ERDC
Engineer Research and Development Center

High-Fidelity Modeling and Simulation of Ground Robots at ERDC

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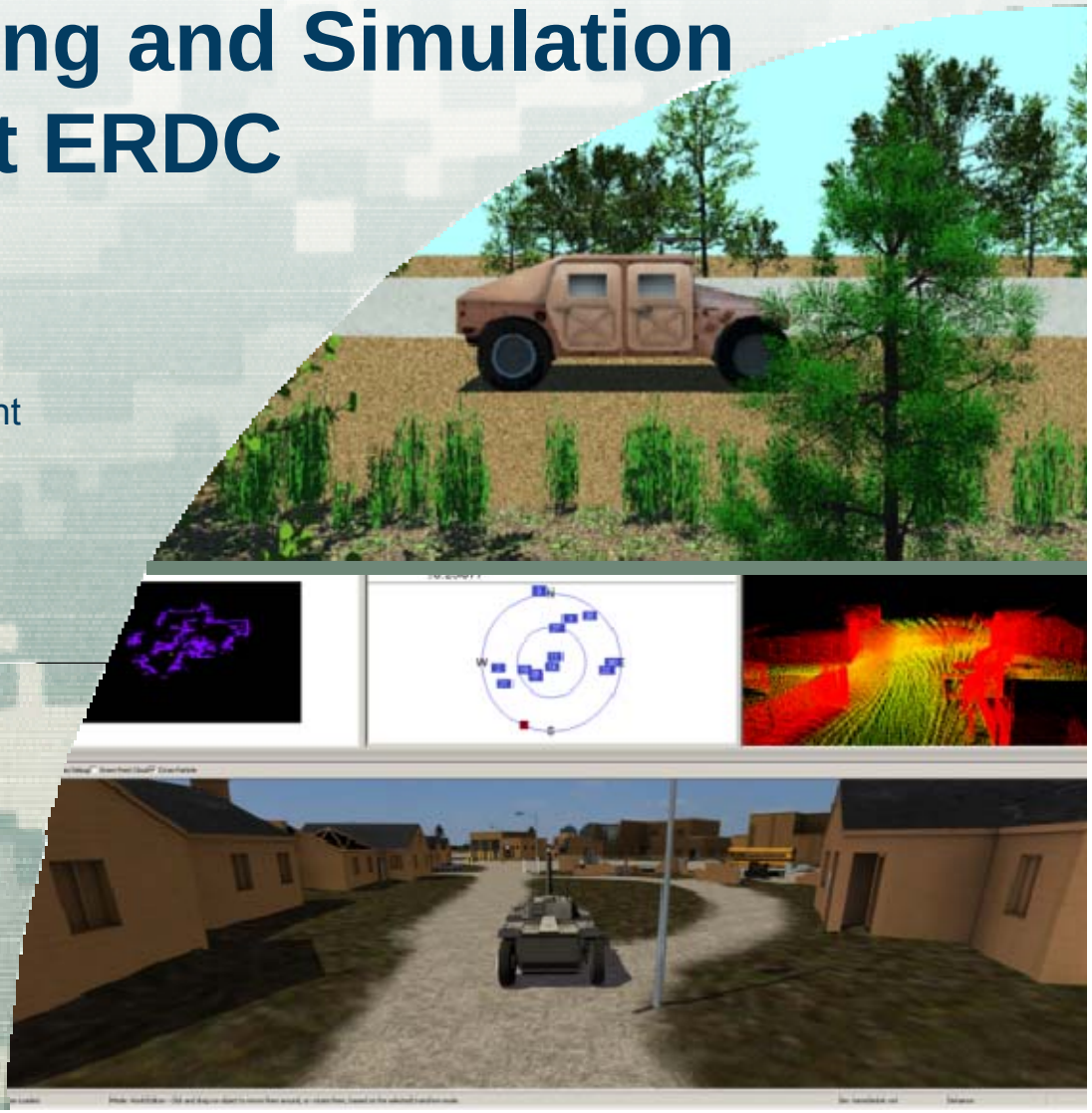
21 June 2016



US Army Corps of Engineers

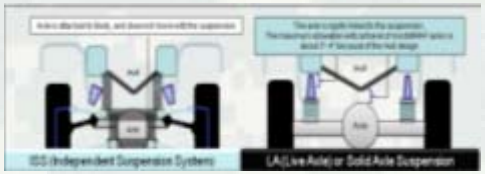
ERDC Mobility History

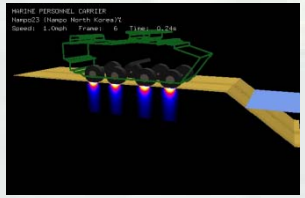
- 1945 – First WES mobility work
- 1951 – Cone penetrometer developed
  - ► GO/NOGO performance relations
- 1954 – Laboratory testing in soil bins
  - ► Single element numeric representation
- 1970s – Development of the NATO Reference Mobility Model (NRMM)
- 1980s – Studies on new tactical vehicles
- 1990s – Wheels *vs*. tracks.
- 2000s – Real-time vehicle-terrain mechanics
- 2008-present – VANE/ANVEL
- 2014-present – CREATE-GV

