High-Fidelity Modeling to Support Route Clearance

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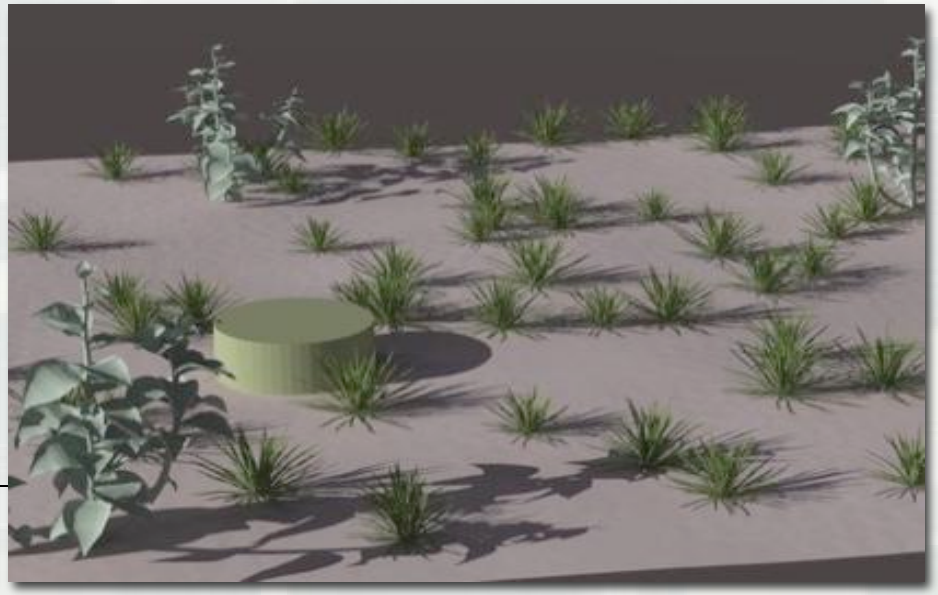
The Goal: A Physics-Based Virtual Environment for Sensor Performance Assessment

- Combine high-fidelity models for soil, vegetation, weather, atmosphere and sensors to produce realistic synthetic sensor imagery
- Use synthetic imagery to train operators and automated target recognition algorithms (ATR)
- Synthetic scenes need not match a specific place on the earth, but must have the same *character* and *complexity* to be useful

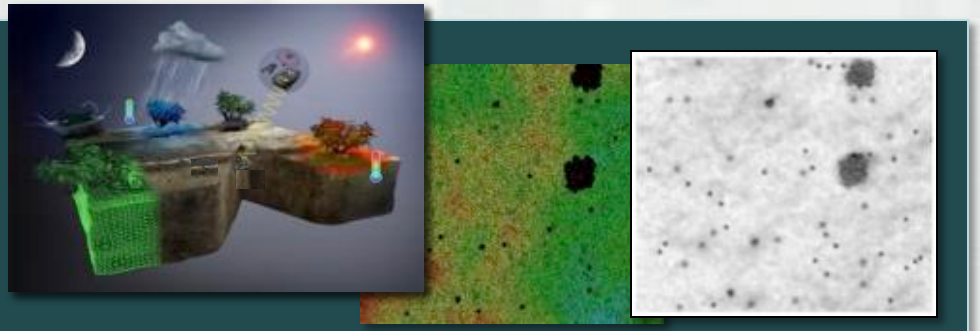


Sensor Performance Virtual Environment

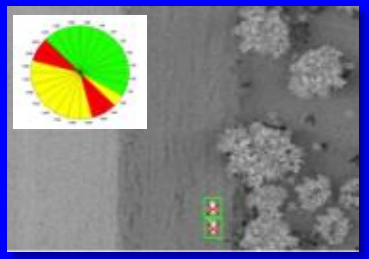
- *Visual* realism is near – great for immersive training, like flight simulators
- How good does a sensor performance virtual environment need to be?
- Synthetic imagery must evoke the same response from analysts and automated target detection algorithms (ATRs) as 'real' imagery

Outline

Overview of Computational Tools



Application to Sensor Deployment and Acquisition Strategies

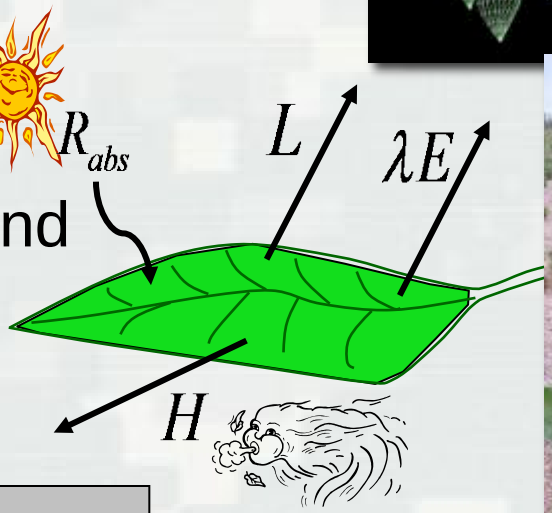


The Future

Vegetation Model

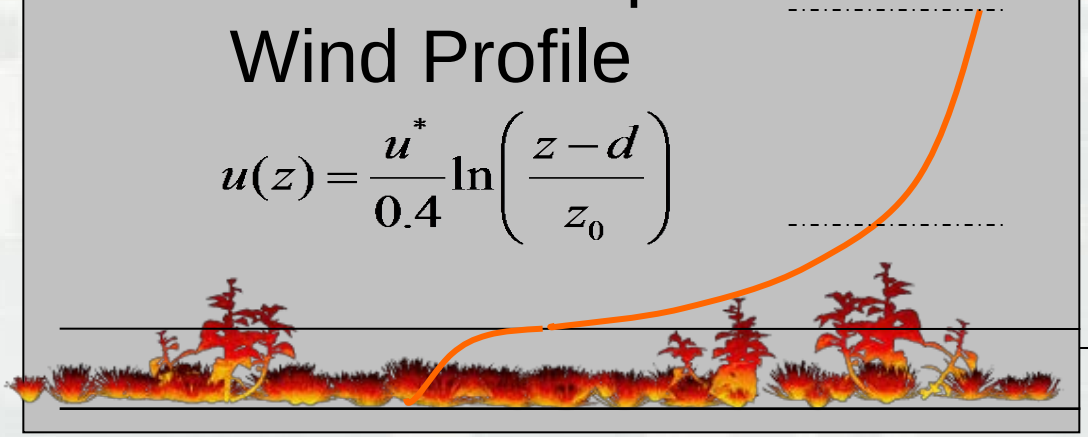
- Driven by meteorological data
- Equilibrium heat exchange

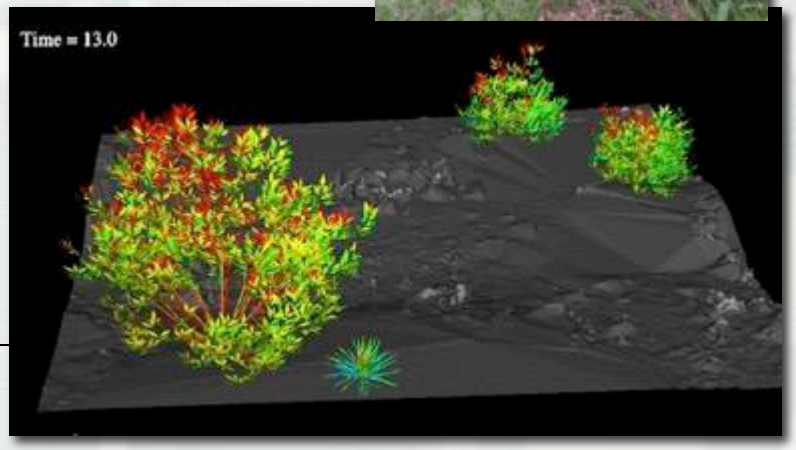
  (no lateral flow)
- Computes transpiration demand
- Accepts surface heat fluxes, returns surface temperatures



Assumed or Computed Wind Profile

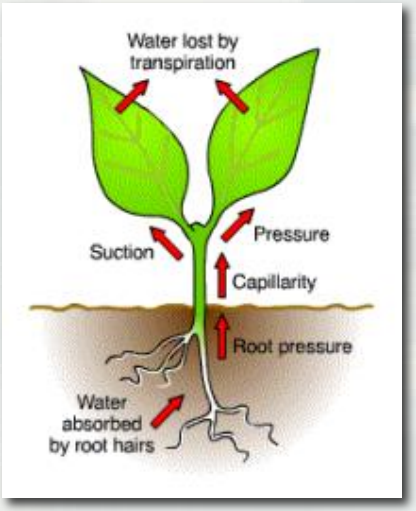
$$u(z) = \frac{u^*}{0.4} \ln\left(\frac{z-d}{z_0}\right)$$

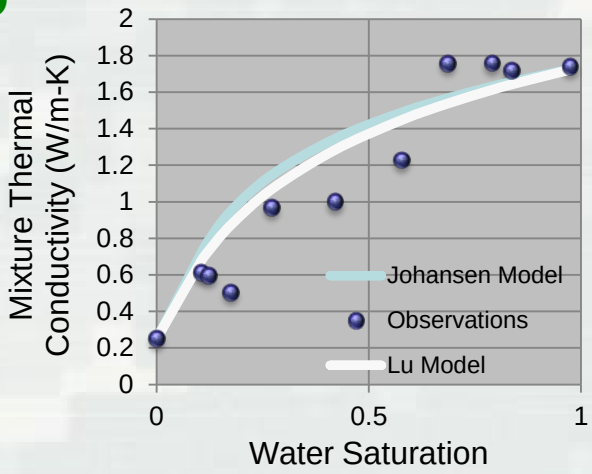


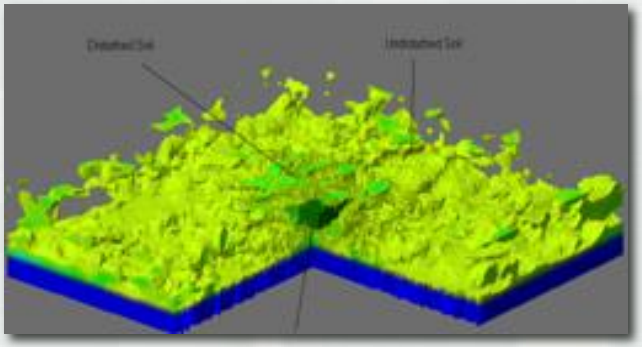


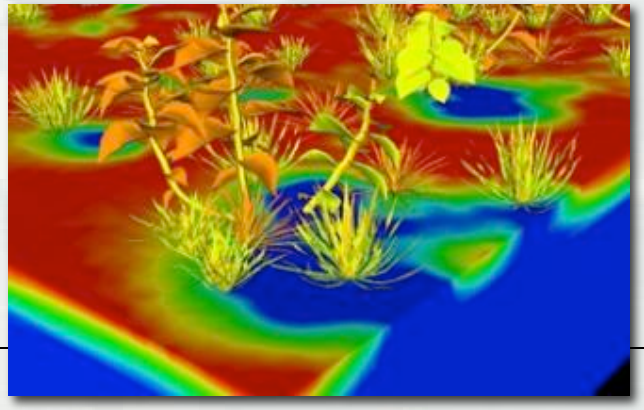
Soil Model

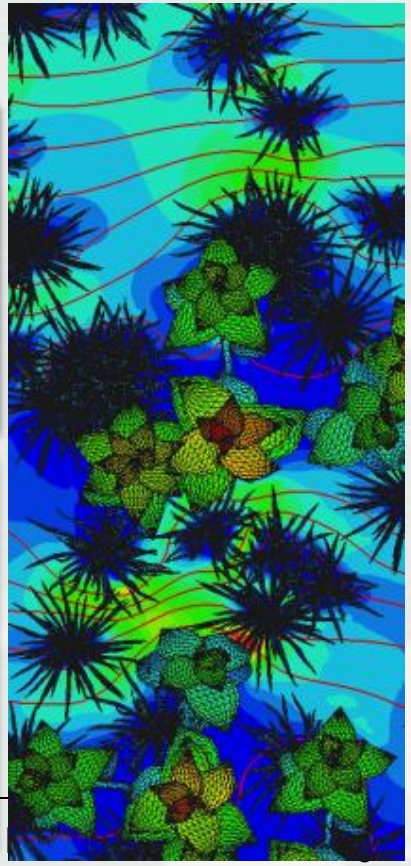
- 3D finite element model for groundwater flow and heat transport through soils
- Heat transport is a function of soil moisture
- The soil model includes:
  - Partially saturated fluid flow in heterogeneous soils
  - Heat conduction and convection with moisture-dependent properties
  - Surface heat exchange
- Accepts surface heat flux, returns surface temperatures





