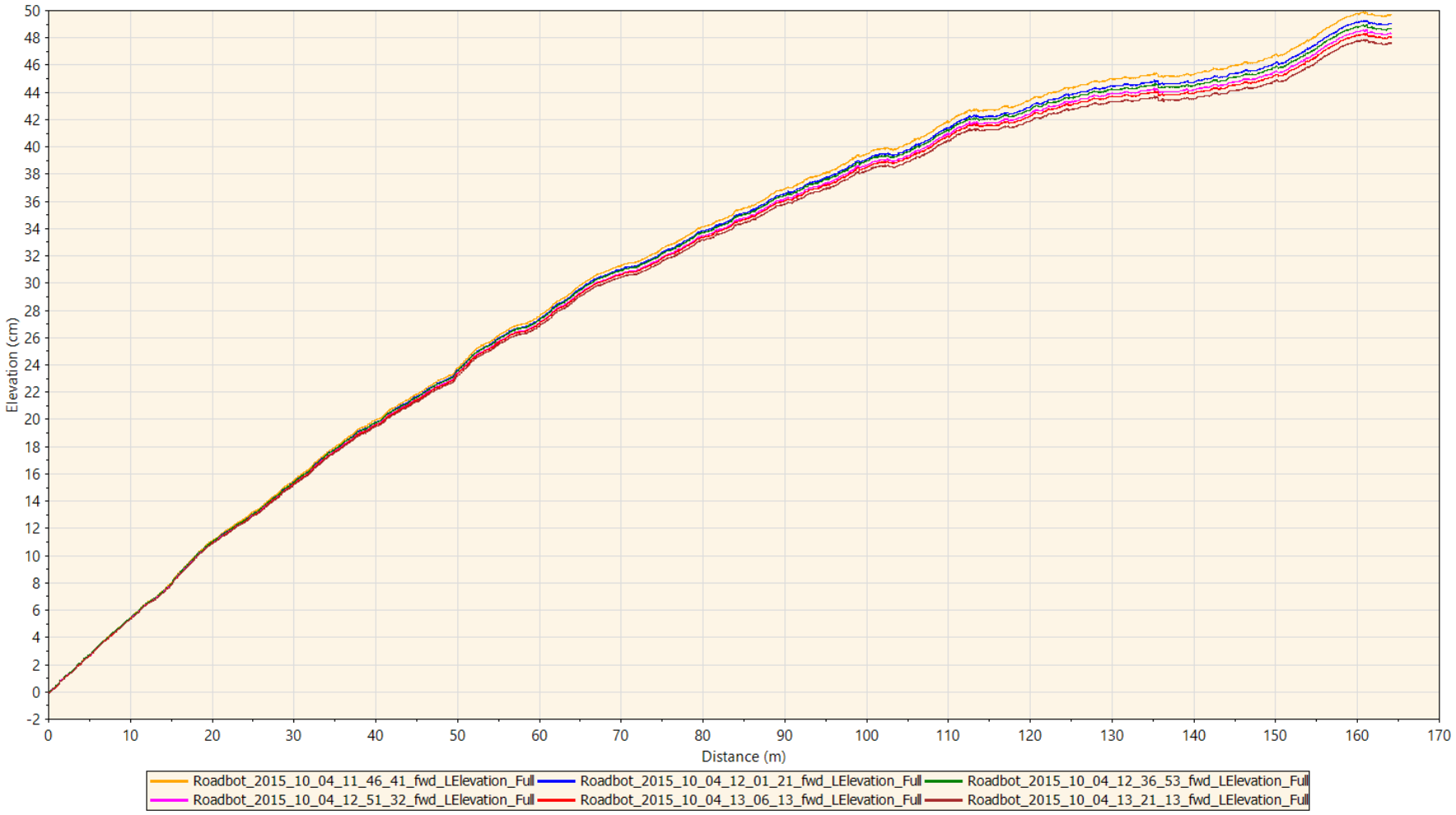
Center blue line is “zero error” target for steering system

