


SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Advanced Methods to Identify Asphalt Pavement Delamination (R06D) Ground Penetrating Radar (GPR) Caltrans

William Owen

Peer Exchange
August 1-3, 2018

U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO

Introduction

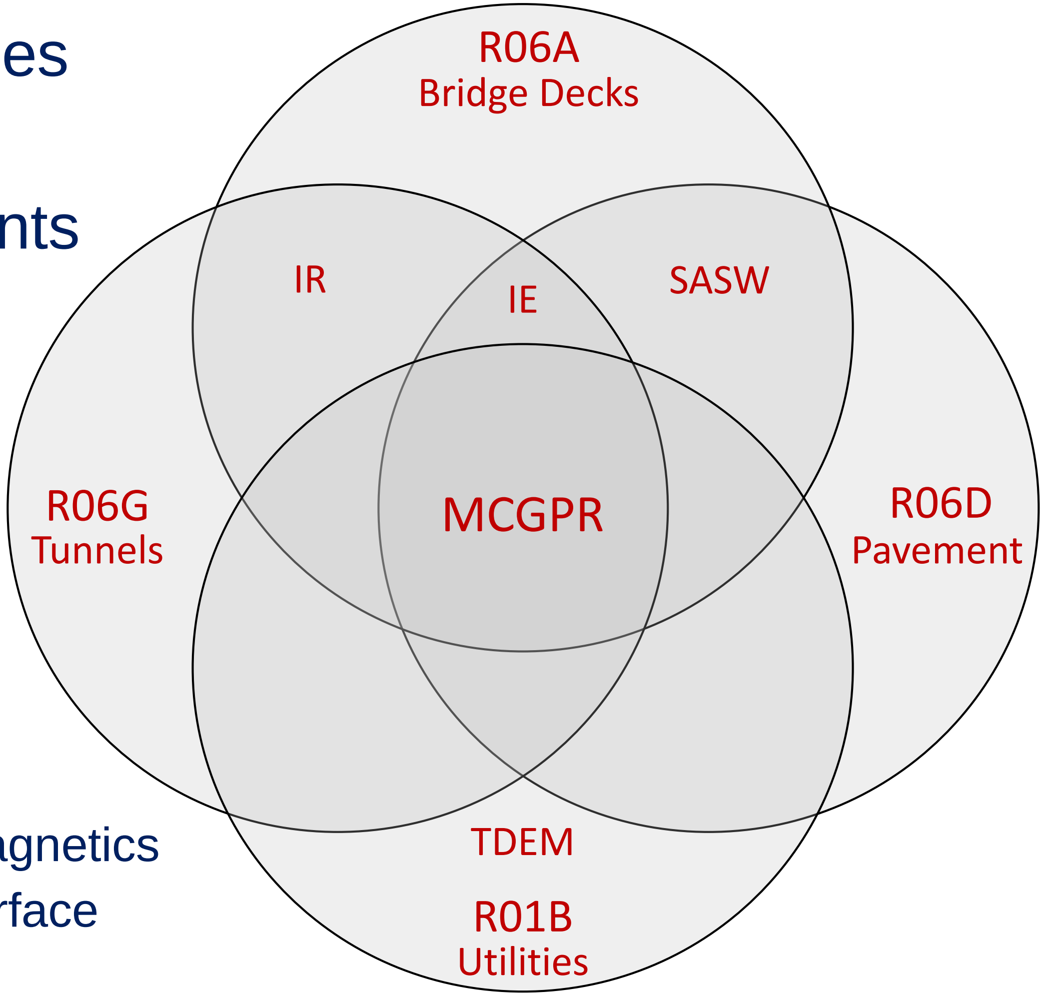
- How We Got Here
  - ✓ Strategic Highway Research Program, (SHRP2)
- History of GPR at Caltrans
- A Little GPR Background
- A Bit More Inertial Aided GNSS Background
- Results So Far
- Possible Follow-Ups

History of Caltrans GPR

- 1998: PE IV and PE 1000
  - Utilities, NDT, Geotech
- 2000: Tow Cart
  - Pavements
- 2001: 2-½ D Applications
  - Void mapping
  - Pavement research
- 2006: 3-D Visualization
- 2008: Upgrades (PE Pro)
  - Improved tow cart, larger grids, high sample density
- 2009: Pavement Management
  - 58,000 Lane Miles (2009-2012)
- 2011: SUE
- 2015: Multichannel Radar
  - Product Demos (IDS, 3D Radar)
  - Bridge Deck Pilot (3D Radar)
  - SHRP2 Round 6 (R01B-SUE)
- 2016: SHRP2 Round 7
  - R06D (Pavement)
  - R06A/G (Bridge decks/Tunnels)
  - R01B (SUE)

SHRP2 Technology Overlap

- No single grant provides full funding
- Leverage multiple grants for technology acquisition

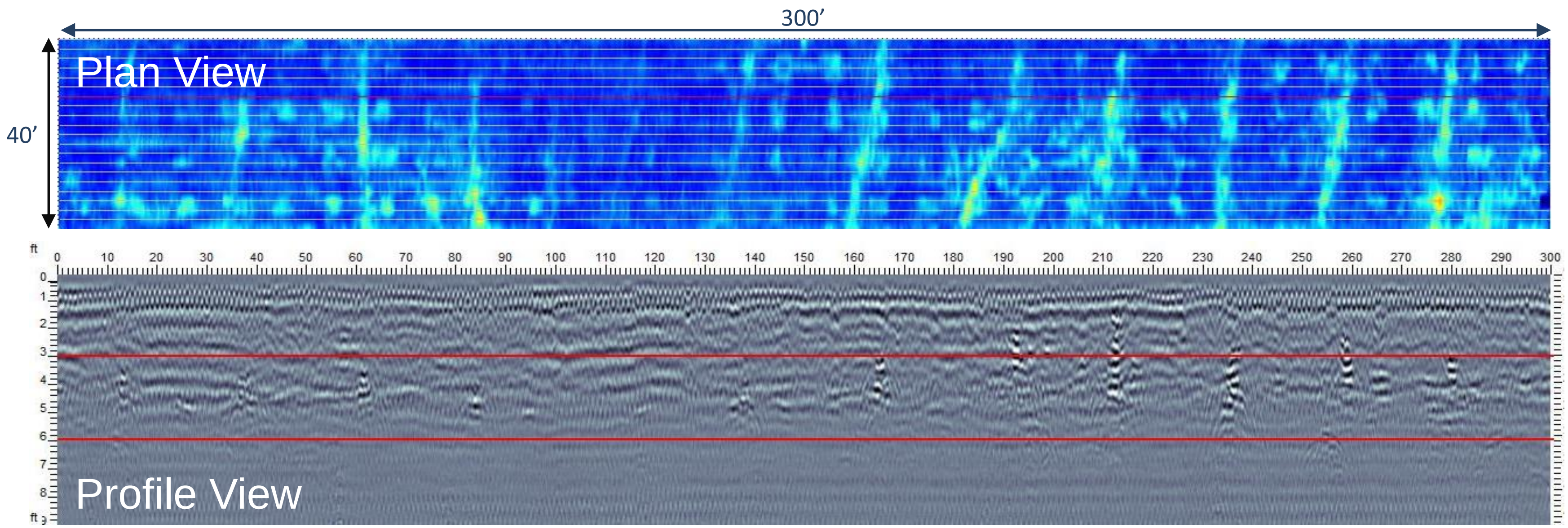


IE – Impact Echo
IR – Infrared (Thermal Imaging)
TDEM – Time Domain Electromagnetics
SASW – Spectral Analysis of Surface Waves
MCGPR – Multichannel GPR