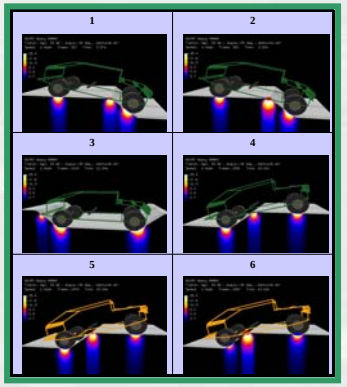
ERDC Vehicle Mobility Research Areas

Vehicle Field Testing

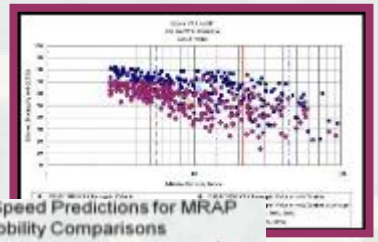
Vehicle-Terrain Interaction

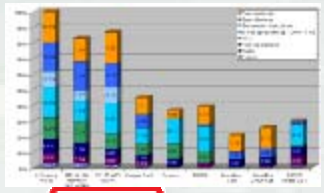


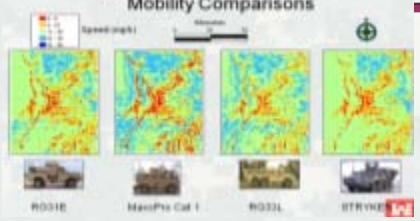




Mission Level Vehicle Evaluation







Modeling & Simulation

Test and Evaluation of Ground Vehicles



ERDC has experience performing testing in:

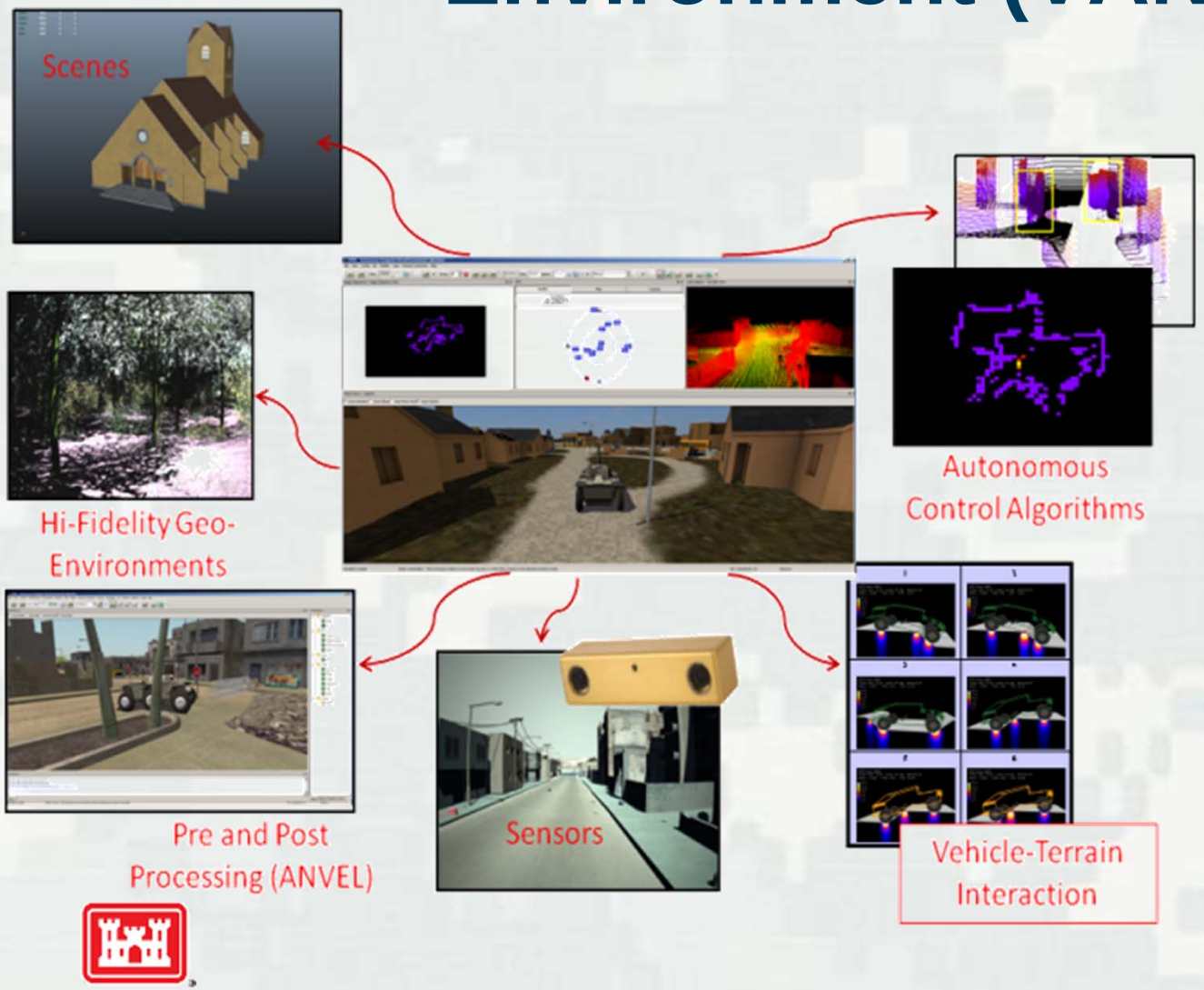
- Soft soil performance (VCI_1)
- Ride quality
- Max shock
- Slope climbing
- Obstacle crossing
- Steering stability
- Swimming/fording

Testing performed on new vehicle concepts as well as to evaluate design changes to existing vehicles.