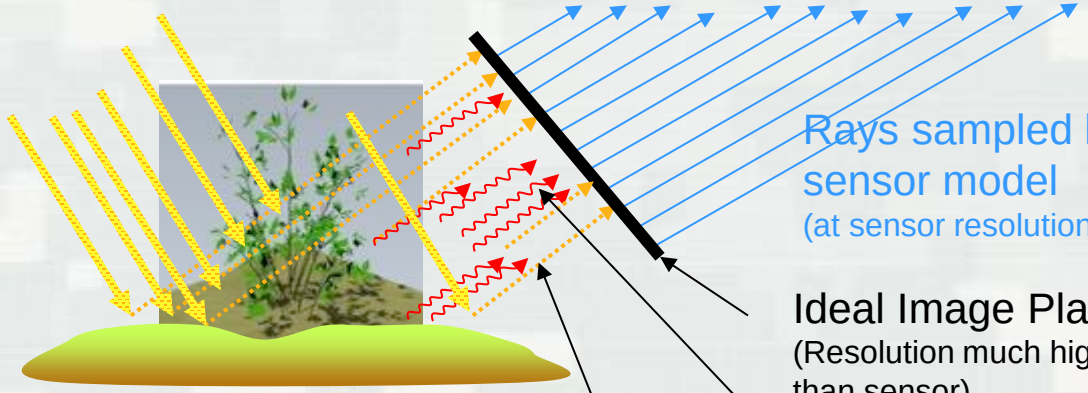


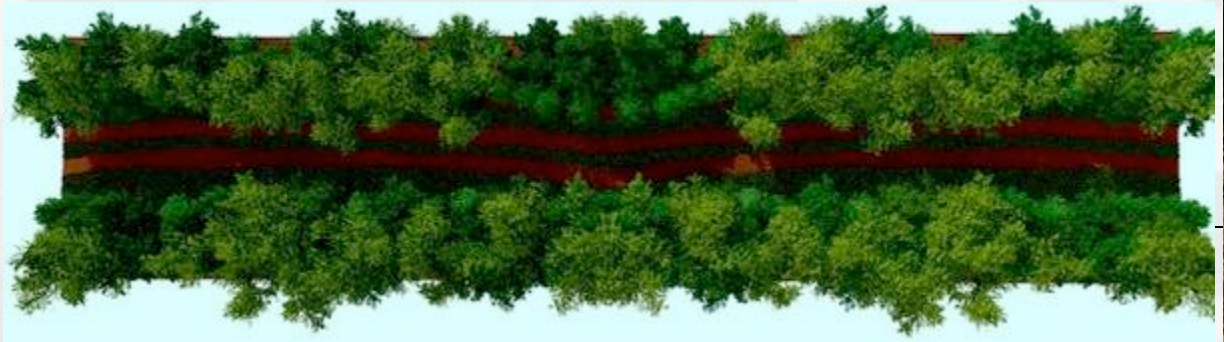




Energy-based Ray Casting Model

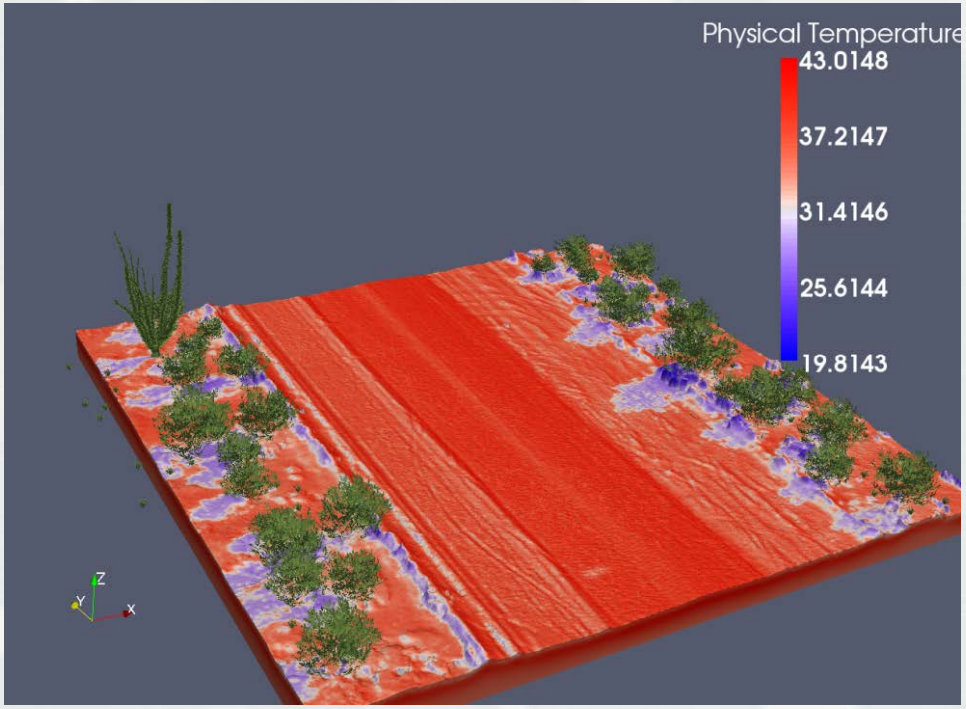
- Provides surface energy to soil and vegetation models
- Accumulates reflected and emitted energy to a near-ground ideal image

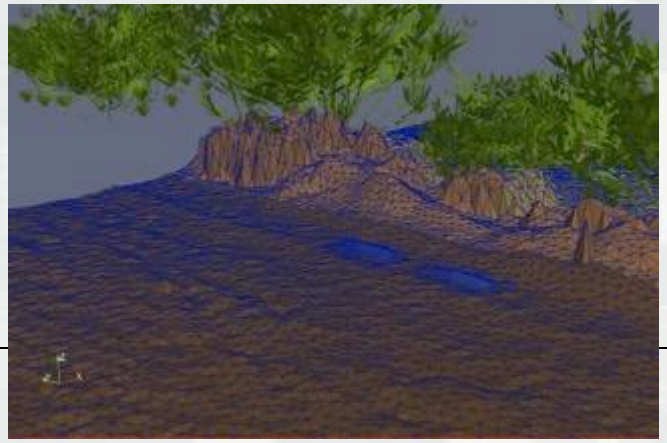


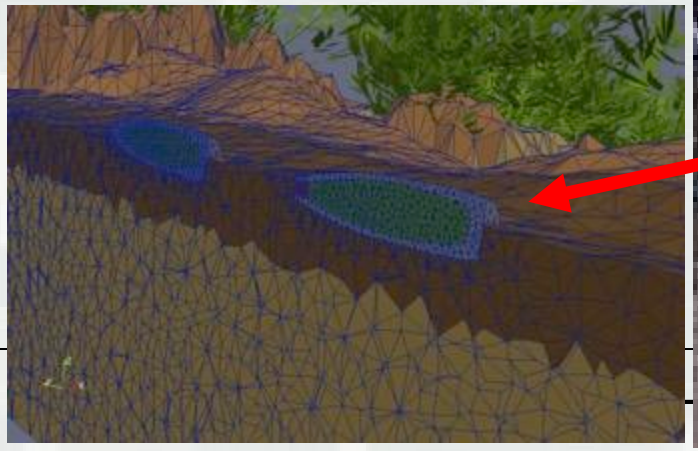


Desert Environment Simulation

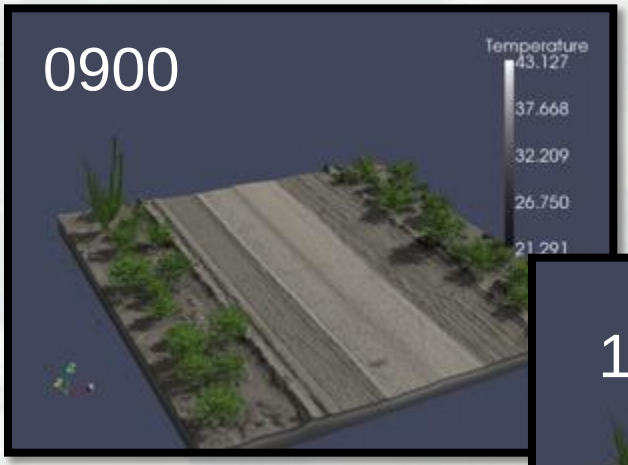
- Desert road
- Domain is 30m x 30m x 1m
- Two partially-buried threats and a soil disturbance

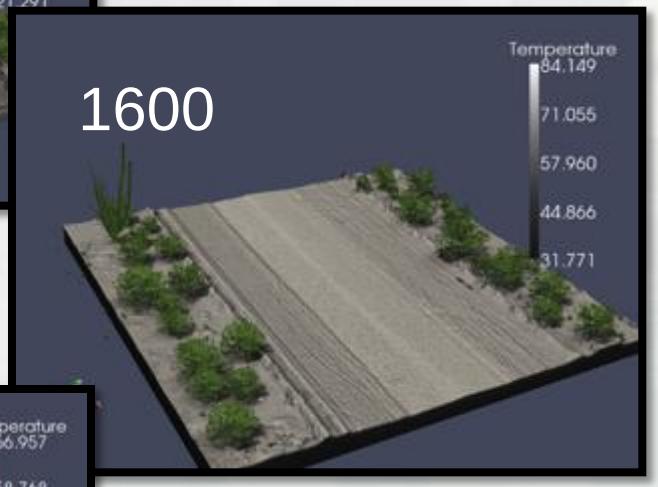


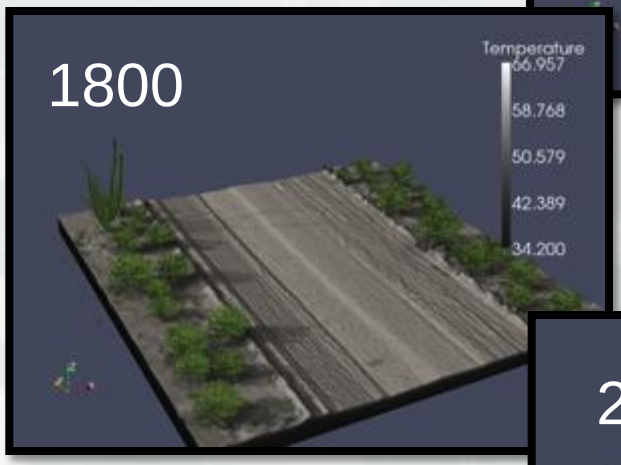


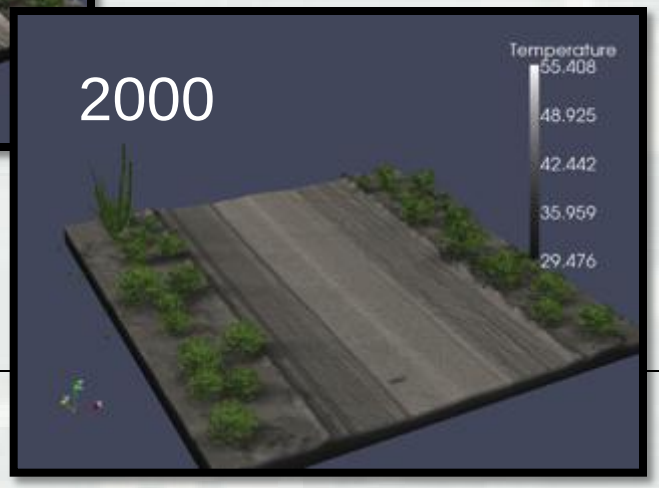


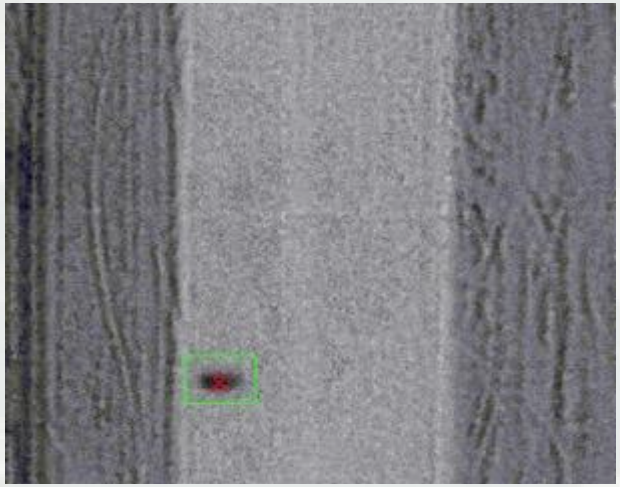
Physical Temperatures and Synthetic Sensor Images