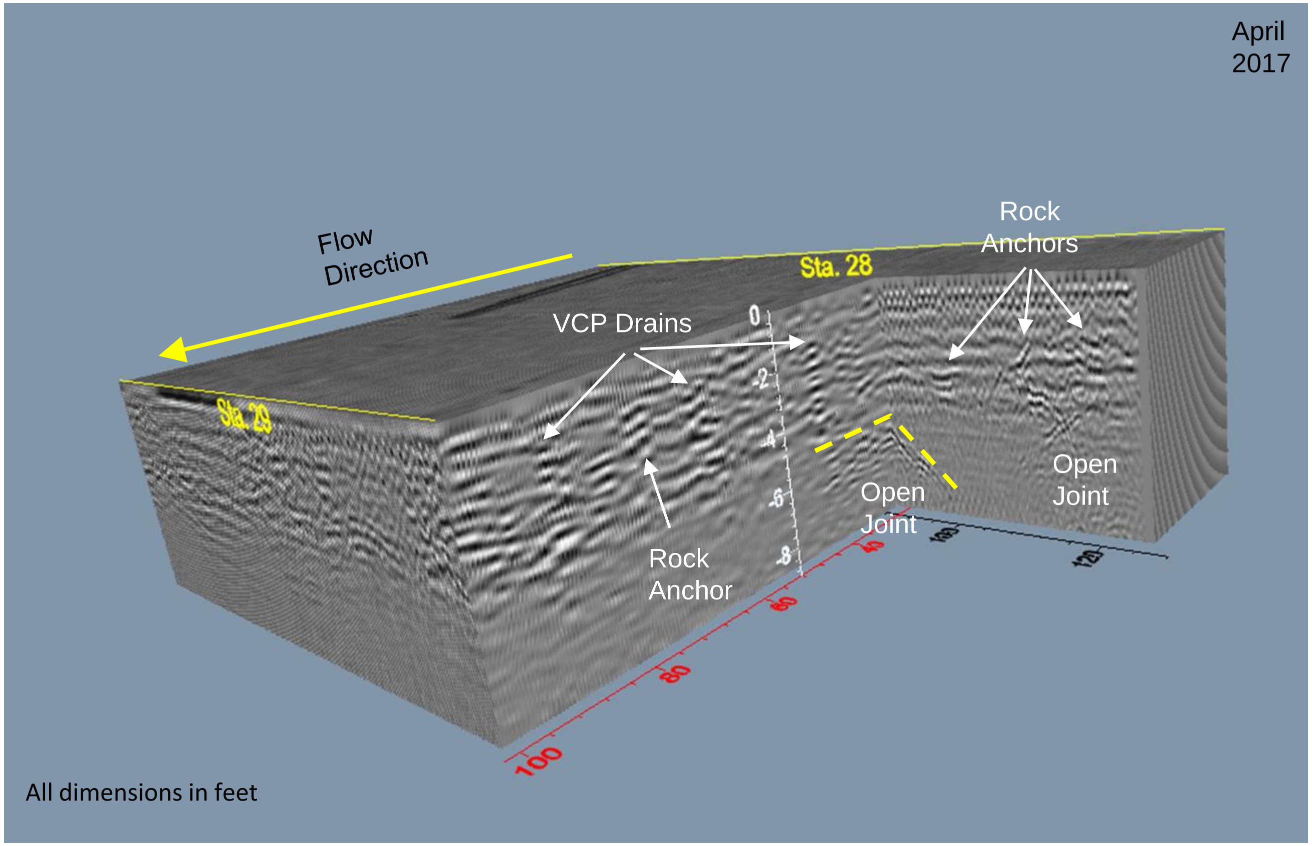
Caltrans SHRP2 Goals

- Validate GPR technology for diverse applications
- Bring high-speed GPR technology to Caltrans for pavements & bridge decks
- Improve testing methodology and reporting
- Training and technology transfer
- Develop appropriate roles, responsibilities and business practices for collaboration