ERDC Mobility Software

- **NRMM** – Mission-level performance analysis of ground vehicles
- **VehDyn** – 2D multi-body dynamics simulator
- **STNDMob** – API for incorporating mobility relationships into force-on-force simulators like OneSAF or COMBATXXI
- **Ground Contact Element** – API for integrating vehicle terrain interaction (VTI) into dynamic simulations
- **VANE** – High-fidelity computational test-bed for robotics that includes detailed sensor simulations
- **ANVEL** – Real-time desktop simulator for robotics
- **CREATE-GV** – Cutting edge mobility software that includes 3D multi-body dynamics for proving-grounds style performance evaluations, as well as improved mission-level analysis tools

The Virtual Autonomous Navigation Environment (VANE)



- Integrates high-resolution models for environment, terrain, vehicles, and sensors.
- Core product simulates geoenvironmental influences on sensor responses and vehicle dynamics to predict robotic behavior in a given environment.
- Simulations visualized interactively with the Autonomous Navigation Virtual Environment Laboratory (ANVEL)

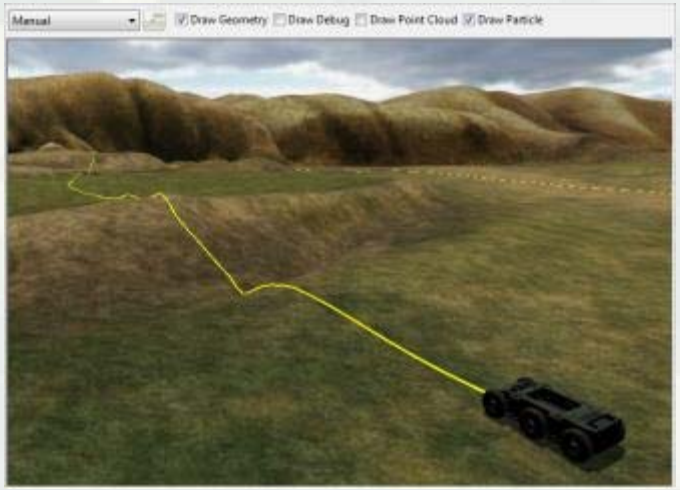
Autonomous Navigation Virtual Environment Laboratory (ANVEL)

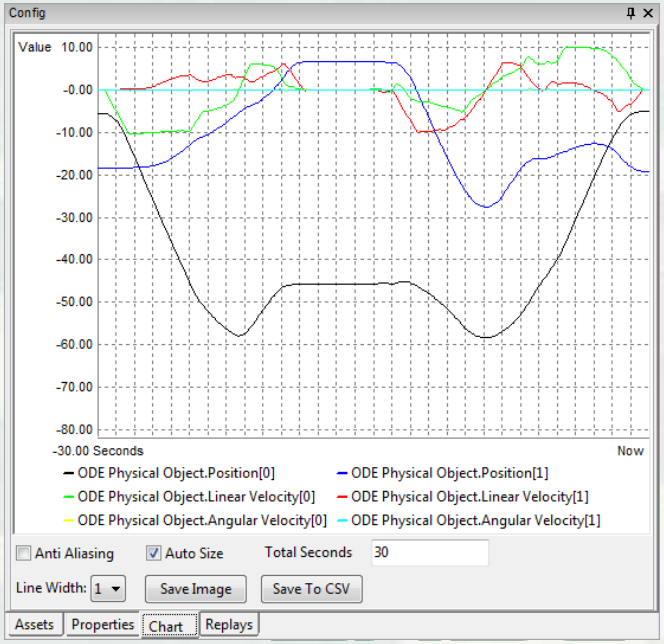
- The ANVEL is a Windows-based, desktop simulation tool for robotics that includes vehicle dynamics, sensors, and terrain editing into a simple, graphical user interface.
- ANVEL supports software plug-ins, allowing users to link in their own autonomy, sensor, or other simulation component. It can also be used to set up and view VANE simulations.

- ANVEL 1.0 distributed to researchers at, Mississippi State University, Carnegie Mellon University, University of Michigan, TARDEC, ARL, AMSAA, MSCOE, PdM-ALUGS and the Naval Postgraduate School.