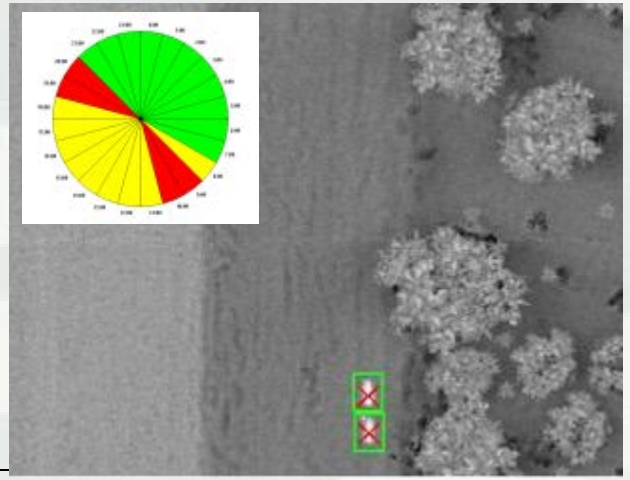






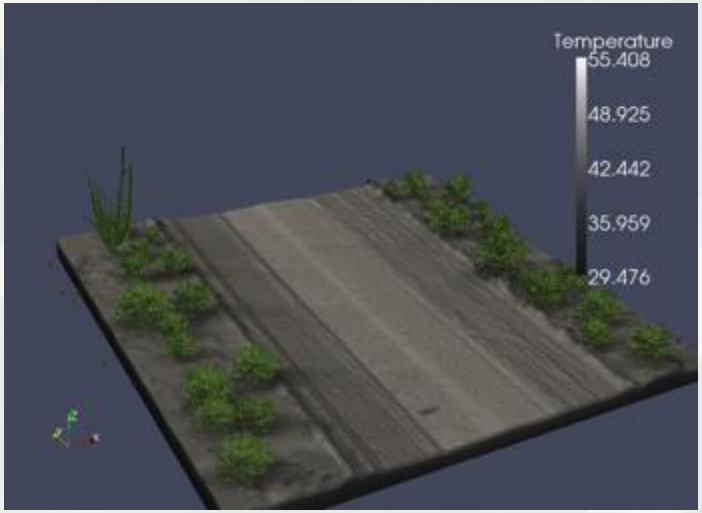


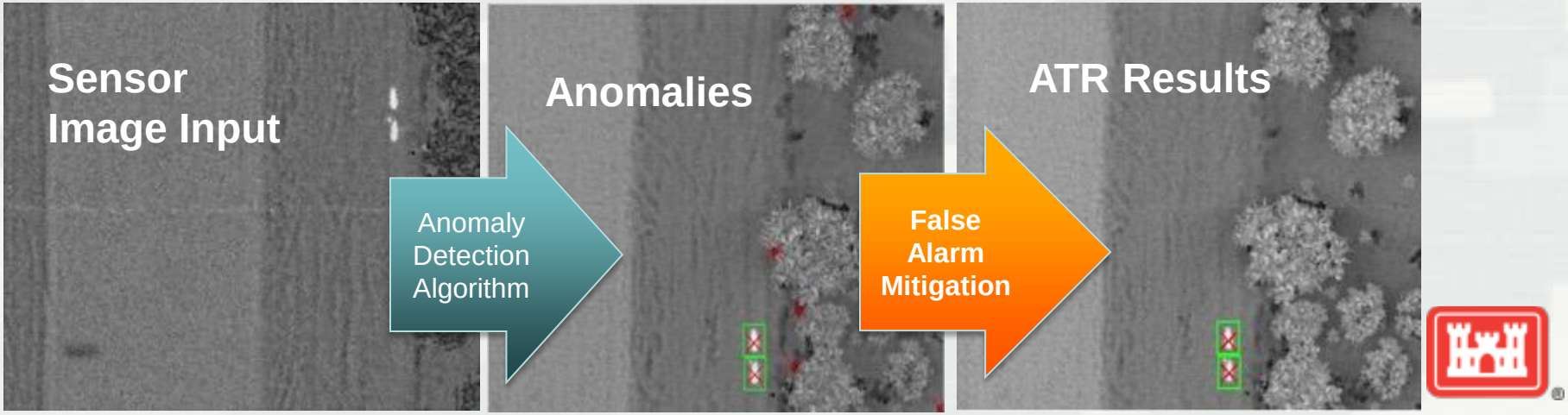




Synthetic Imagery for Assessing Sensor Performance

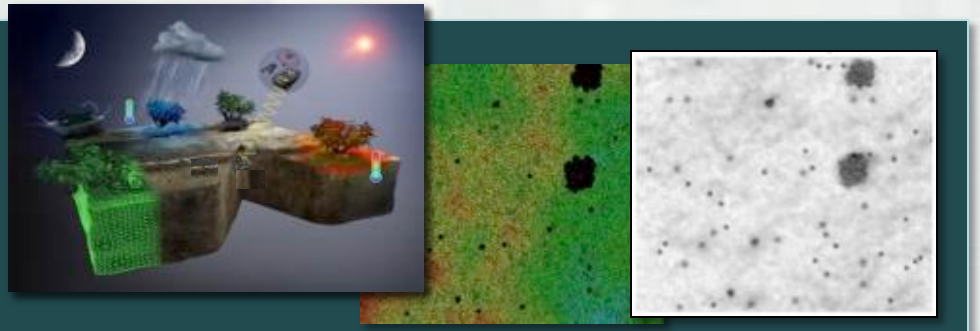
- Yuma Proving Ground desert road
- Can test against a variety of weather conditions and material models
- Runs on about 1000 processors





Outline

Overview of Computational Tools



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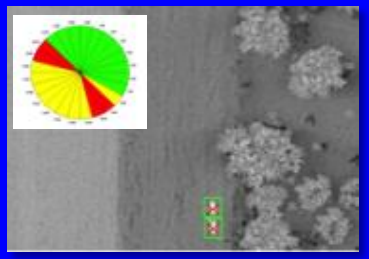
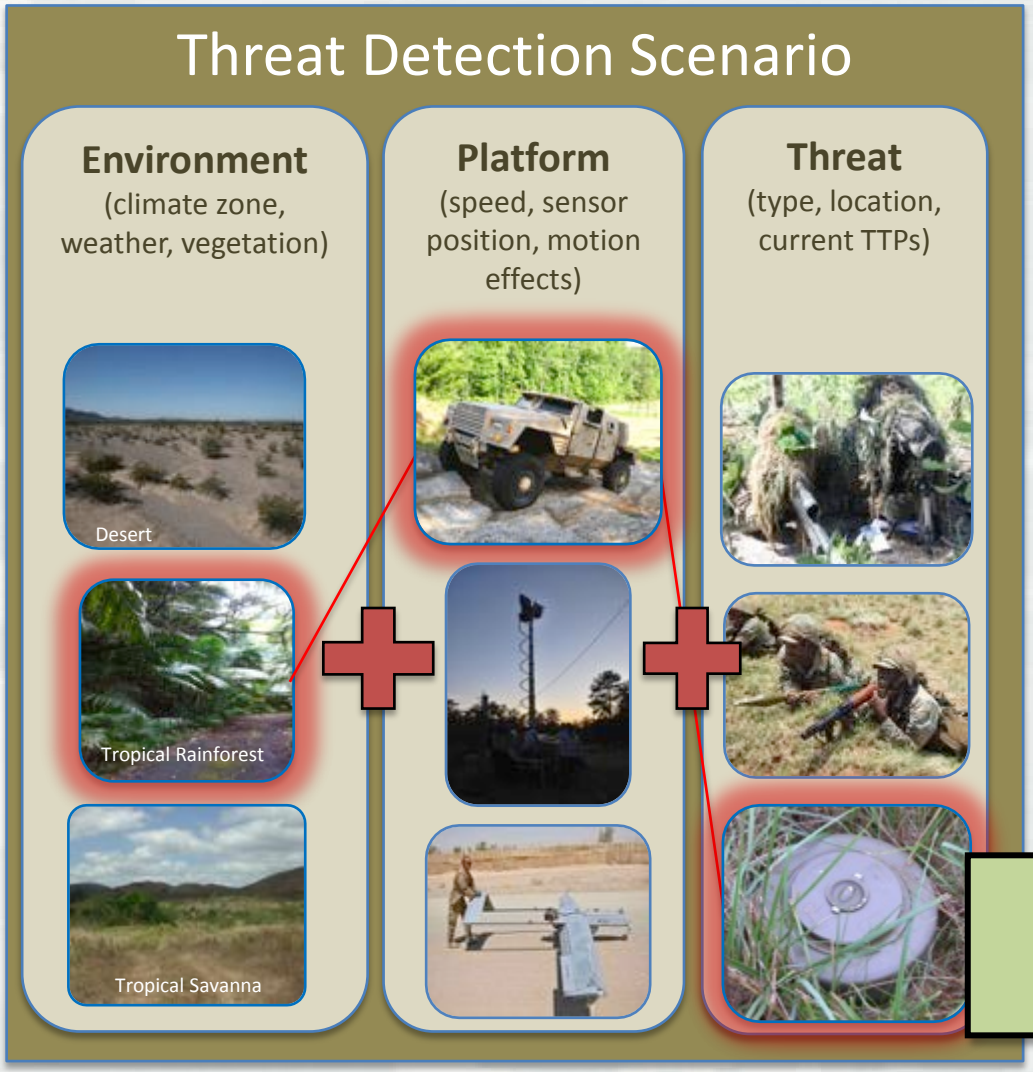
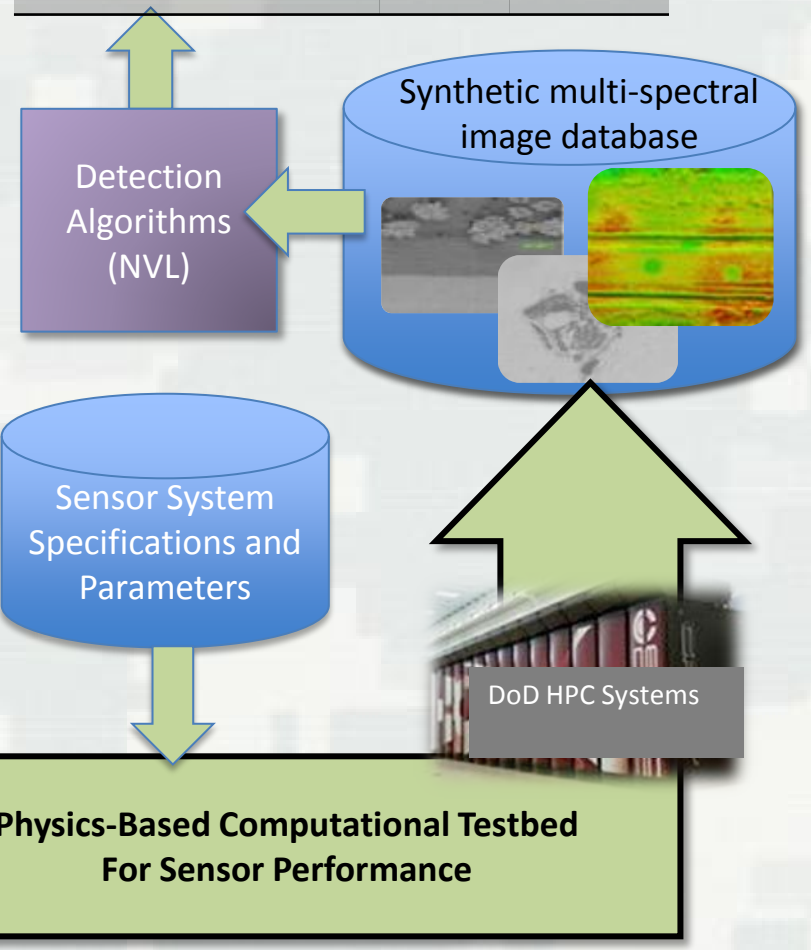


The Future

Support for Sensor Acquisition and Optimized Deployment

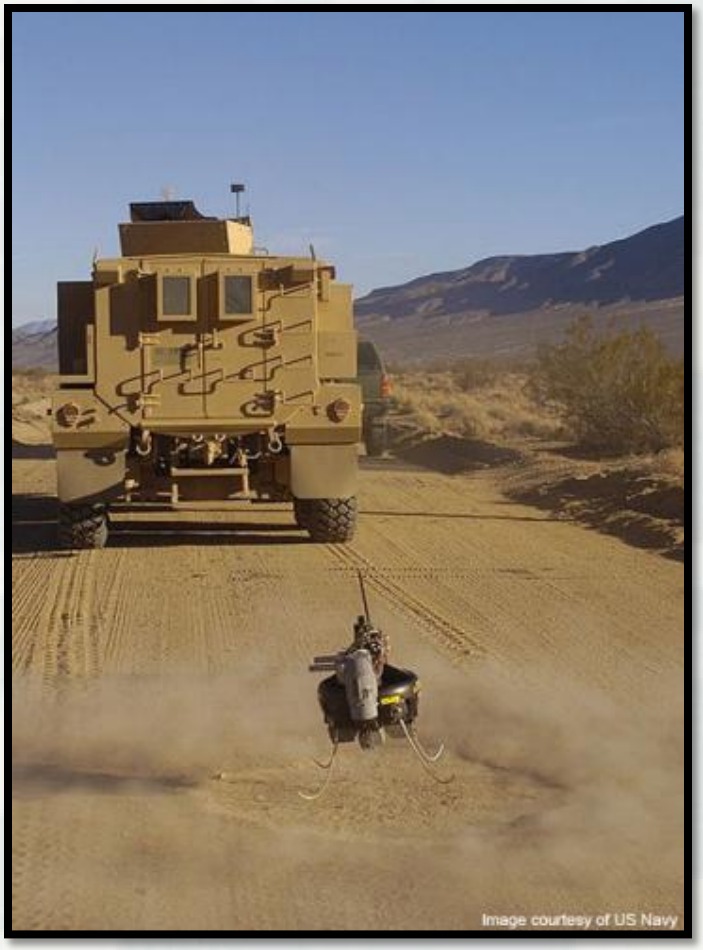
Sensor System	Pd	FAR
Sensor A/Sensor B	0.95	0.005
Sensor C/Sensor A	0.90	0.01
Sensor A	0.82	0.02
Sensor B	0.74	0.001
…	…	…