2D GPR Rendering



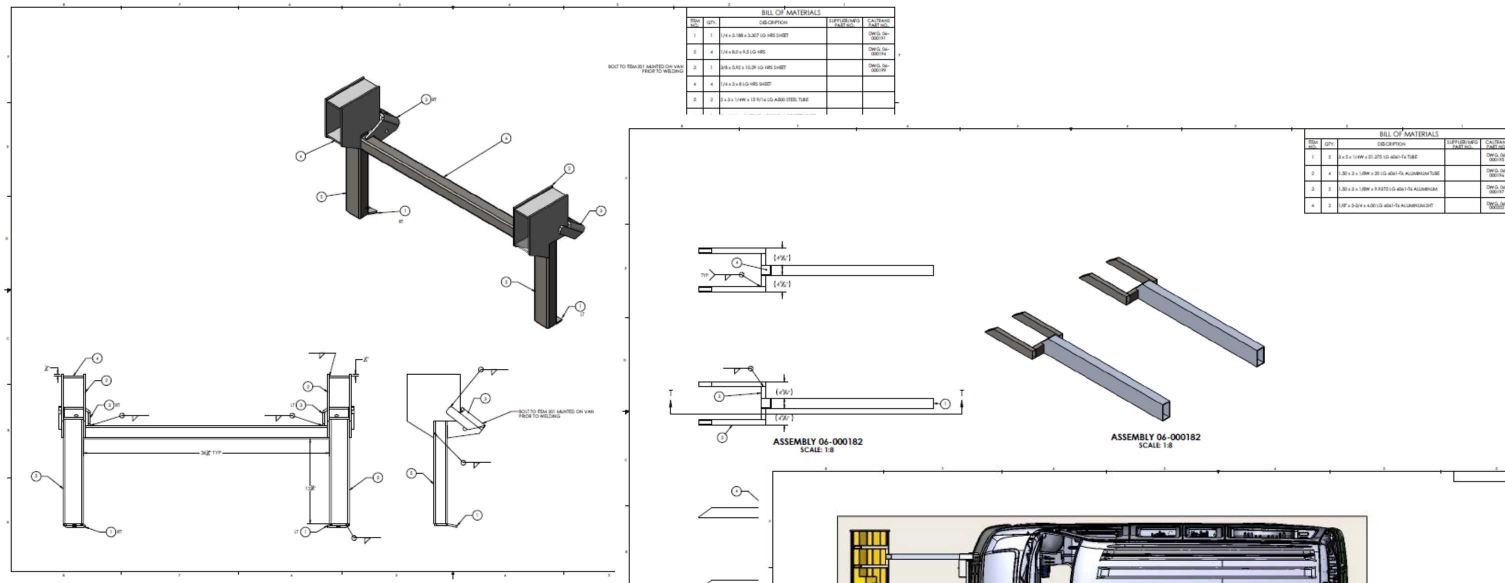
3-D Rendering

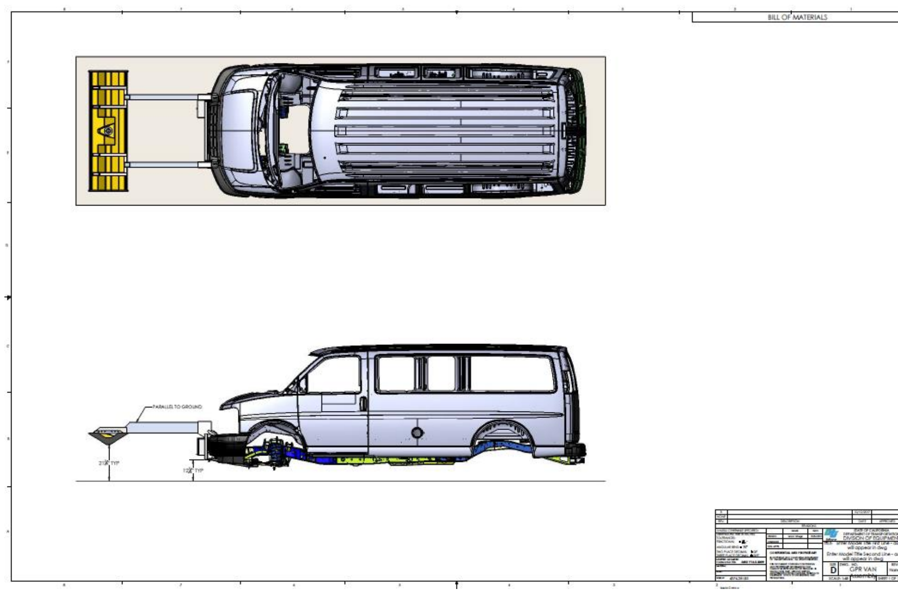


3D Radar Implementation

- Collaboration at State & National Level
  - Funding through FHWA & AASHTO
  - Design and Fabrication through CT-GS and CT-DOE
  - Installation and Testing through CT-GS and UC Davis
- Implementation Challenges
  - Short Delivery Schedule
  - Rigid Mounting System
  - Reliable Power Supply
  - I/O From Multiple Data Streams

Mounting System Fabrication



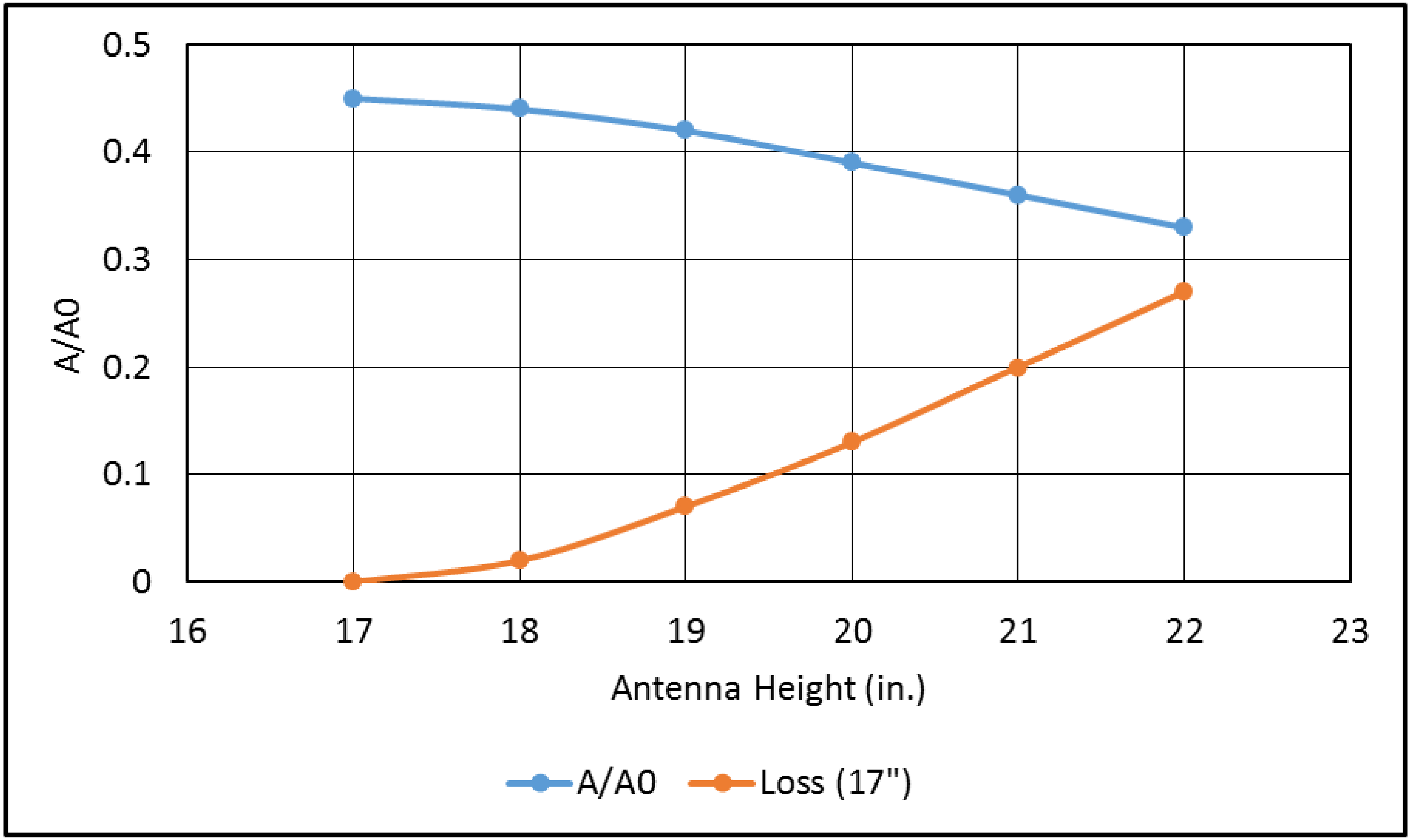


- **Critical Design Criteria**
  - 48” Antenna/Vehicle Separation
  - <24” Antenna Height
  - Use All Four Mounting Brackets