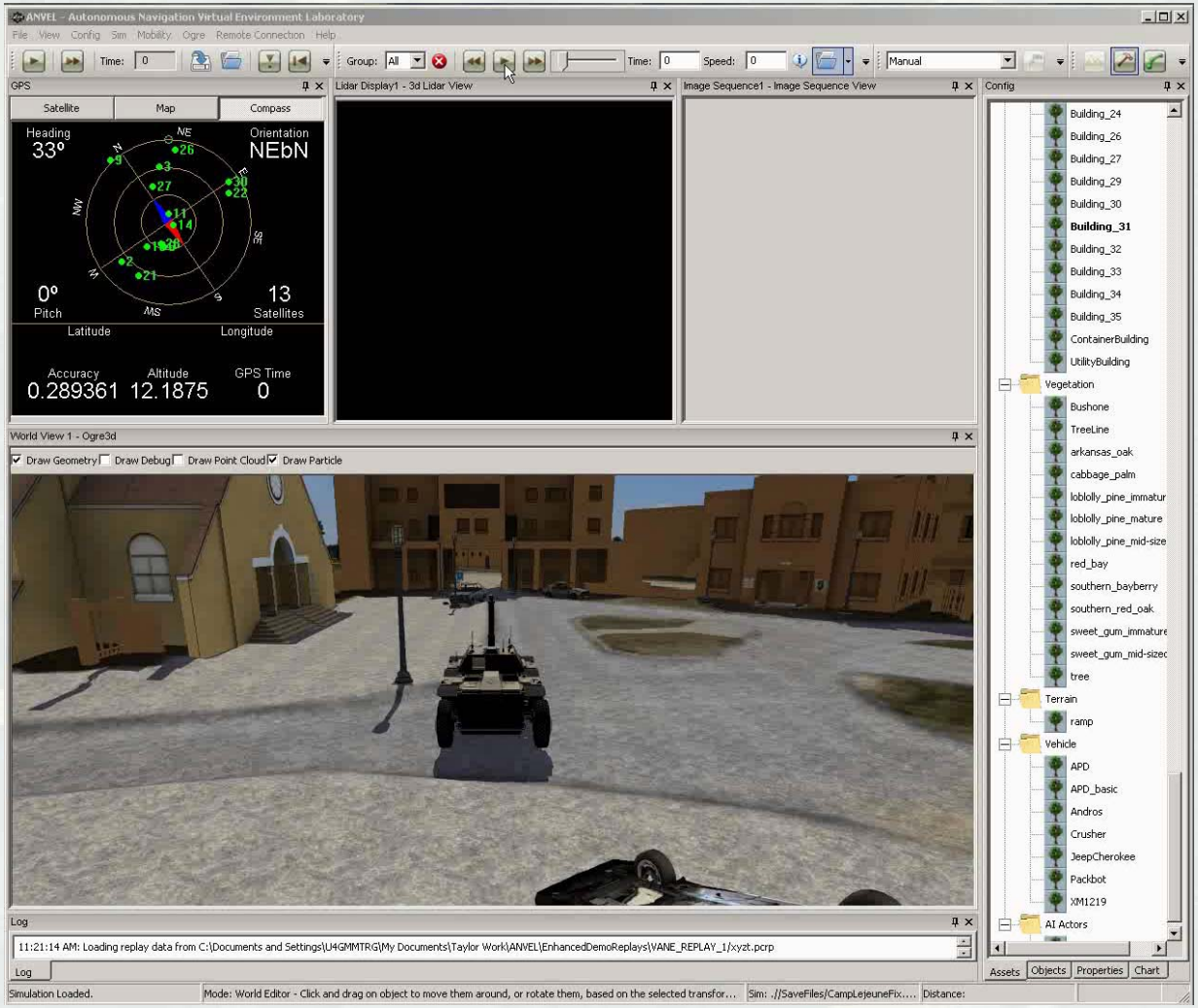
ANVEL Features

- Path Editing
  - Create for scripted vehicles/entities.
  - Create at runtime or load waypoints.
- Simulation Properties
  - Edit at run-time.
  - Change positions, surface types, etc.
  - Log data for post-processing.
- Data Logging
  - Visualize and save data related to simulation parameters.
  - Replay data from previous simulations.
- Simulation Replay
  - Record data from vehicles, sensors, or other physical simulation properties.



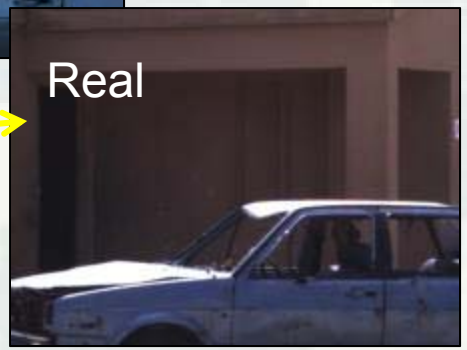


VANE/ANVEL Example



VANE Sensor/Environment Modeling

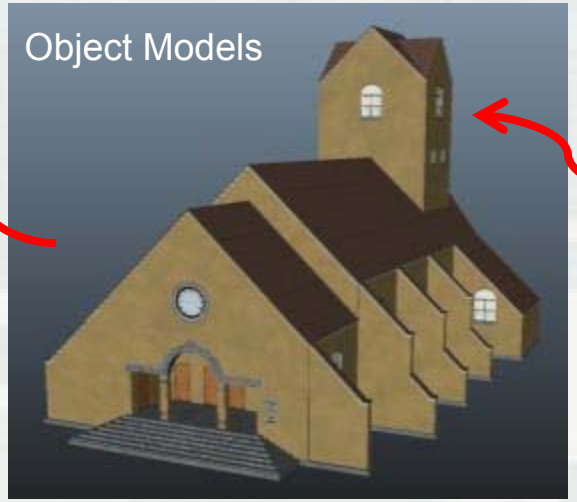
- VANE sensor models use government developed, HPC optimized ray-tracing.
- Models are fully spectral and can account for environmental effects such as water or atmospheric conditions
- Types of sensors include visual, near infrared (NIR), and infrared (IR) cameras, LIDAR, GPS, and inertial sensors (MEMS accelerometer, MEMS, ring laser, and fiber-optic gyroscopes).



Sony Digital Camera

VANE Digital Scene Generation Example

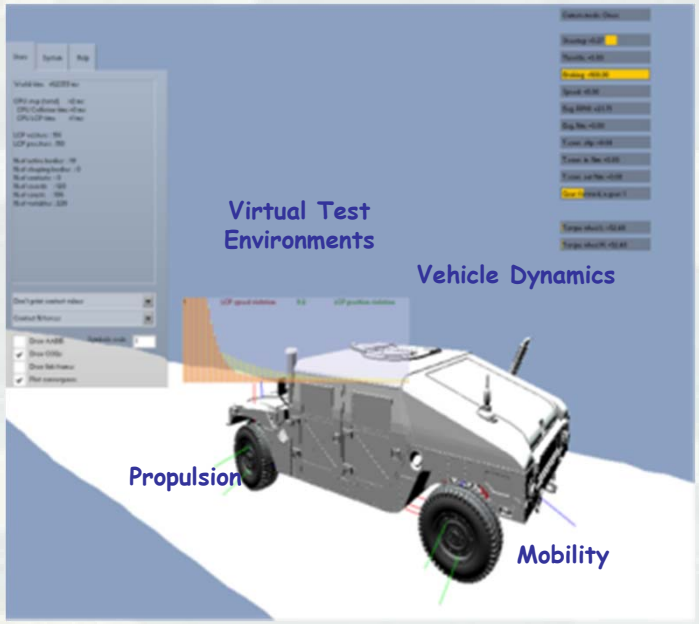
- Camp Lejuene MOUT
- 59 Million triangular elements with spectral attributions.
- >300 trees, >30 buildings
- Terrain attributed with mobility properties.