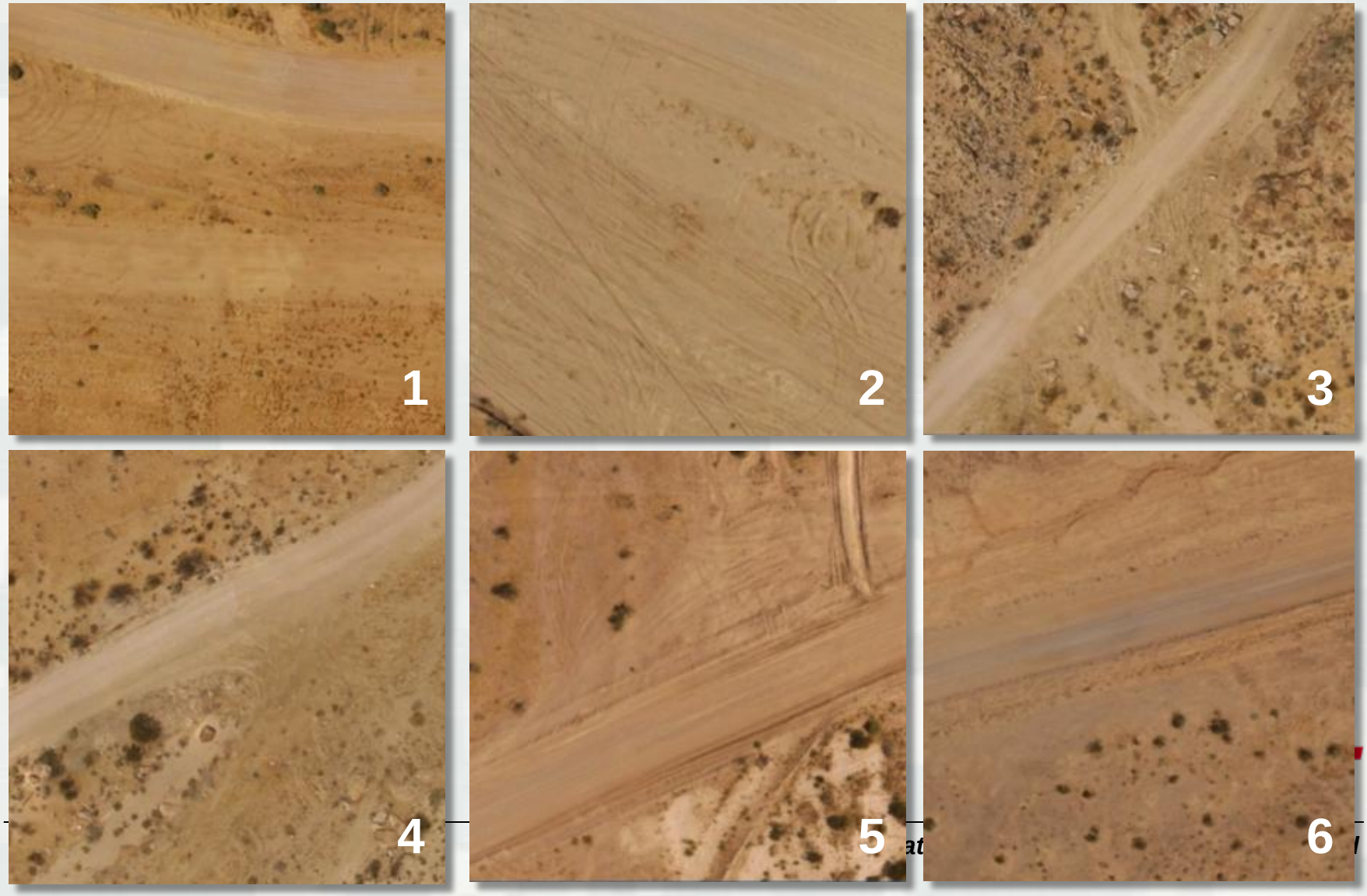
Support for Route Clearance

- Evaluating the relative worth of sensor types and platforms for route clearance
- Using models to create synthetic imagery that ‘appears’ like it came from a sensor onboard a UAV or mounted on a vehicle
- Can evaluate different weather conditions and times of day
- Can explore deployment options and novel sensor concepts

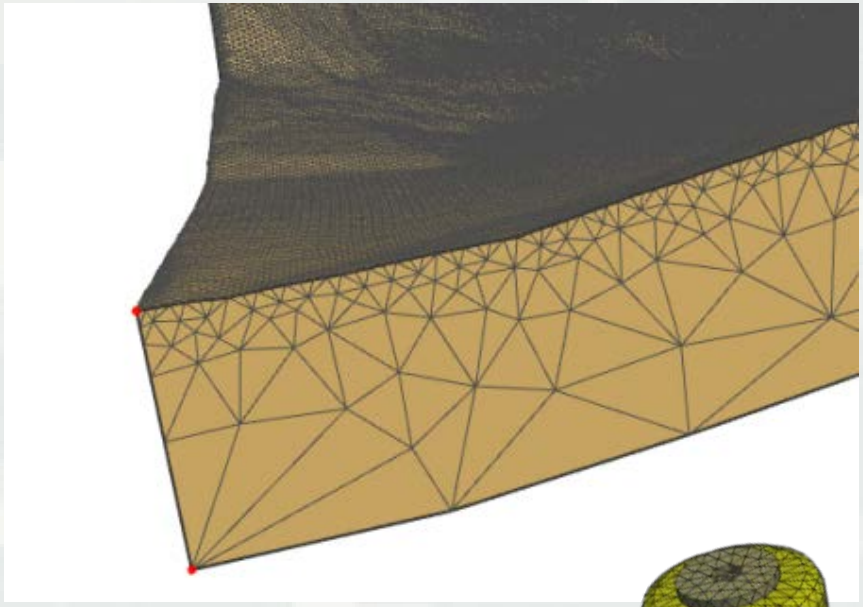


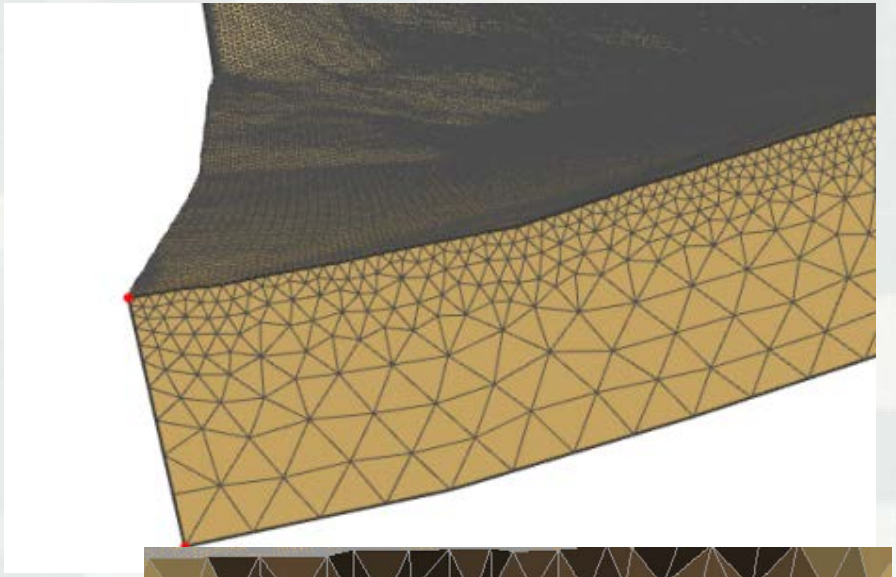
Named Areas of Interest at CONUS Test Location

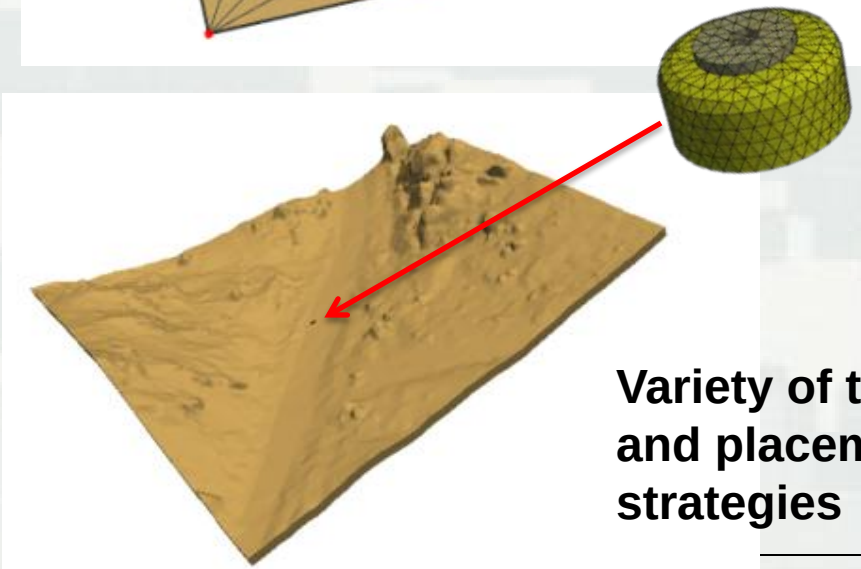
Example Scenes
(50m x 50m x 1m)
Up to 100M elements each



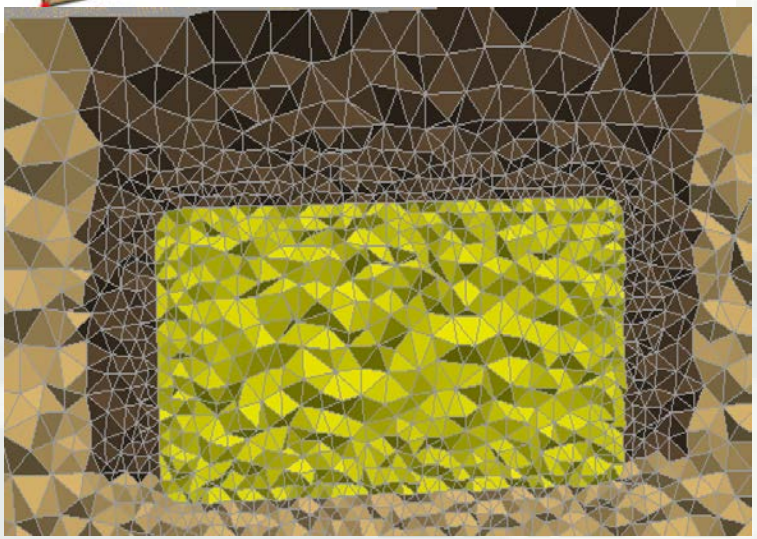
Example Meshing



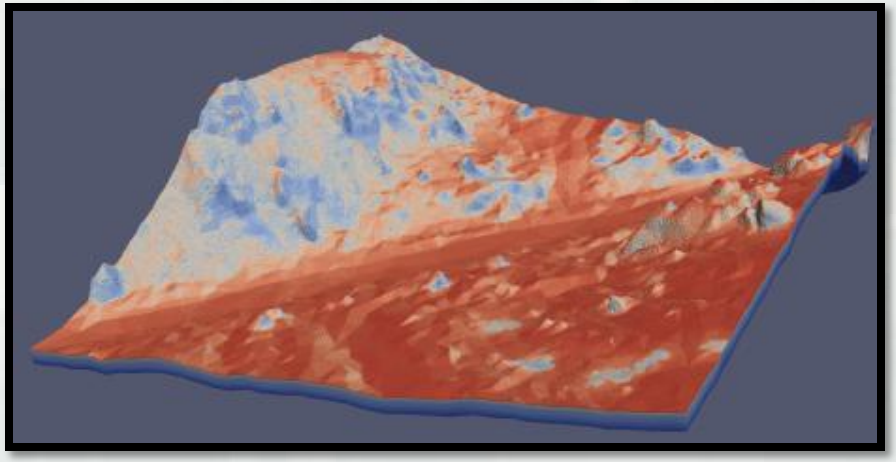




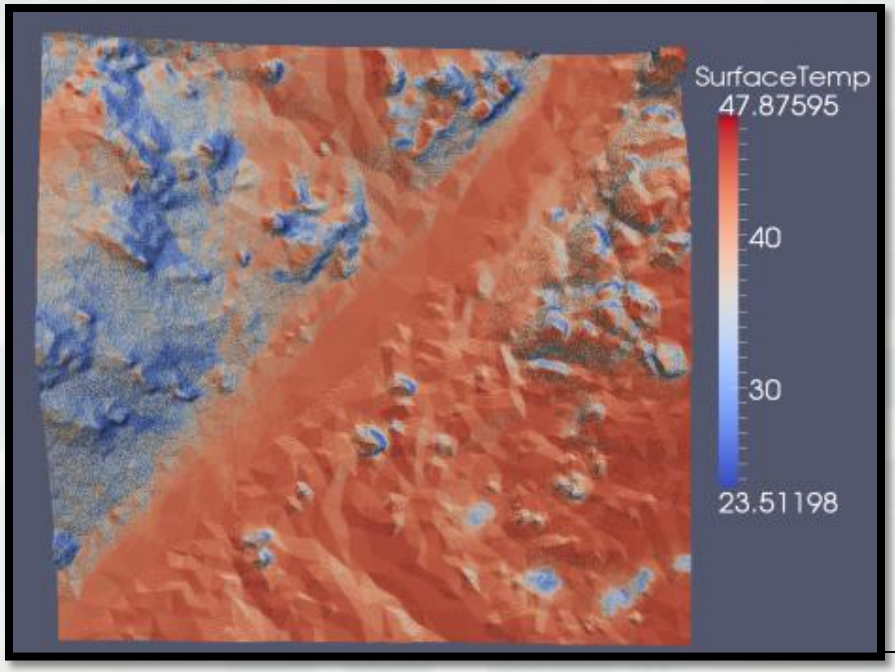
Variety of threats and placement strategies