Final Assembly

Final Assembly, Interior

Energy Loss vs. Antenna Height



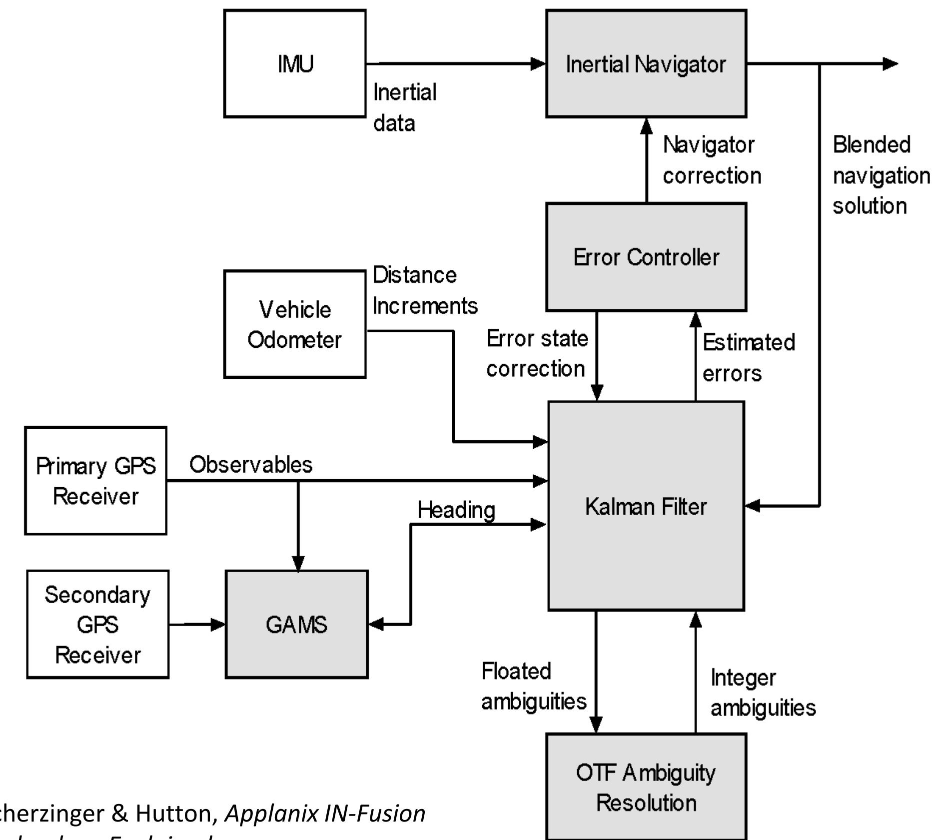
POS LV - GNSS Aided Inertial Navigation

- Dual Antenna GNSS
  - ✓ position, attitude & heading
- Three-axis IMU
  - ✓ Accelerometer & gyroscope
  - ✓ 100 Hz output
- DMI Odometer
  - ✓ Up to 20,000 pulse/m
- Integrated processor
- PC interface
  - ✓ Real-time output
  - ✓ User parameter controls

https://www.applanix.com/img/gallery/pos_lv_imu_ant_dmi.png

Real-Time Onboard Processing

- Kalman filter -- raw pseudorange & carrier phase
- IMU -- resolution of initial ambiguities, maintains accuracy during “cycle slip” or GNSS outage (solution from last known position
- GNSS Azimuth Measurement Subsystem (GAMS) --heading & attitude
- Distance Measurement indicator (DMI) -- constrains velocity error and IMU drift



Scherzinger & Hutton, *Applanix IN-Fusion Technology Explained*
https://www.applanix.com/pdf/Applanix_IN-Fusion.pdf

Post-Processed Inertially-Aided Kinematic Ambiguity Resolution

Post-processed tightly coupled inertial and GNSS data using POSPac MMS software

Smoothed Best Estimate Trajectory (SBET) solutions computed using forward and reverse-time processing of data

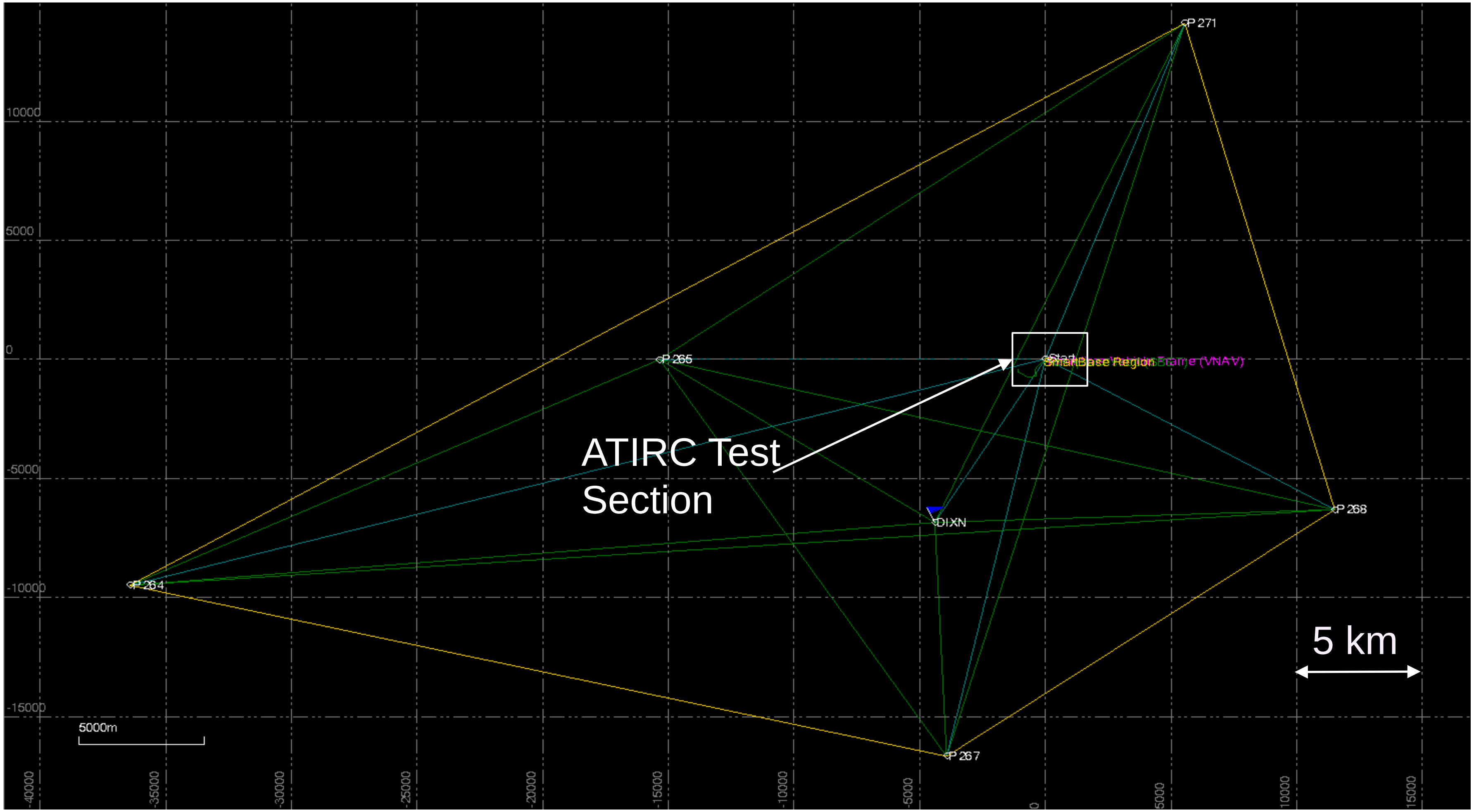
Advantages

- ✓ Eliminates need for radio link
- ✓ cm-accuracy maintained with base distance up to 20 km (decimeter up to 70 km)
- ✓ Maintains position accuracy during GNSS outages