ERDC

VANE Vehicle Dynamics – Interface with CREATE-GV Mercury

- ERDC is leading the development of the Computational Research and Engineering Acquisition Tools and Environments – Ground Vehicles (CREATE-GV) software.
- Mercury is the high-fidelity, computational backbone to CREATE-GV.
- Mercury can output vehicle simulation data to ANVEL format, allowing Mercury and VANE to couple through ANVEL



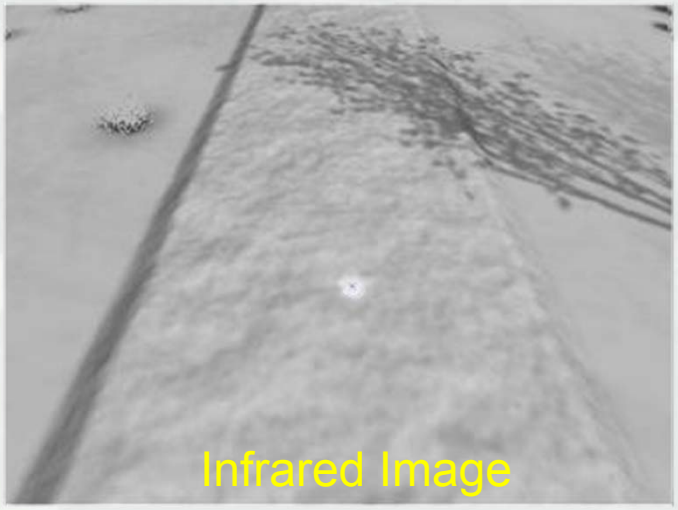
VANE AND ANVEL EXAMPLE APPLICATIONS

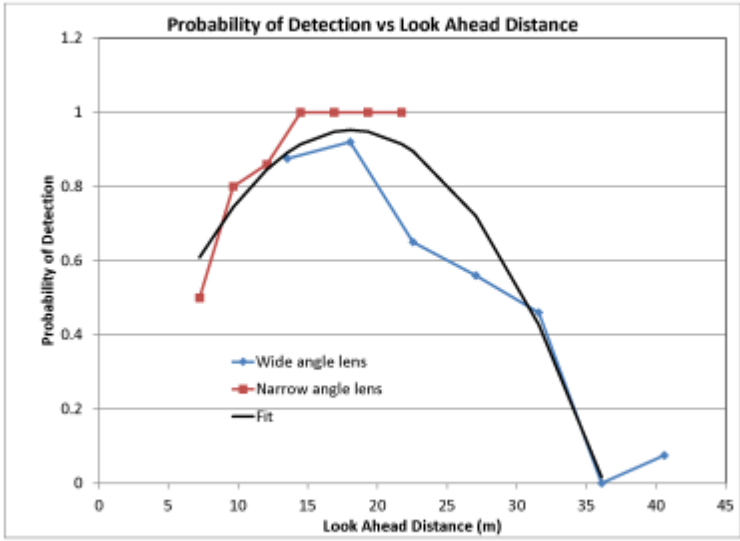
VANE Closed Loop System Analysis

- Simulated the Autonomous Platform Demonstrator (APD) in Camp Lejeune MOUT site.
  - Vehicle navigated autonomously using GPS, IMU, and LADAR sensors.
  - Followed waypoint plan defined in ANVEL.
  - Supported Enhanced Demonstration Experiment for the SOURCE-ATO.

VANE Vehicle-Mounted IR Sensor Placement

- Developed method for integrating thermal environment simulations with sensor simulations in VANE.
- Simulated a FLIR-SC640 camera navigating a dirt road with RXD anomaly detection algorithm.
- Used two different camera configurations with 7 different mounting heights for a total of 14 scenarios run, with over 4000 images generated.
- Result is a parametric curve predicting the probability of detecting a shallow buried threat versus the look-ahead distance, which will be a limiter on mission speed if the goal is to stop short of a detected threat.