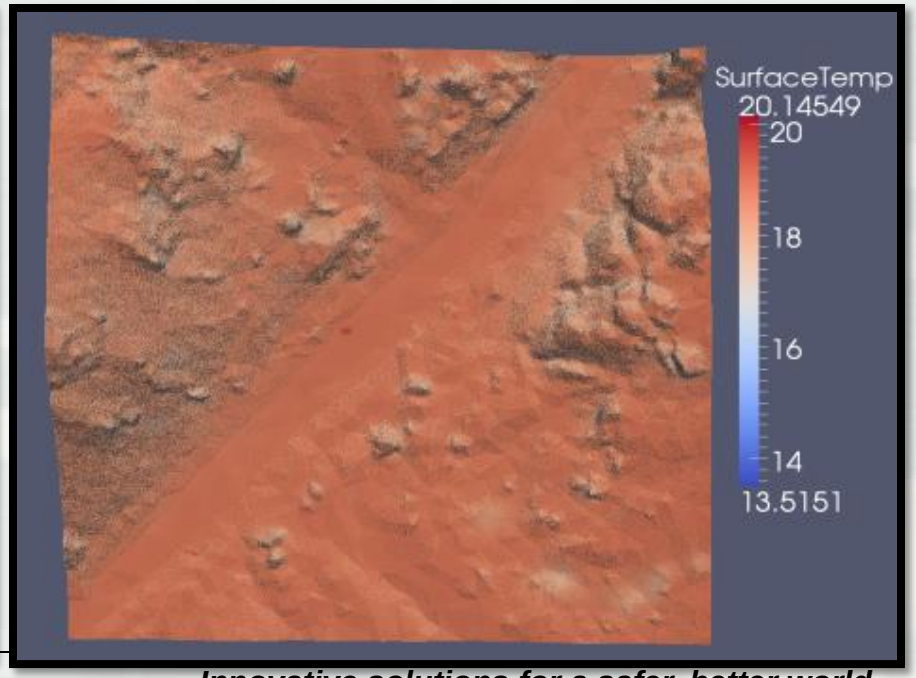


Simulation Results for Area 3

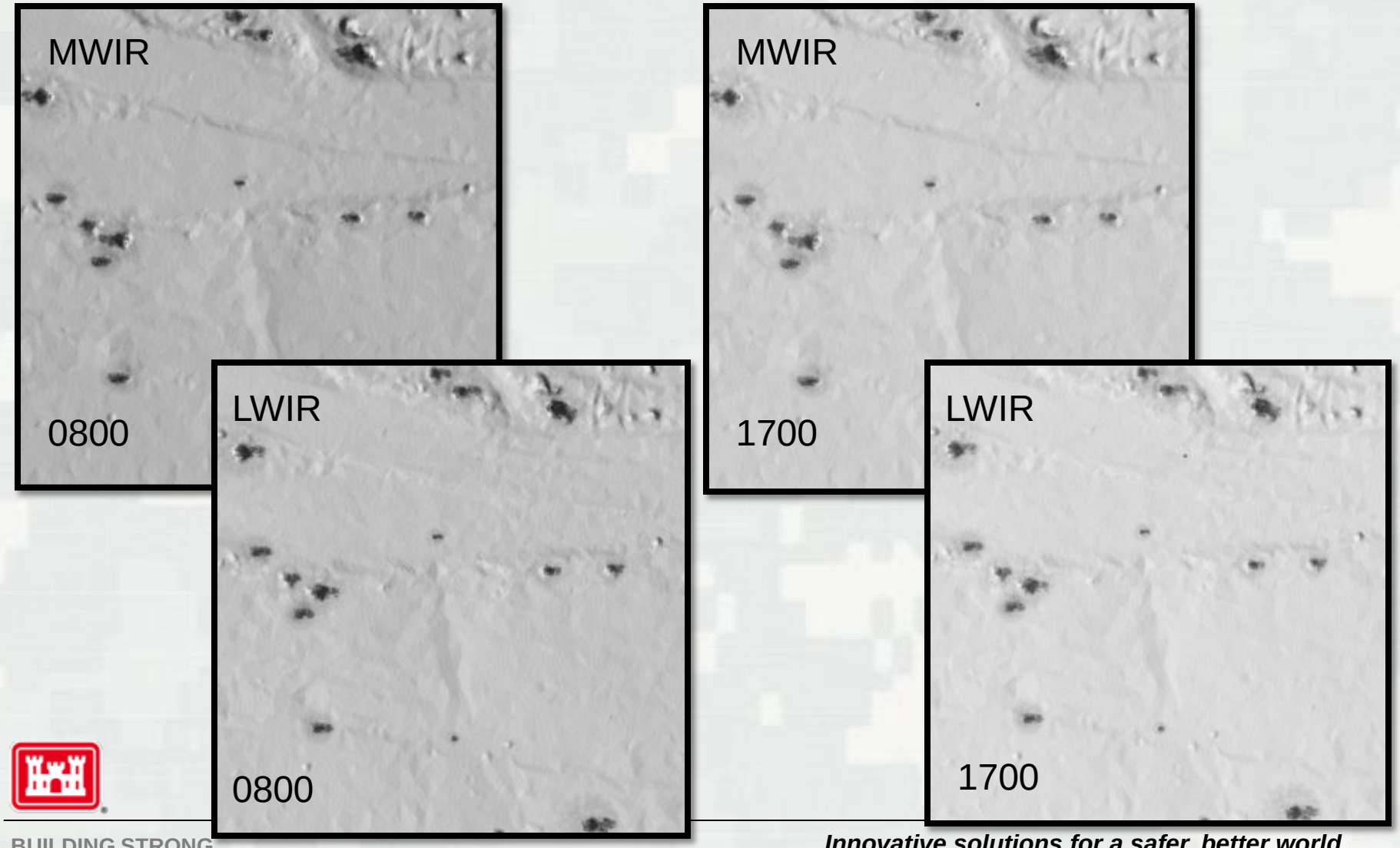


- Physical temperatures for day and night snapshots without targets

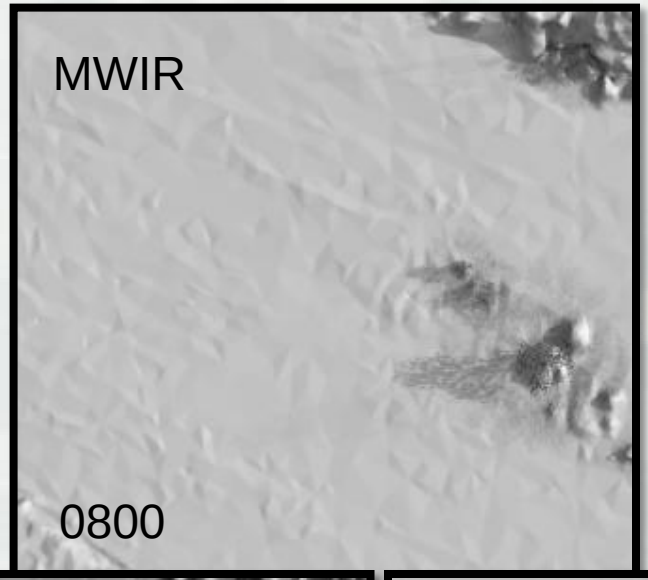


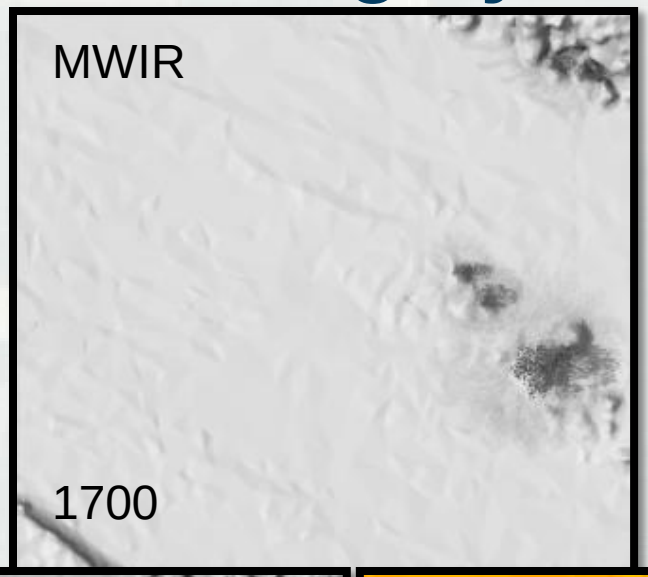


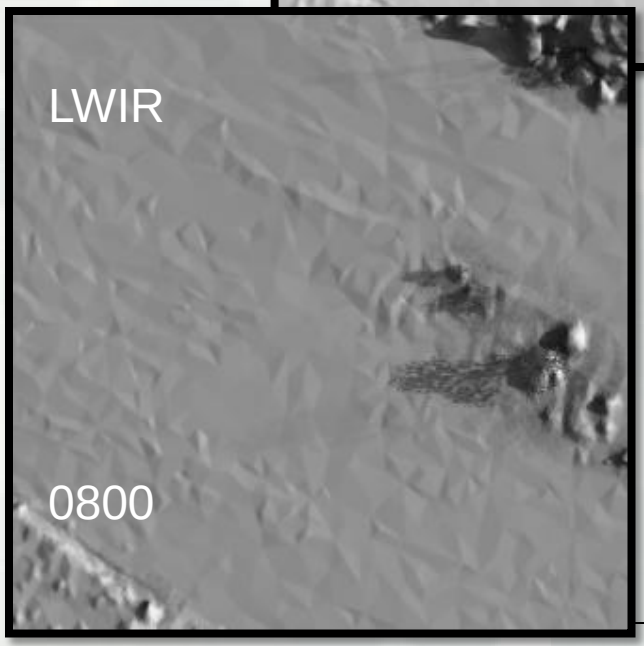
Synthetic MWIR and LWIR Imagery for Area 1

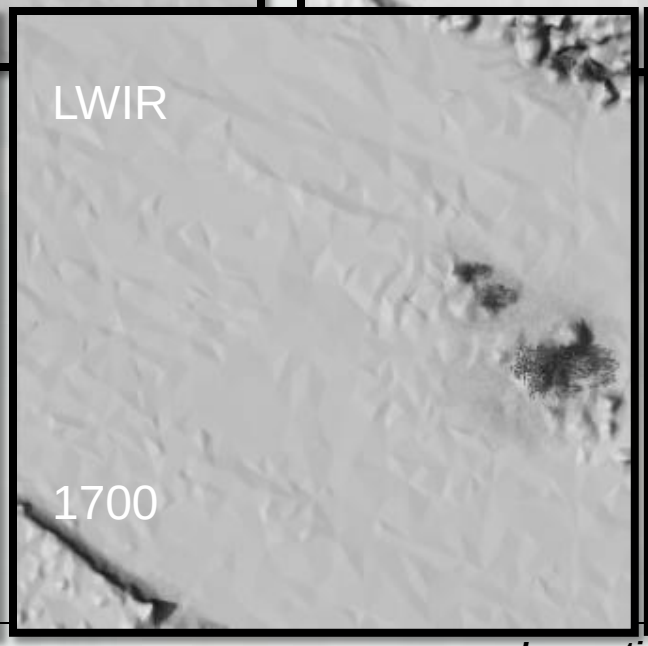


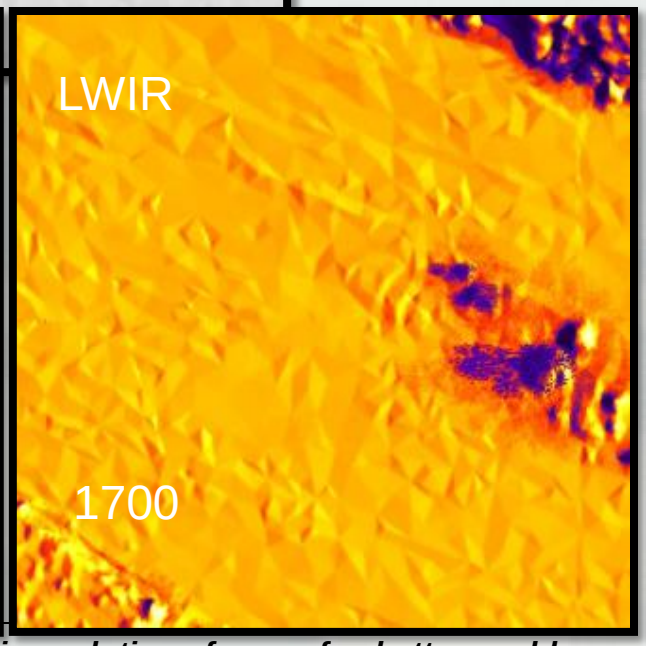
Synthetic MWIR and LWIR Imagery for Area 2