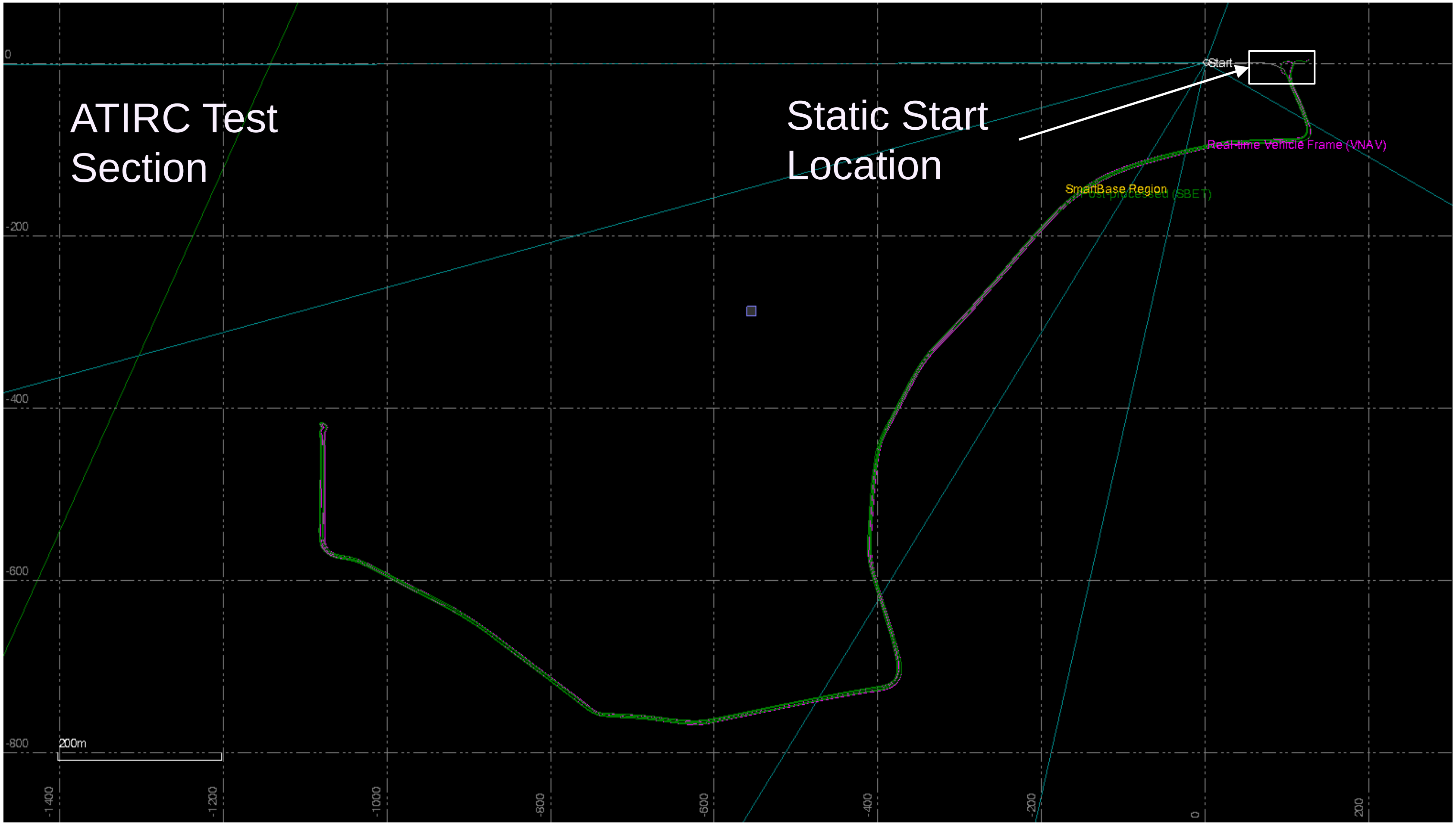
Disadvantages

- ✓ Range from base station limited to 20 km using single base
- ✓ Decreased accuracy occasionally occurs with SmartBase solution