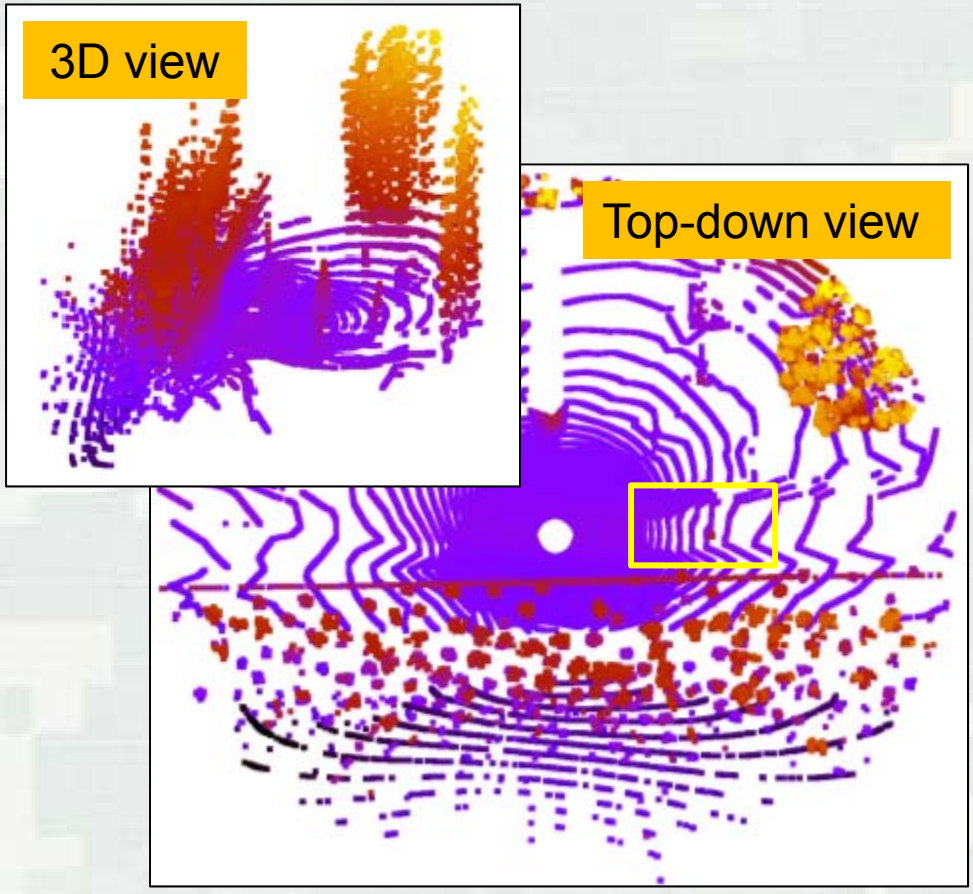


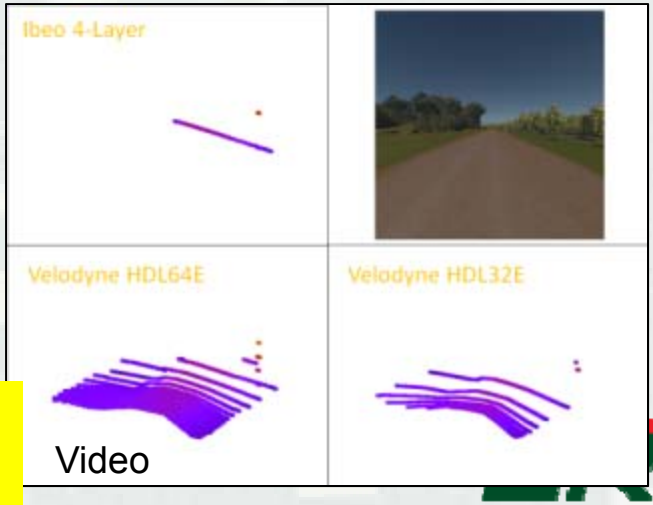
SIL for RCIS testing

- TARDEC using ANVEL in Software-in-the-loop (SIL) test facility to support the Route Clearance and Interrogation System (RCIS) program
- ERDC supporting with digital terrains and vehicle models.