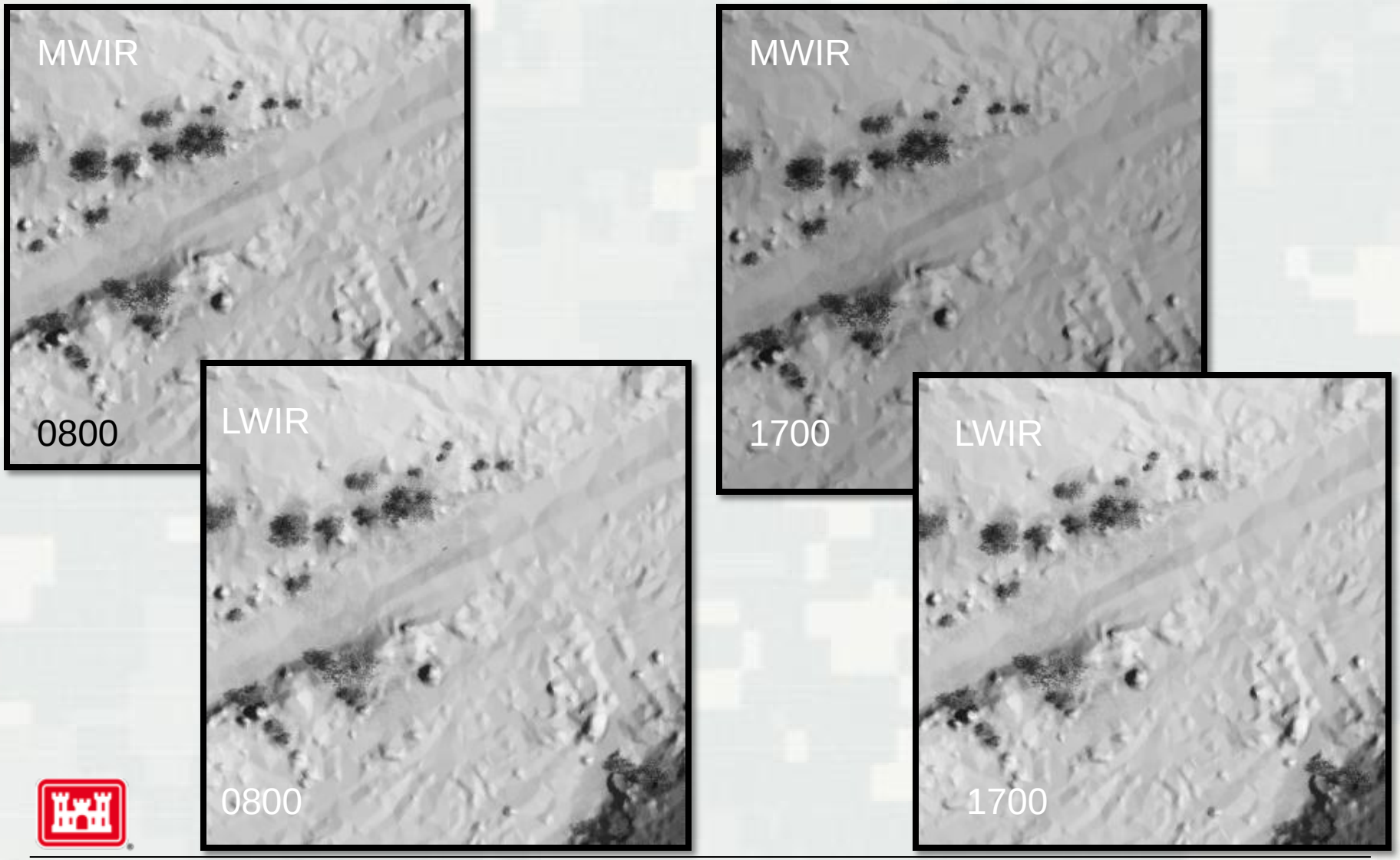




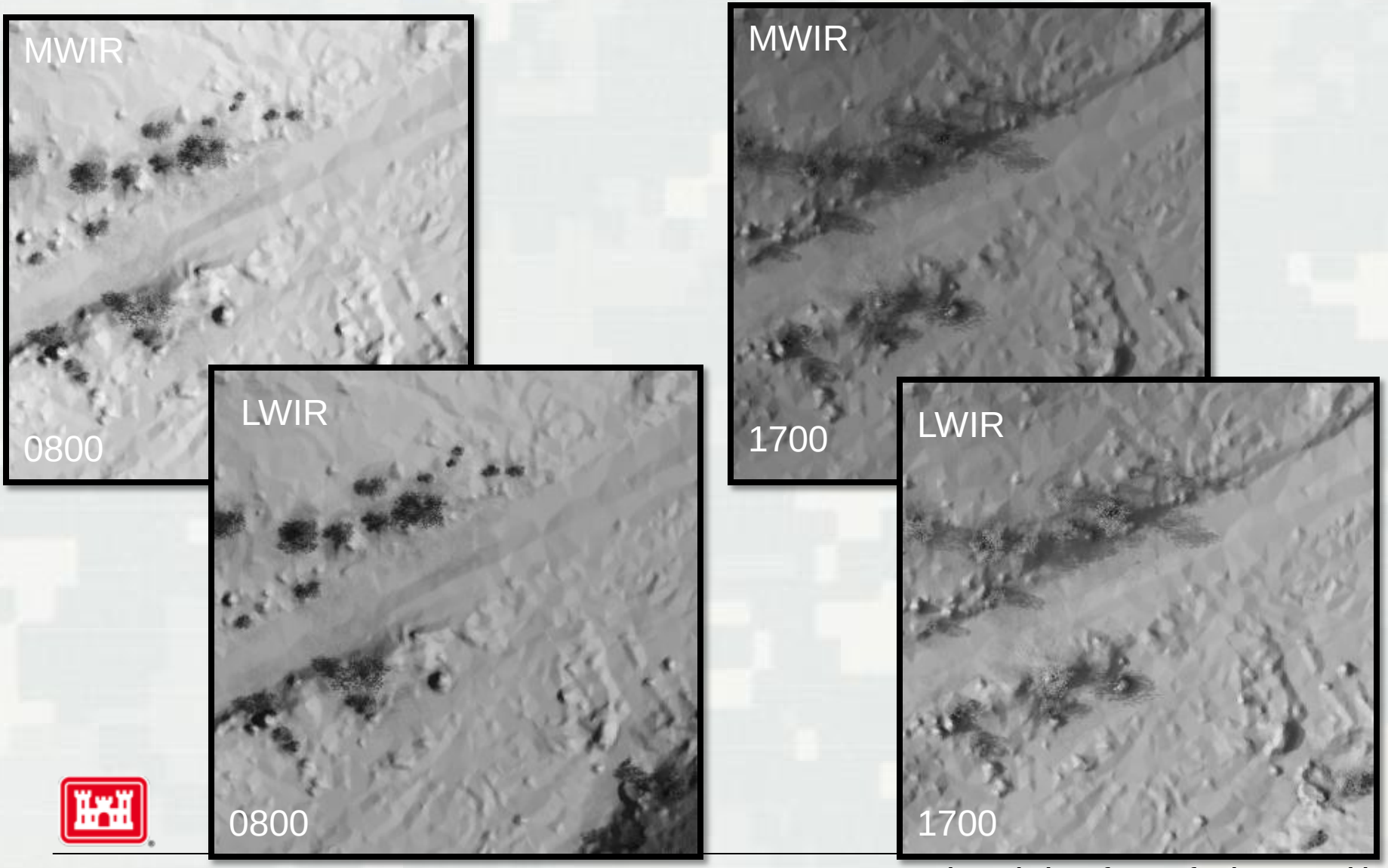




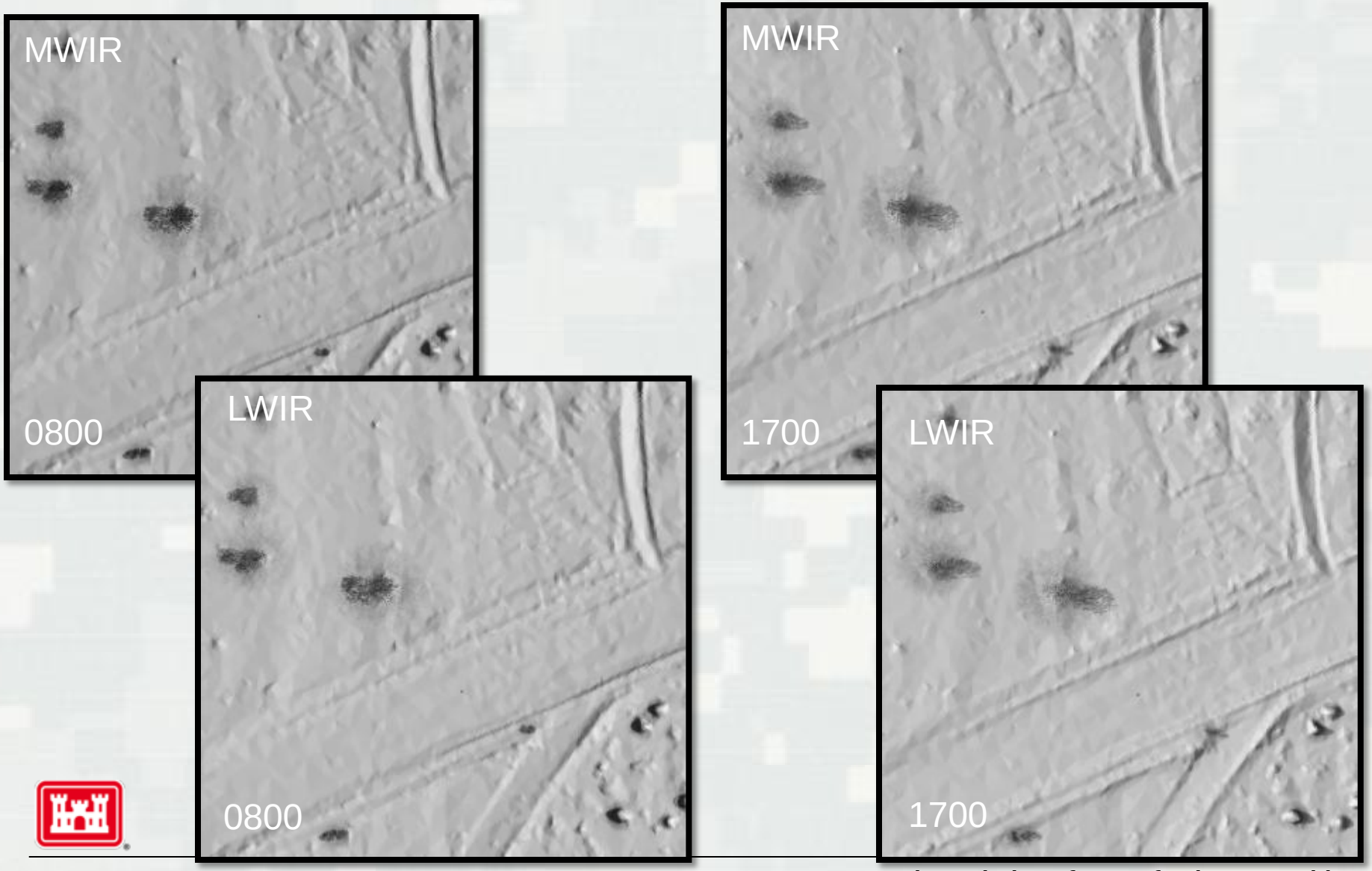
Synthetic MWIR and LWIR Imagery for Area 4