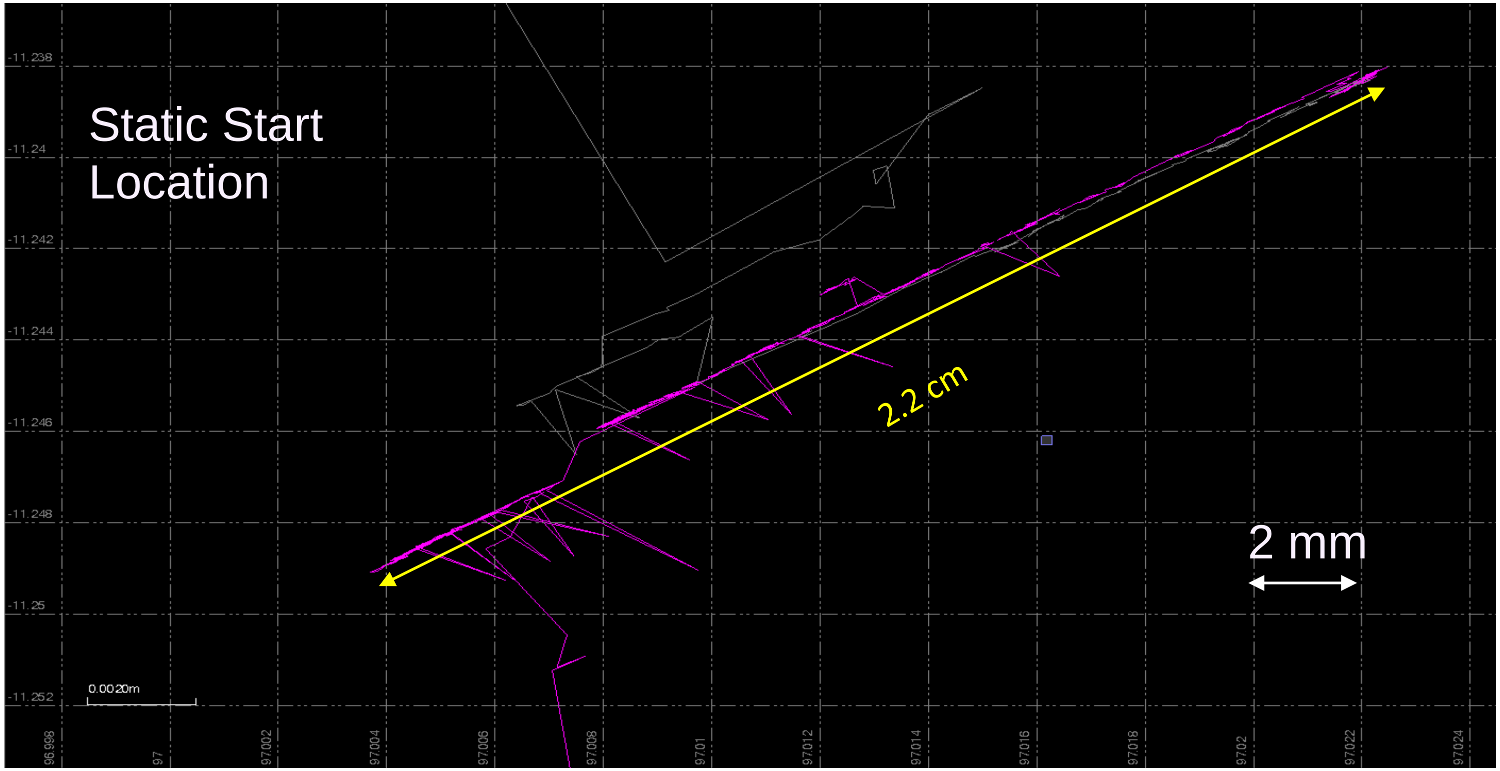
Base Station Network



Test Section Location

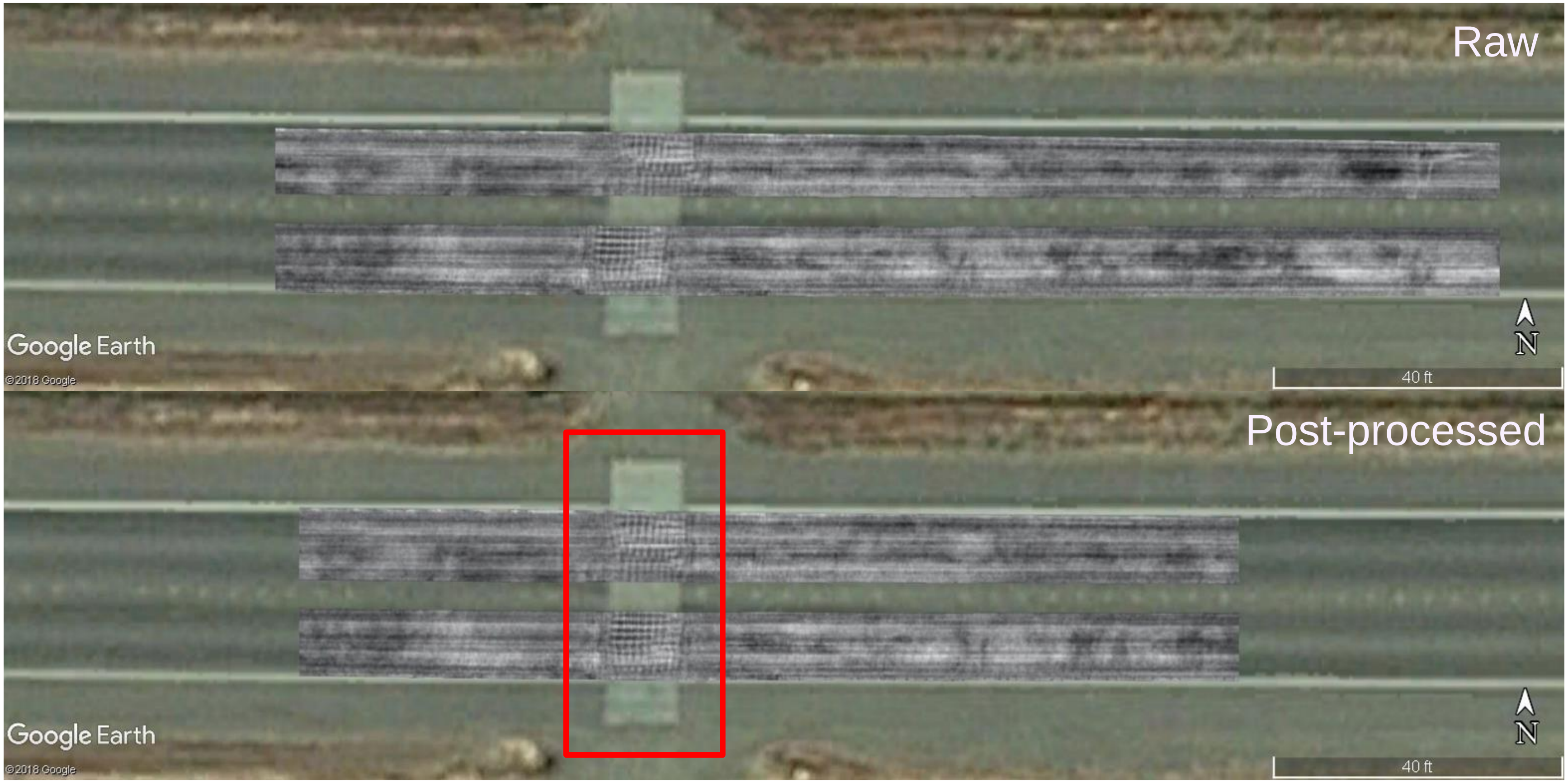


Static Start Position

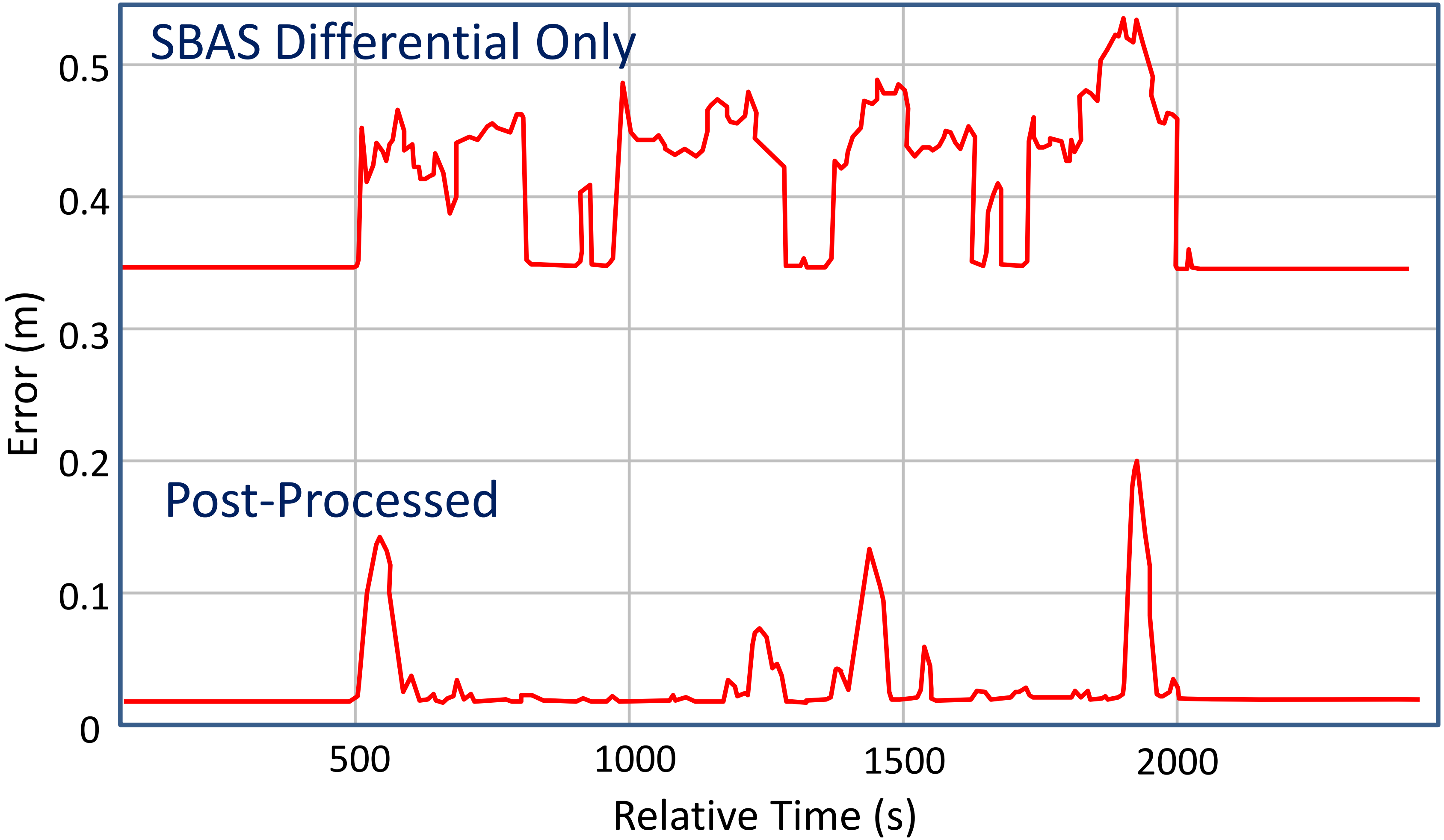


Examiner Image Correction, 20 MPH

Examiner Image Correction, 50 MPH



GNSS Post-Processing