Sensor tradeoff simulation example

Environmental effects on autonomous pedestrian detection



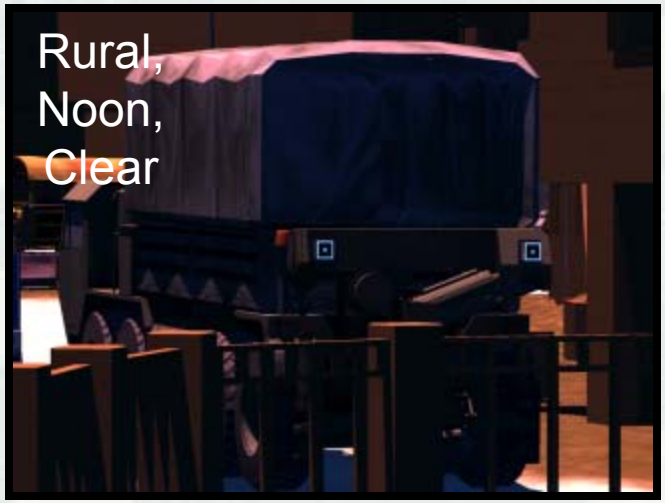


Demonstration of incorporating new sensor payloads onto vehicle models


Video Replay – Full Speed

Analysis of NIR enable navigation with VANE

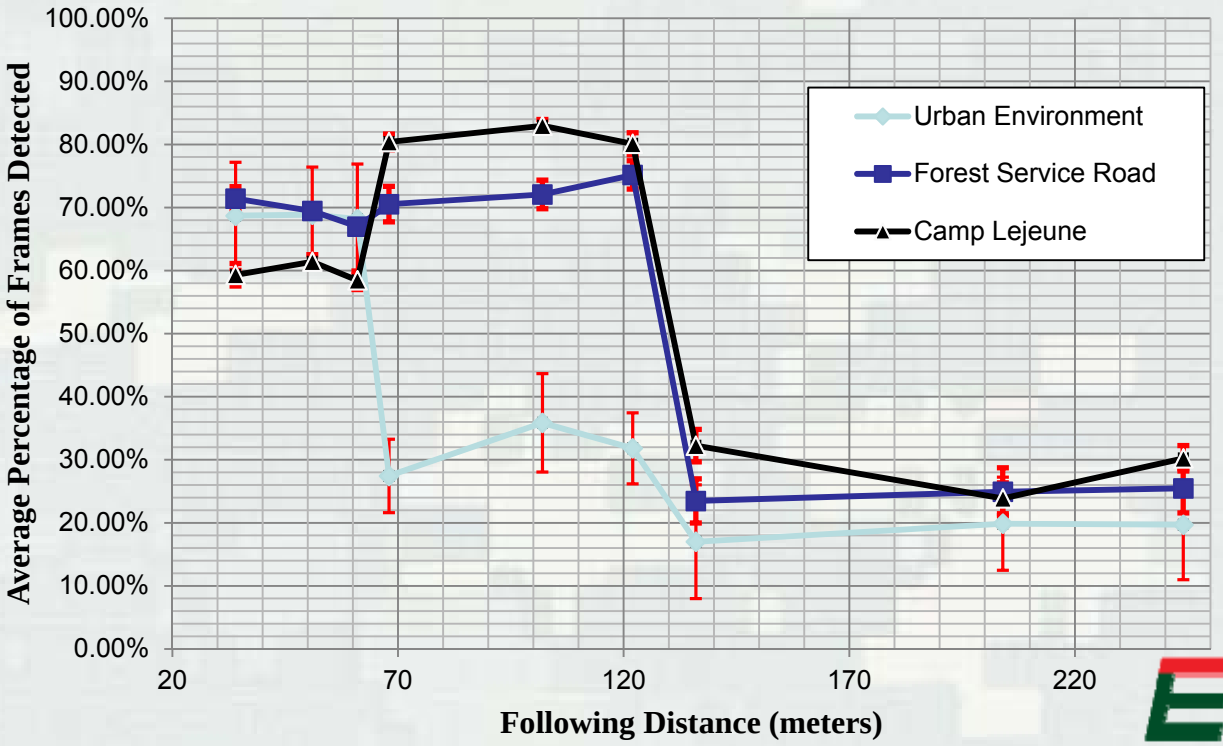
- VANE used to analyze performance of NIR sensor in detecting fiducial marker on the rear bumper of a lead vehicle in different environments and conditions
- Purpose was to determine the performance limits of the camera system for detecting marker



Video

Environment Analysis Results

- Initial results show sharp decline in camera performance at 120 meters
- Not sensitive to environmental conditions



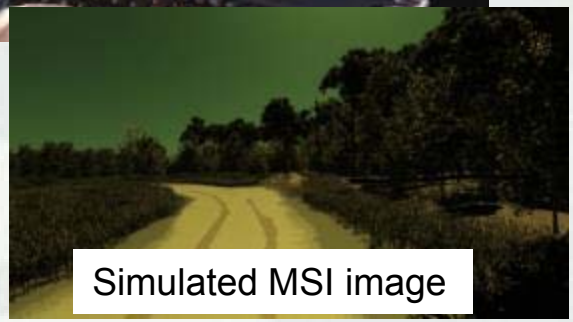
Evaluation and training of terrain classification algorithms with simulated data

Goal:

- A predictive simulation tool for determining the effectiveness of vehicle mounted sensor systems in a variety of environments.

Field experiments with SwRI MSI system.

Terrain classification software



Simulated MSI image

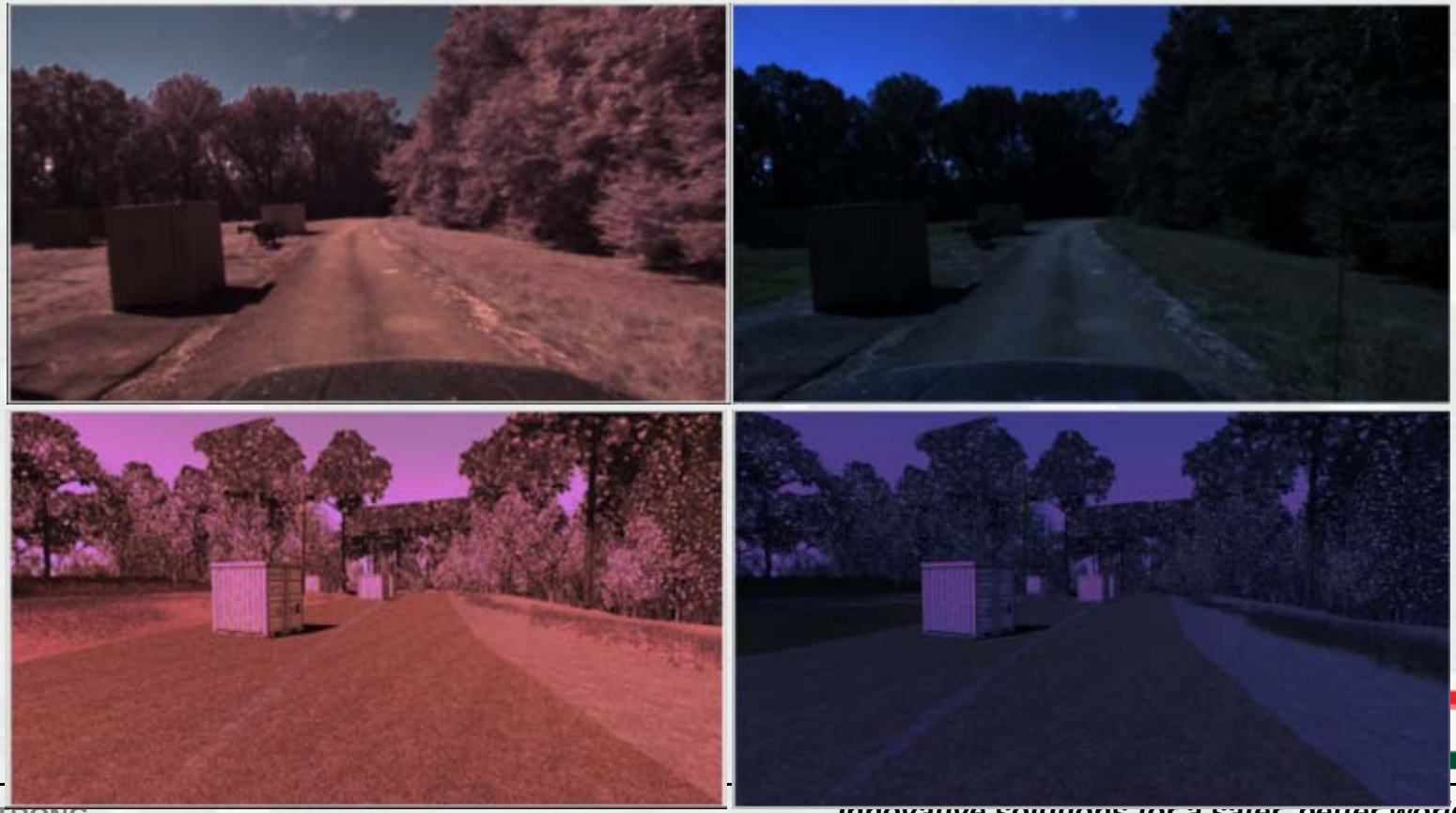
SwRI MSI sensor evaluation and simulation