Additional Guidance Options

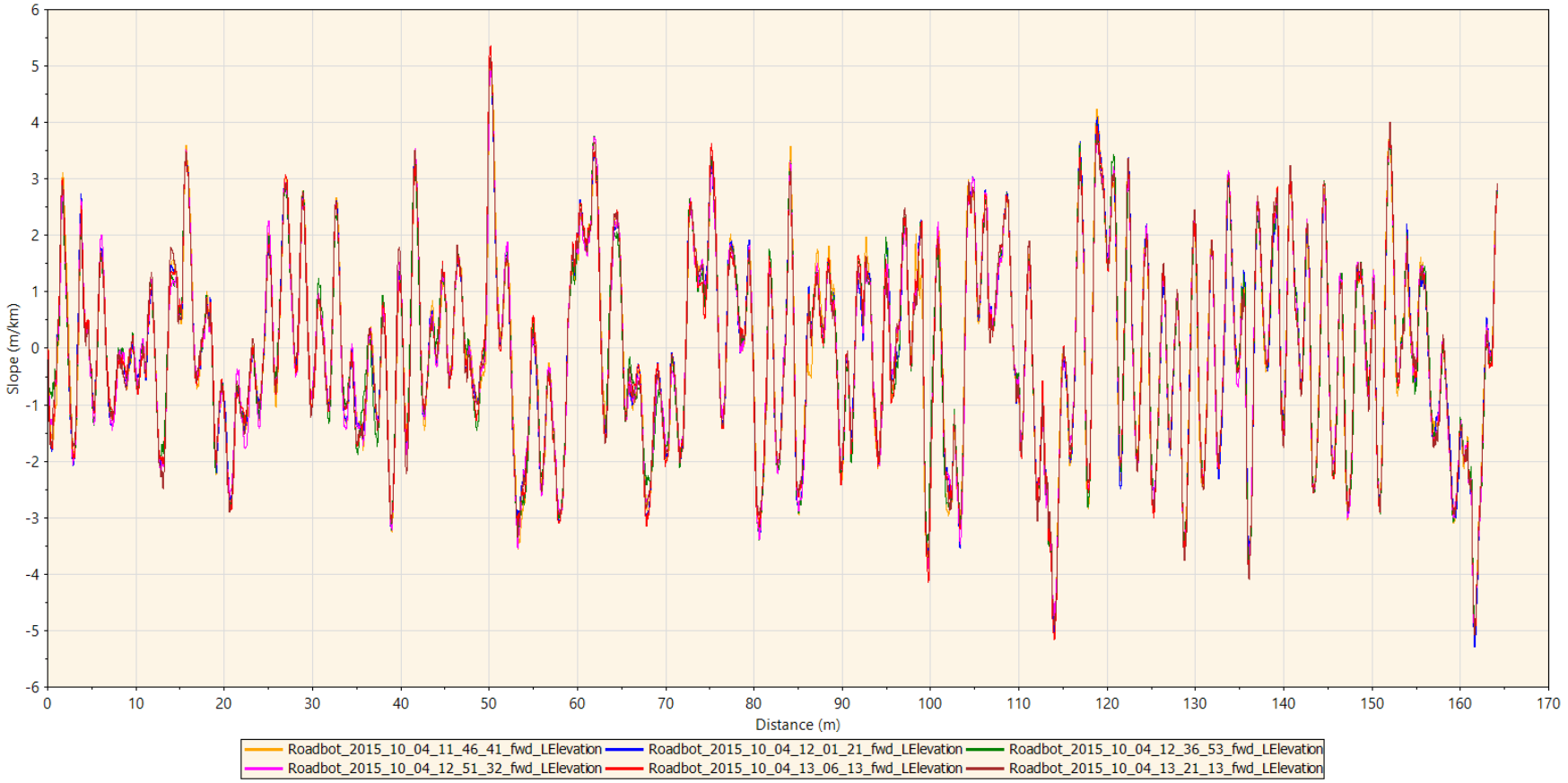
- Rope, chalk, paint, metal tape line
- Radio source beacon direction finding
- Light source beacon direction finding
- Fog line guidance (constant offset)
- Programmed path and Gyro referenced guidance
- GPS