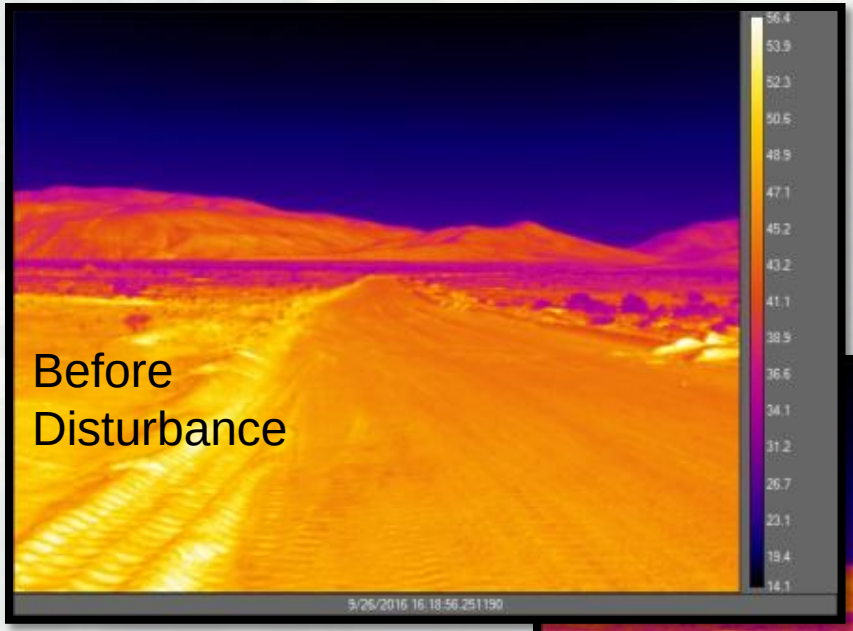
Synthetic MWIR and LWIR Imagery for Area 4

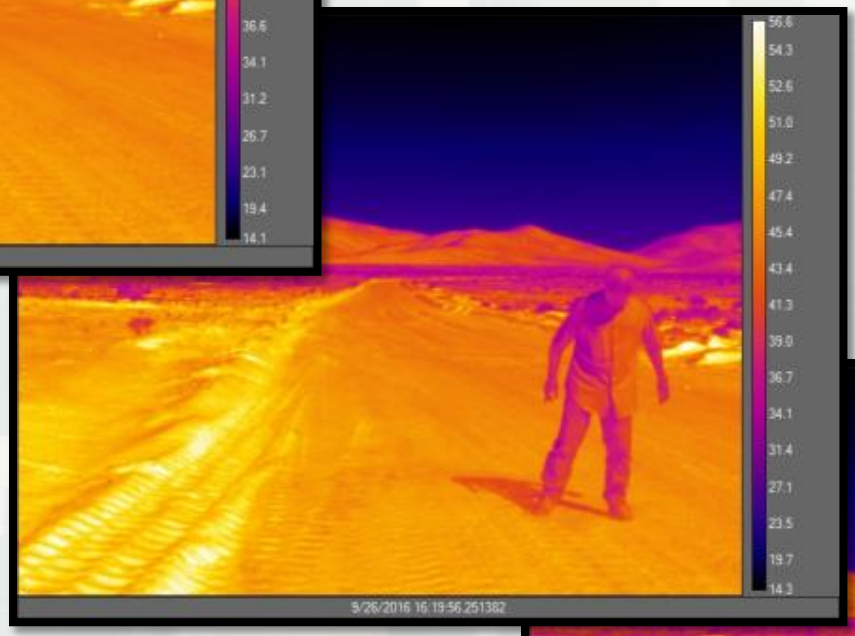


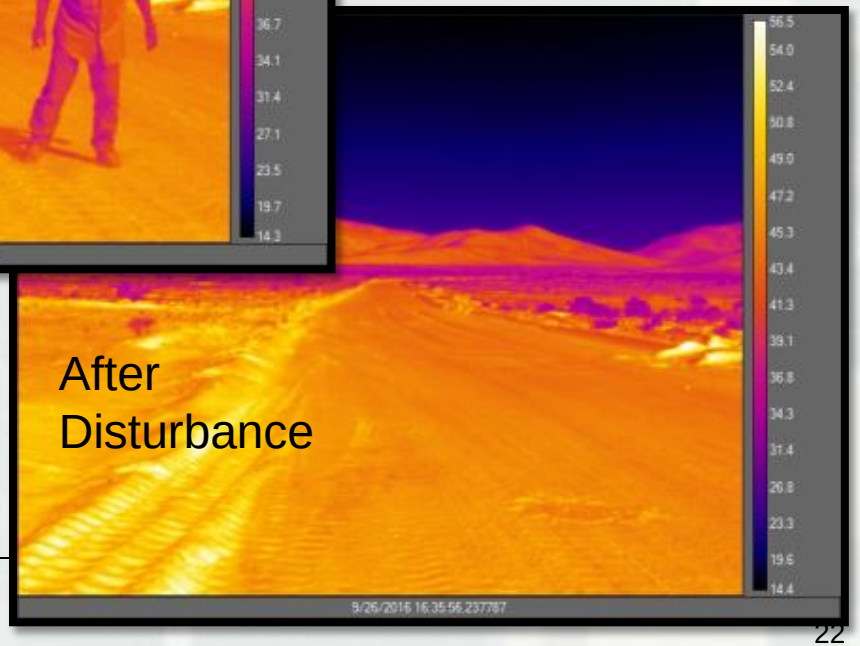
Synthetic MWIR and LWIR Imagery for Area 5



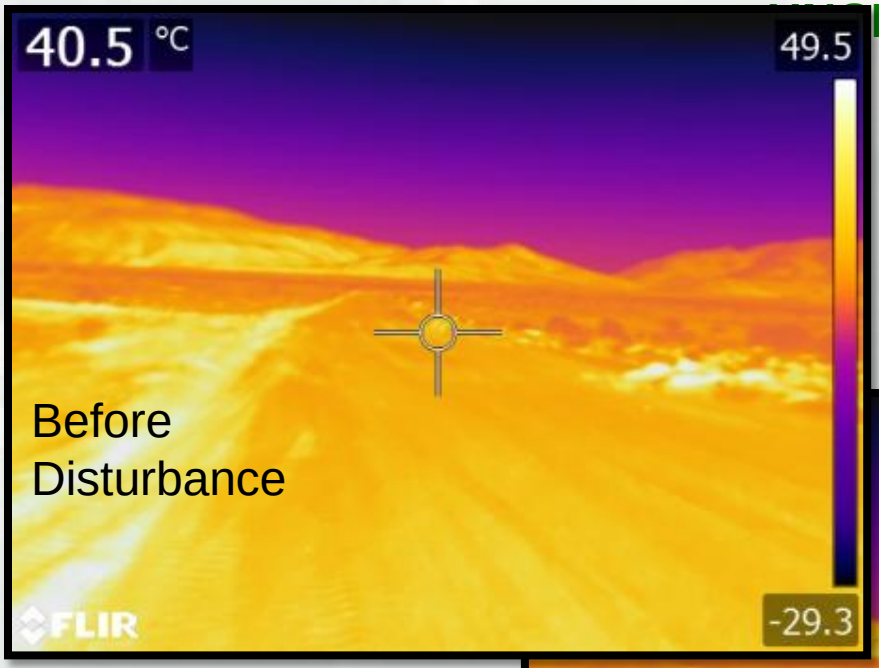
Actual MWIR Imagery for Area 5



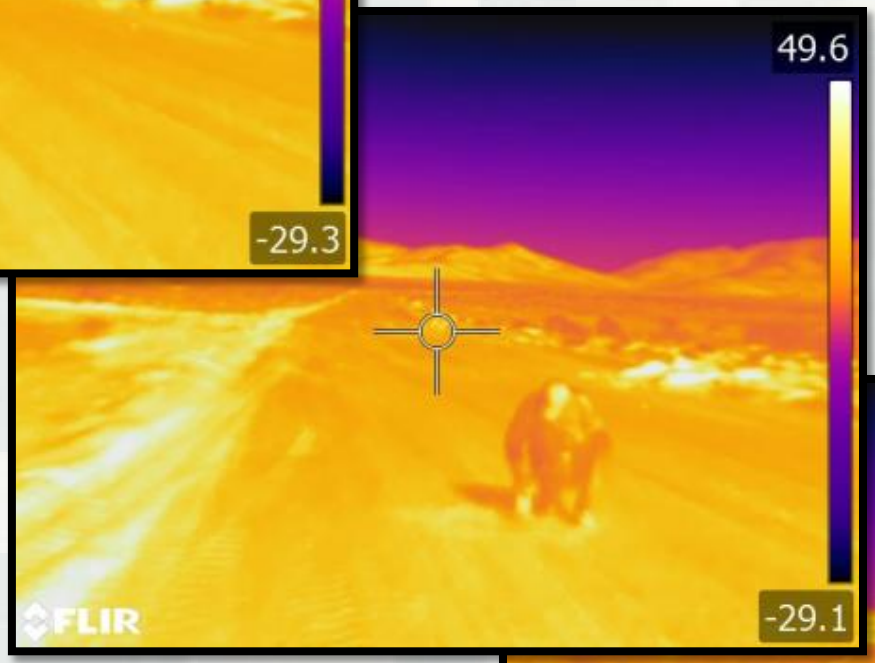


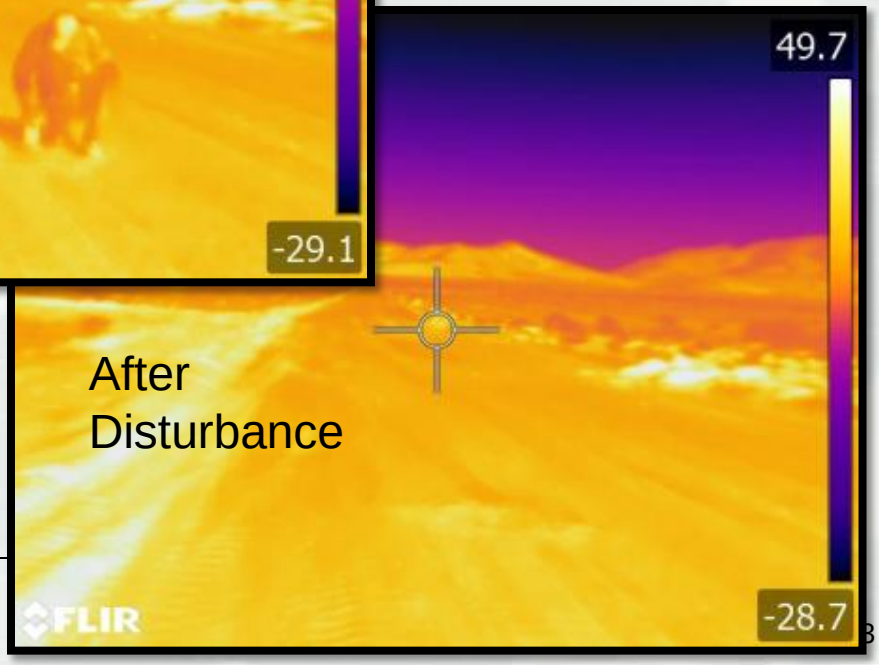


Actual LWIR Imagery for Area 5



Before Disturbance





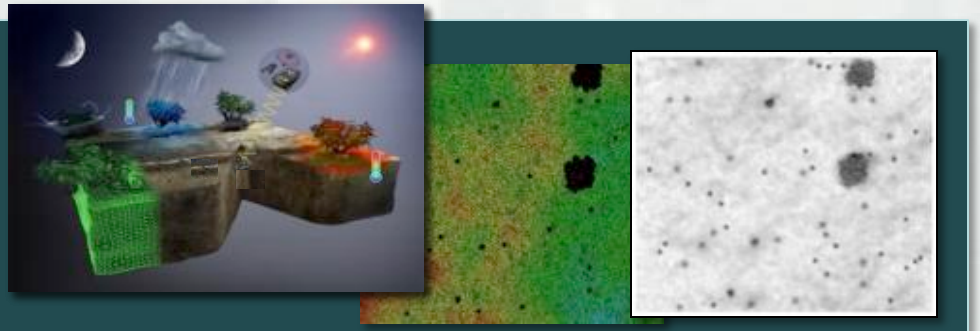
After Disturbance

Application

- Synthetic images with a variety of target types and placements are being shown to route clearance teams in a tabletop exercise