Digital Scene Development

- ERDC Test track at the ERDC in Vicksburg, MS
- 800m loop comprised of asphalt, concrete, and crushed limestone
- Mix of deciduous and coniferous trees and variety of smaller trees and shrubs native to Mississippi
- Storage containers, traffic signs, traffic cones, fences
- 600,000 total objects
  - 15,000 trees
  - 500,000 grasses
  - 1.8 billion triangles
  - 60 unique materials
  - 500m x 100m area

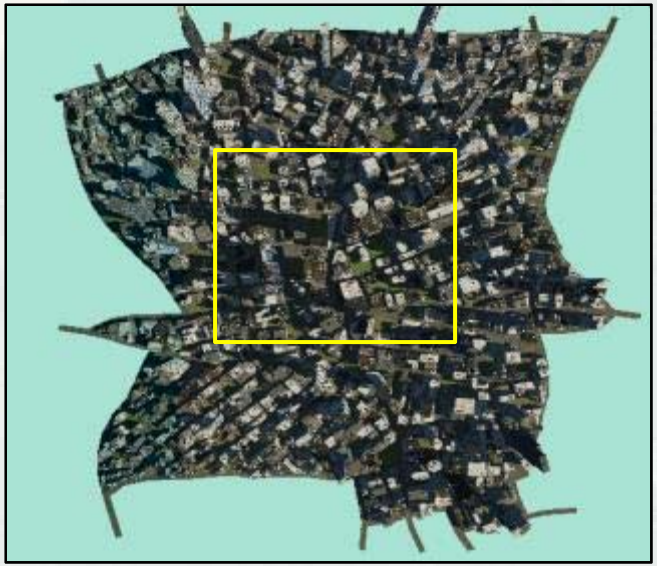
Experiment

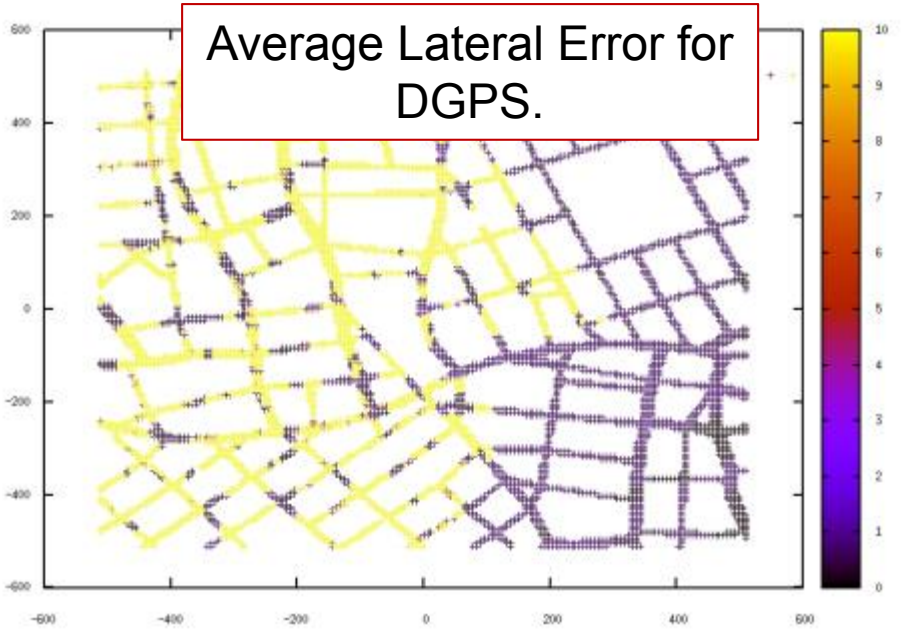
- Validate virtual model for sensor simulation
  - Collect real sensor data at ERDC test track
  - Generate simulated data with ERDC test track scene



Sensor Error Predictions with VANE

- The VANE can be used to predict sensor error in a given environment.
- LIDAR errors include edge effects, extended objects.
- GPS errors include multipath and dropout for DGPS, and atmospheric errors for COTS GPS.
- Simulations conducted in a 4 km^2 urban environment with over 1700 buildings and several narrow streets.





QUESTIONS / DISCUSSION

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