Roadbot at MnRoad 2015

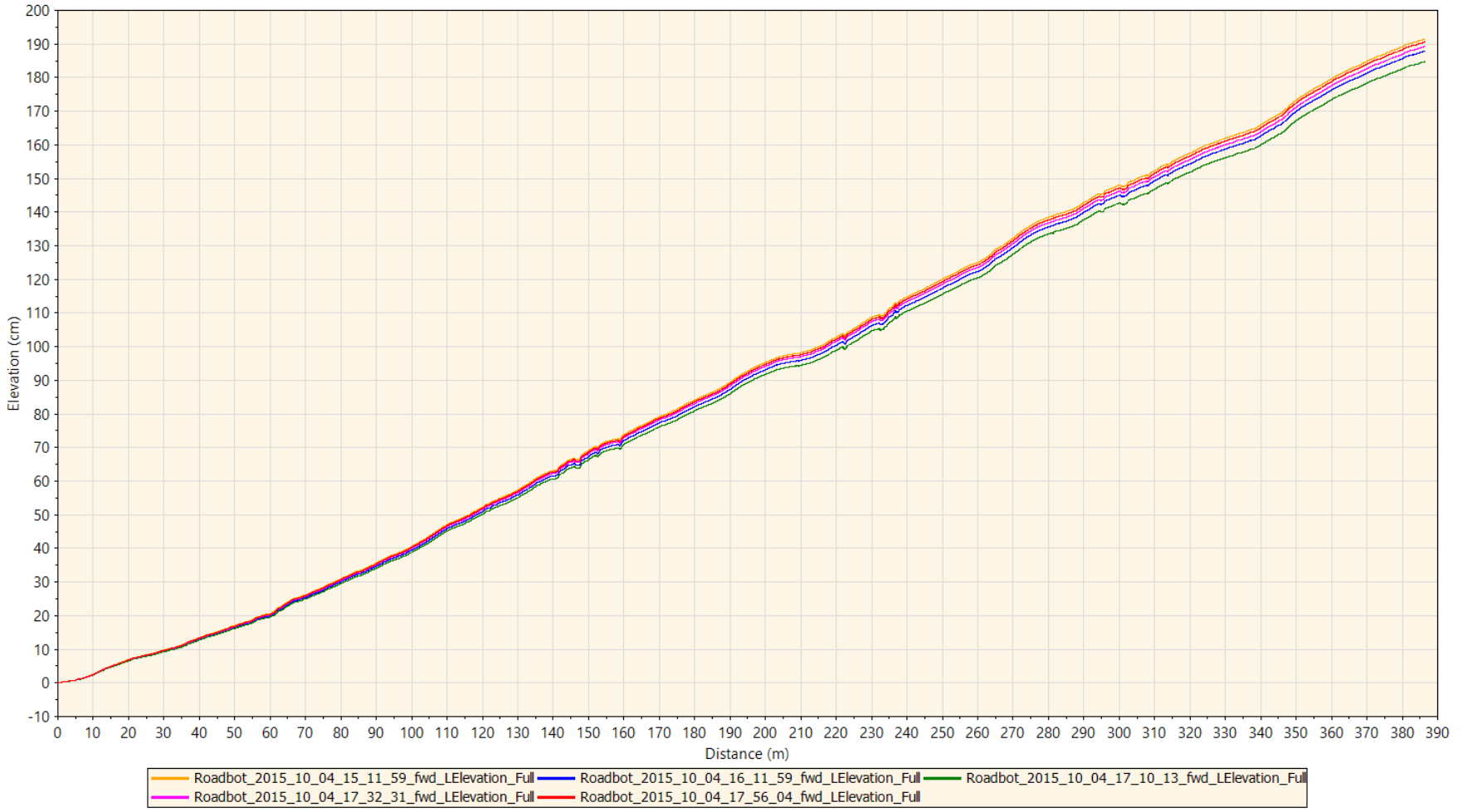
MnRoad 2015
Transverse Tined Concrete



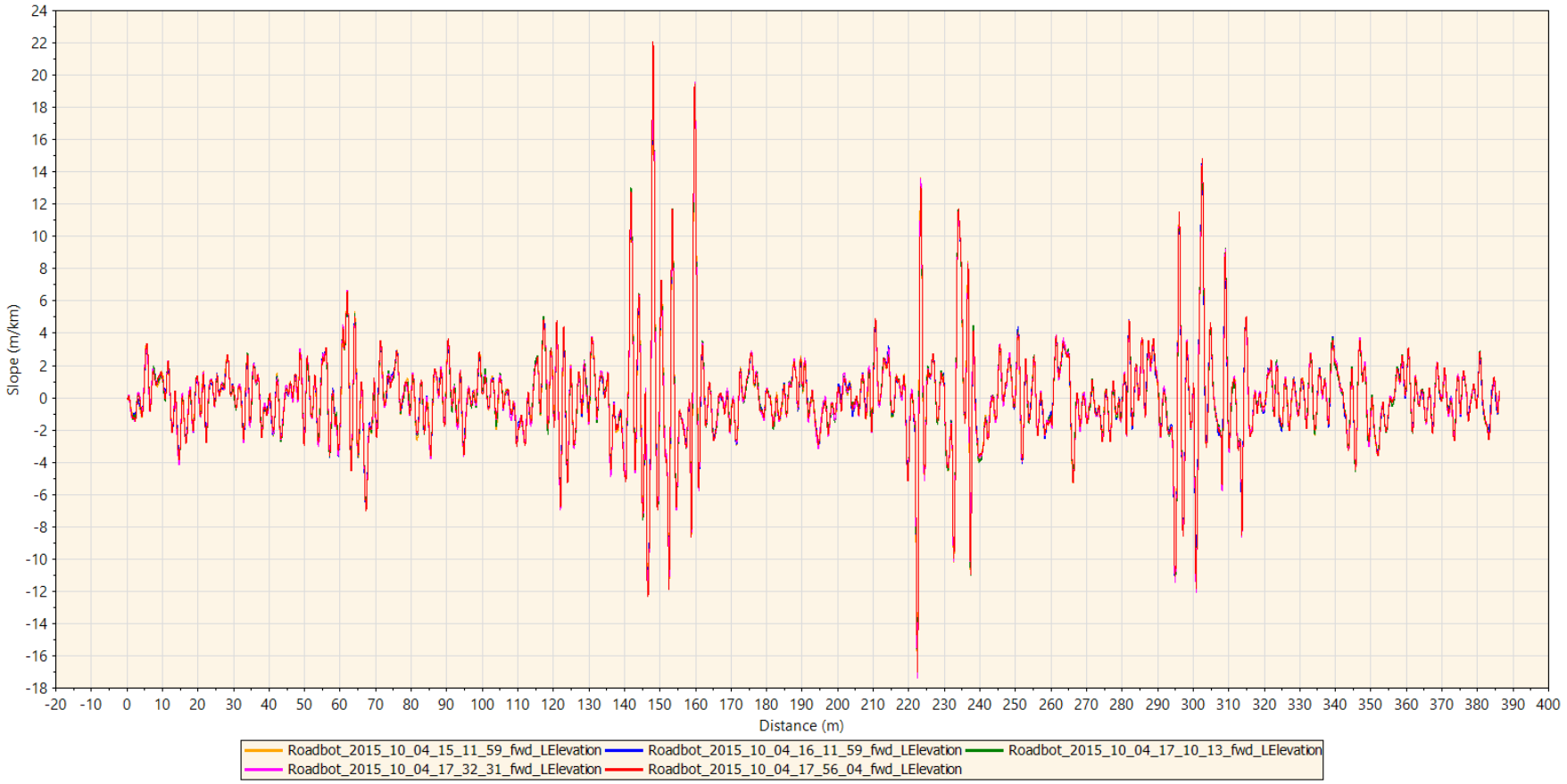
MnRoad 2015
Transverse Tined Concrete



MnRoad 2015
Long Asphalt



MnRoad 2015
Long Asphalt



Roadbot Development
What we learned at MnRoad

- We're still fine tuning and improving performance
- Tuned out PID steering instability "S curves"
- Best performance on transverse tined concrete and long asphalt with CC repeatability of ~0.99
- Computer vision color training improvements
  - Completed and in this presentation
- Use LED flood fill lights to fill shadows or night use
- Loose aggregate drive wheel slip on chip seal
- Gocator 2342 worked well; no issues
- Generally very promising results

Roadbot Development
Next Steps

- Complete user interface (HMI)
- More field testing, goal of CC in high 0.99's
- Co-operation/demonstrations/evaluations with State DOTs and Research Organizations
- Compliance with ASTM E-950-15 draft
  - Benchmark compliance in all wavebands
  - Short waveband, included but not required
  - 76mm wide footprint, included but not required
  - High accuracy optical target DMI needed to support short waveband, included but not required
- Continuous improvement

Benchmark Profiler Challenge

- Host an open Benchmark class rodeo with the goal of finding the best “Ground Truth” device
- Independent expert Test Manager performs all testing and analyzes data to eliminate bias
- Proponents train Test Manager to operate devices
- Test Manager operates devices, manages data
- Each run must be completed from start to end before set up and collect any data for next run
- Analyze IRI, medium, long & short waveband for repeatability CC & accuracy CC with other devices
- Test Manager prepares independent report

Thanks!

To:

- Rohan Perera, SME
- Steve Karamihas, UMTRI
- Darel Mesher, Tetra Tech EBA
- James Richitt, ICC
- Adam Kennedy, ICC
- Leanne Goethe, ICC

For more information please go to:

- surpro.com
- intlcybernetics.com