Examiner Image Quality vs. Position Sample Output

Types of Outputs

Analysis Outputs

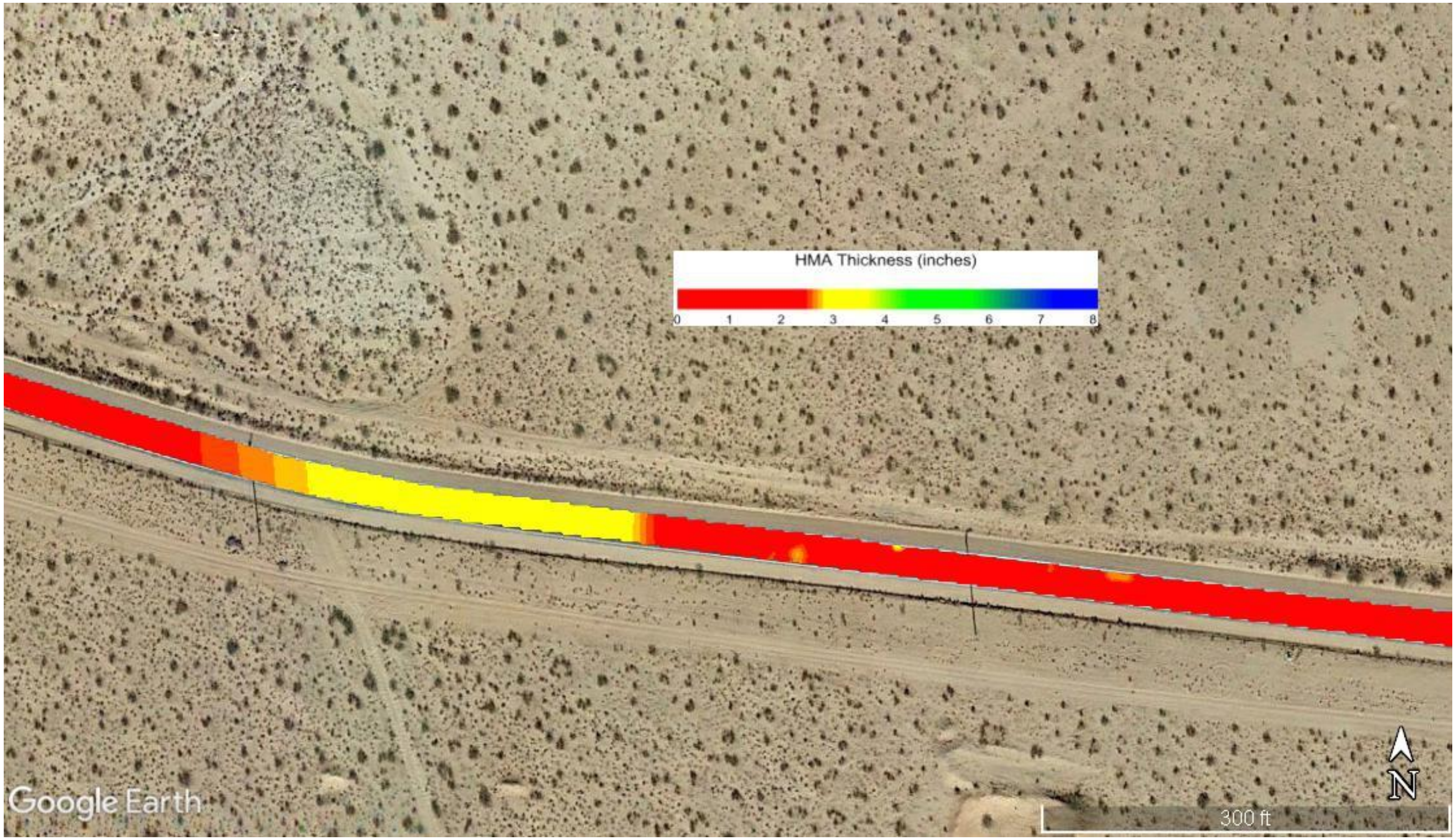
- Total pavement thickness
- Intra-layer (Overlay) thickness
- Overlay delamination
- Void distribution
- Rebar location/condition
- Concrete degradation
- Subsurface utility location