Outline

Overview of Computational Tools



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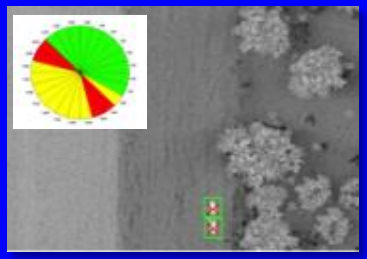
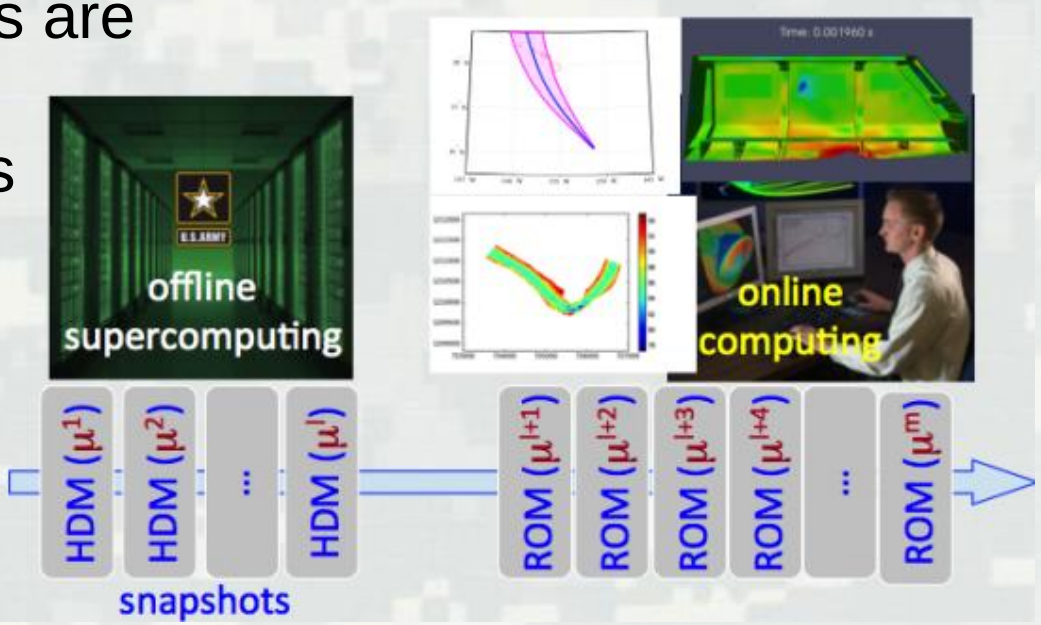


The Future

Applying High-Fidelity Modeling to M&S

- Presently, the models are too slow to support operational decisions
- Database of pre-computed solutions
  - Nearest match
  - Interpolation
  - Extracting statistics



- Reduced Order Models for site-, condition-, and threat-specific detection probabilities with small computational footprint

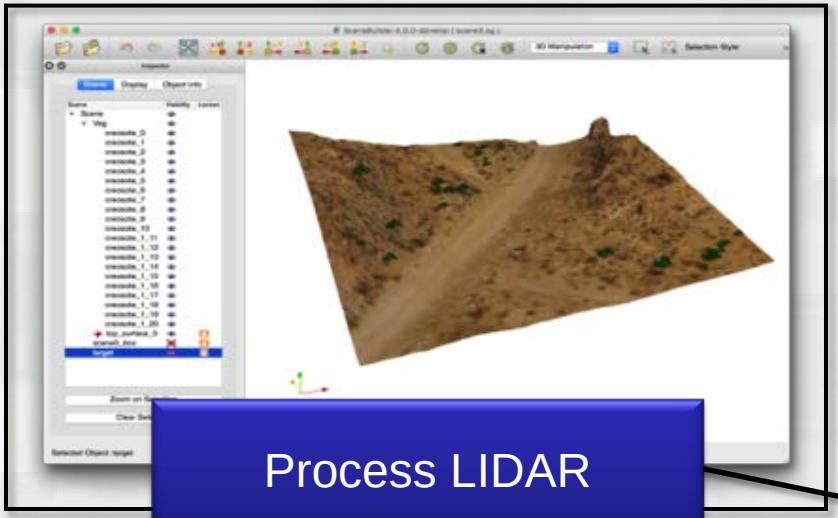
Summary

- Modeling and Simulation can help counter rapidly changing tactics in hybrid conflicts by
  - Adapting detection algorithms to account for changes to threat type or threat placement
  - Optimizing sensor deployment strategies for specific threats and conditions
  - Exploring the potential of novel sensor concepts prior to prototype construction

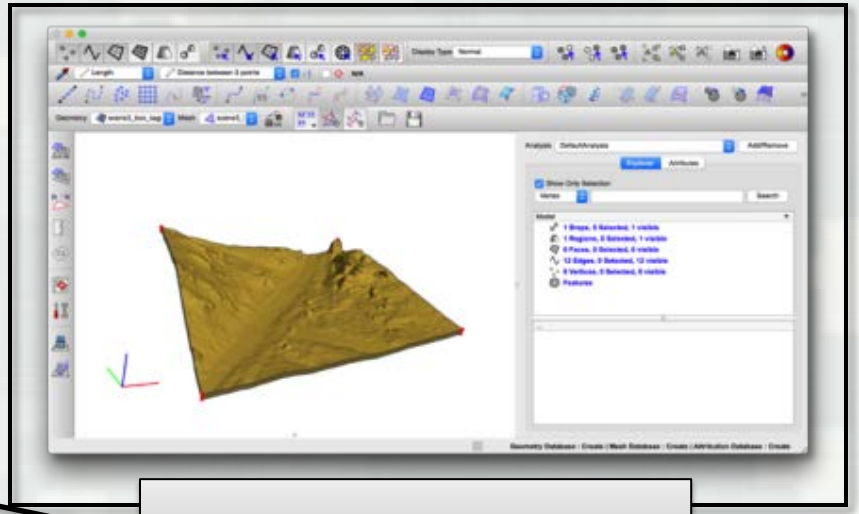
Thank you for your attention.
Questions?

Scene Generation Process

Computational Model Builder (ERDC/Kitware)



Capstone (HPCMP/Create)



Process LIDAR

- Build 3D Domain
- Place Targets and Veg

- Add Attributes to the domain
- Export Model Input Files

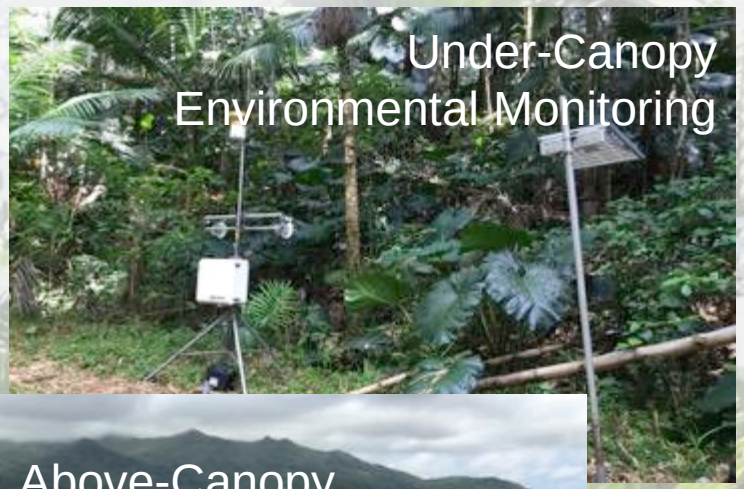
Generate Surface

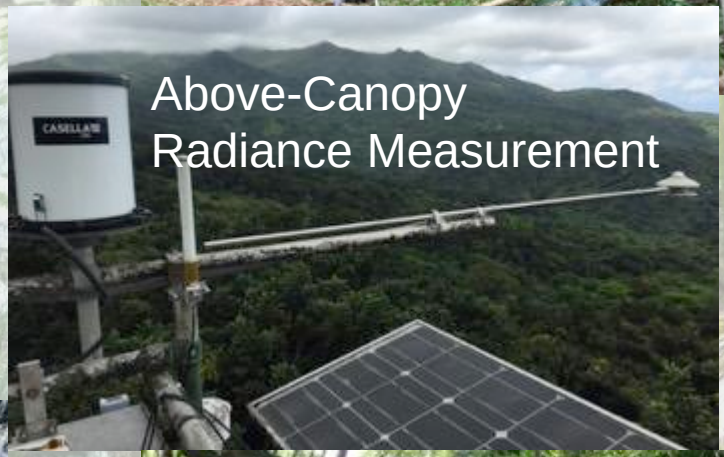
- Merge Targets and 3D Domain
- Generate Mesh (Create & AFLR Meshers)

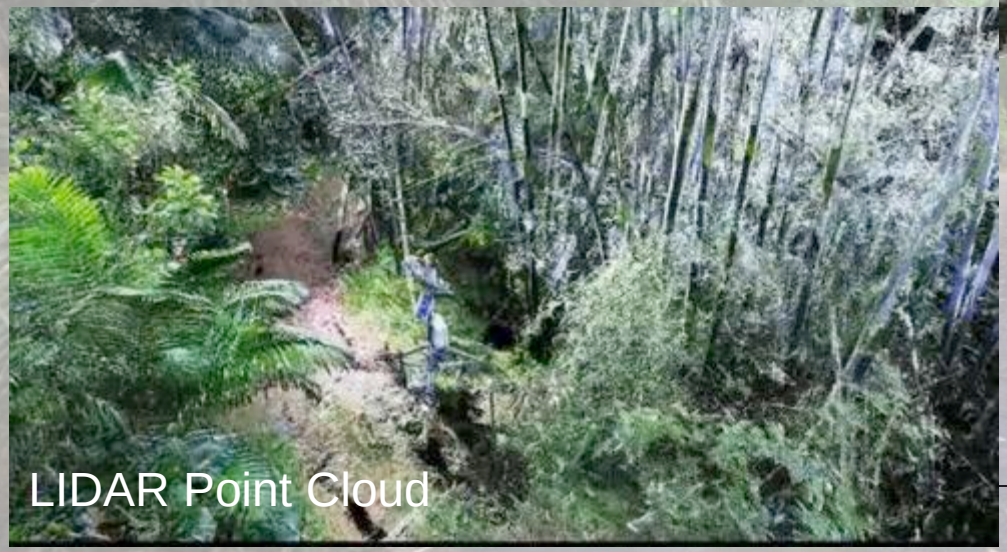
Goal is to script the placement of targets, mesh generation, and BC application

Current Effort Validates Models for Central/South America and the Pacific

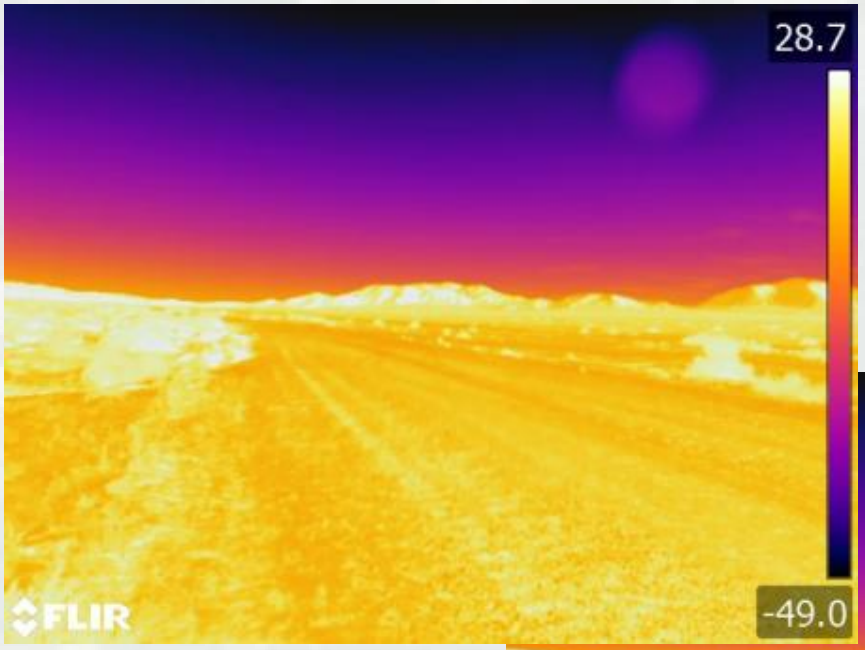
- **Past 13 years have been spent largely in arid regions with little vegetation**
- **Testing tools and methods in wet environments with dense vegetation**

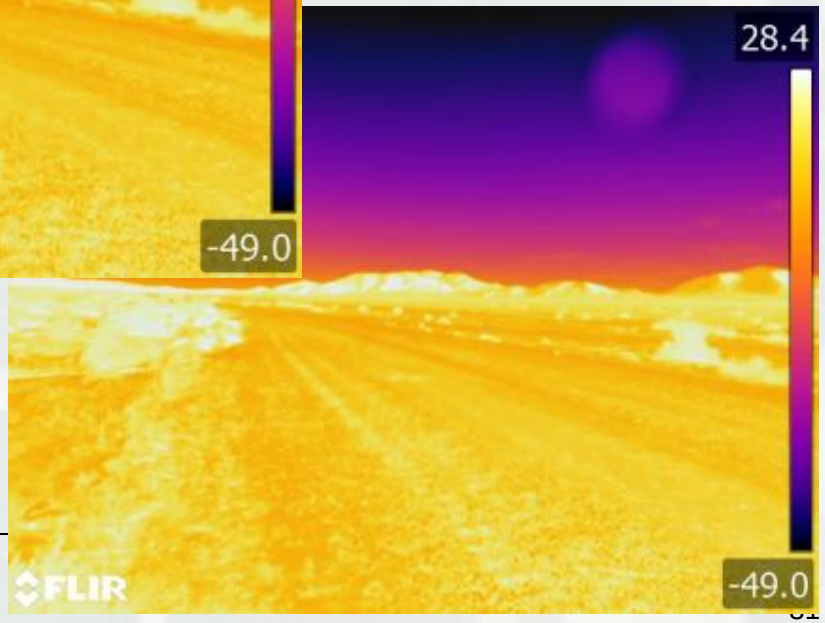






Actual LWIR imagery for Area 1





Actual MWIR imagery for Area 1