QC Outputs

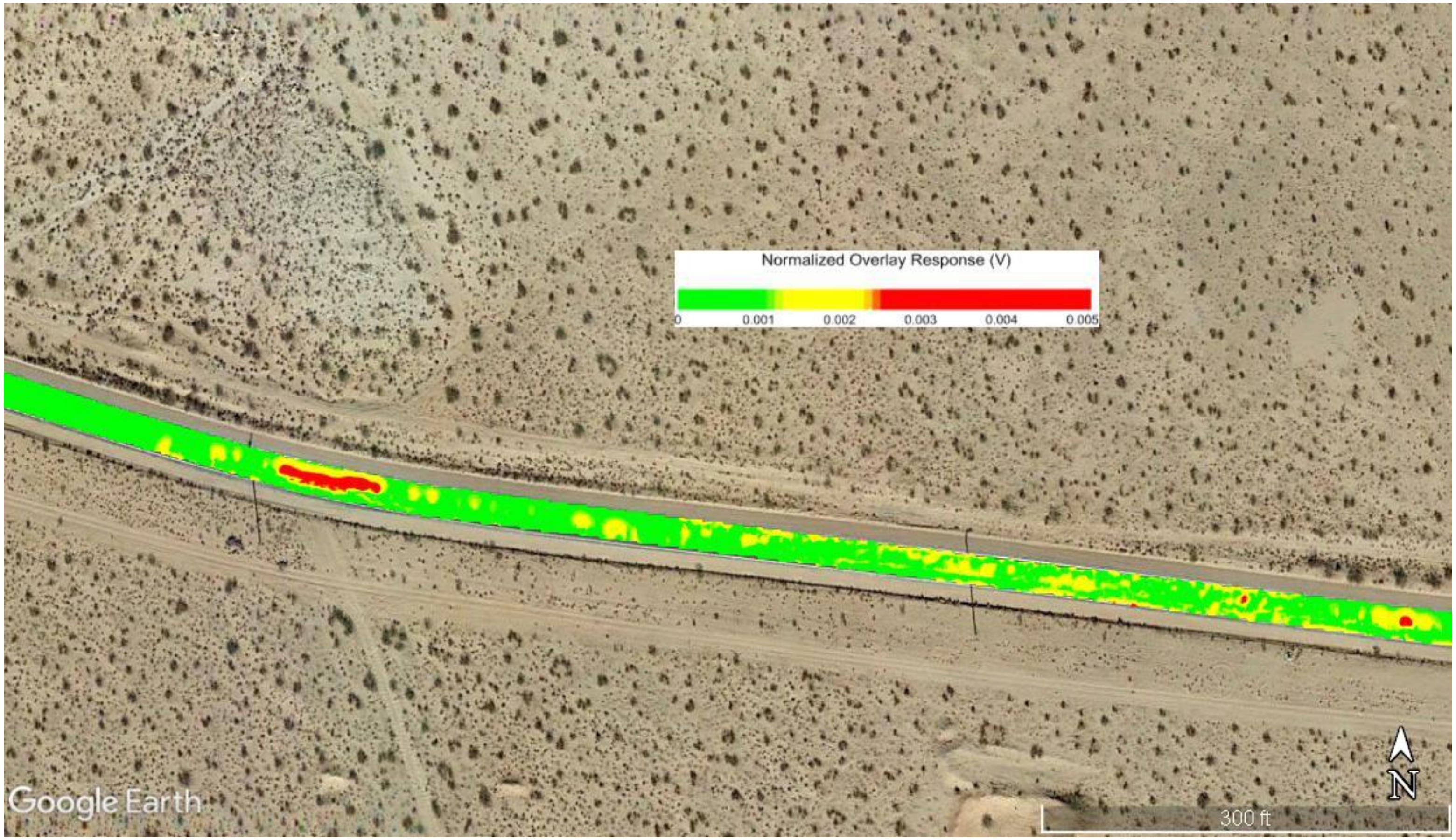
- Gridding accuracy
- Intra-layer accuracy
- Georeferencing accuracy
- Depth/thickness correlation

SR 247, Total HMA Thickness

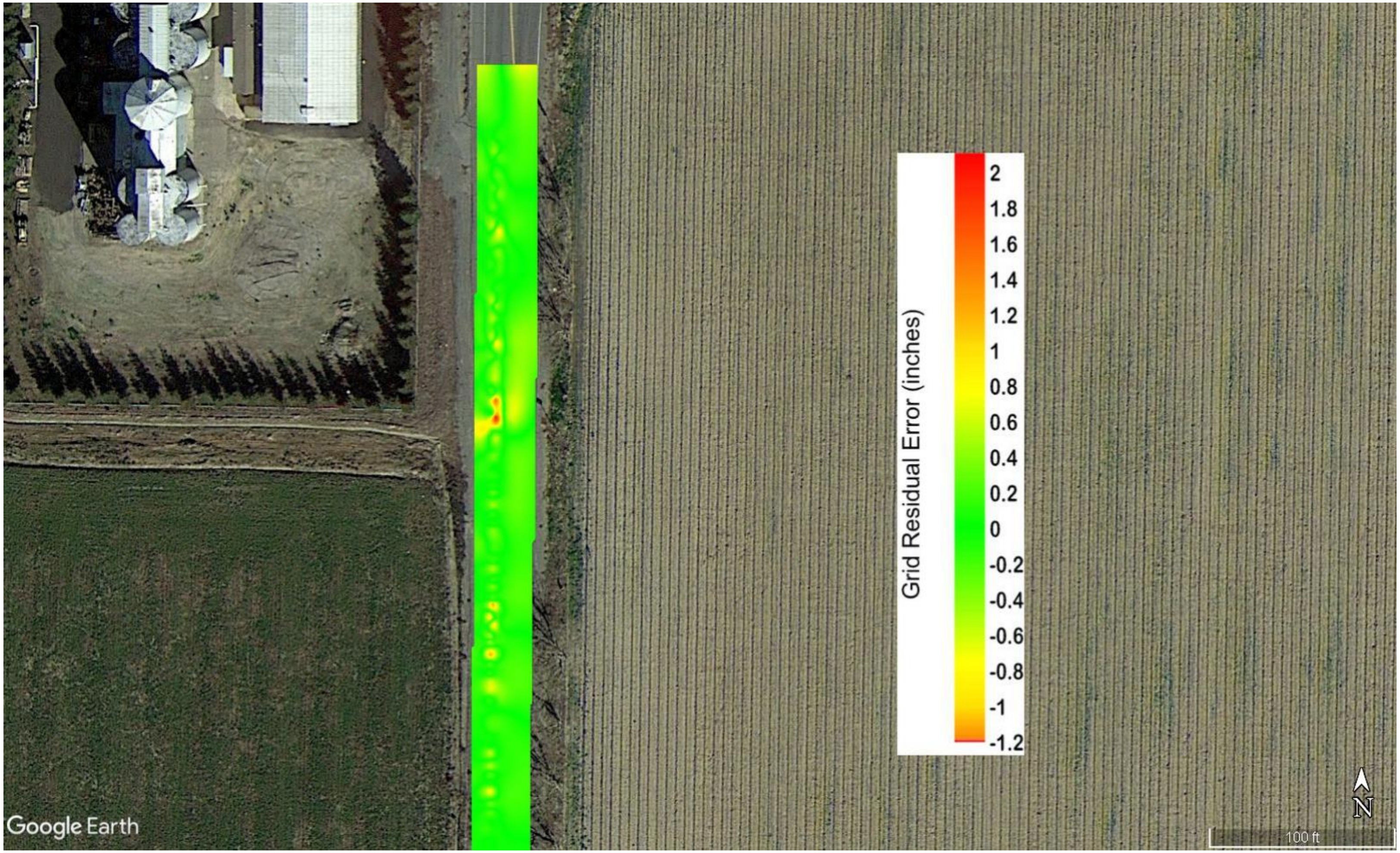
SR 247, Overlay Thickness



SR 247, Overlay Response



QC: SR113 Grid Residuals



QC: SR247 Intra-layer Residuals

Going Forward

- Verification of GPR thickness and overlay delam. Analysis
- Process Improvement
  - ✓ QA/QC
  - ✓ Automation of data processing/analysis
- Integration with Laser Scanner and thermal imaging systems
  - ✓ Full synthesis with existing systems
  - ✓ “One-Pass” acquisition

Acknowledgements

- FHWA/AASHTO
- National Center for Asphalt Technology
- University of California, Davis
  - ✓ Advanced Highway Materials Research Center
- 3D Radar
- Applanix
- California Department of Transportation
  - ✓ Division of Equipment
  - ✓ Office of Land Surveys
  - ✓ Pavement Program
  - ✓ Geophysics and Geology Branch