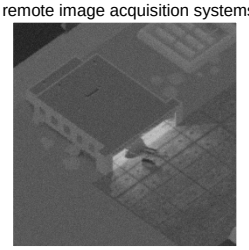
DIRSIG

A complex graphics application for modeling a variety of remote image acquisition systems

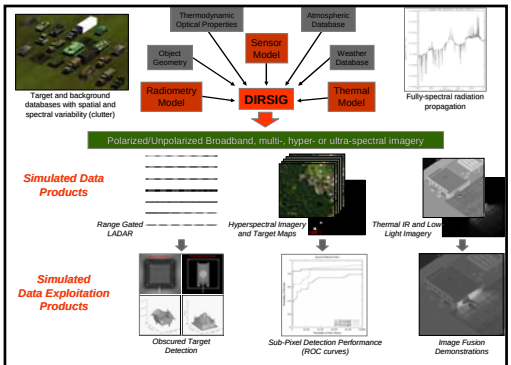


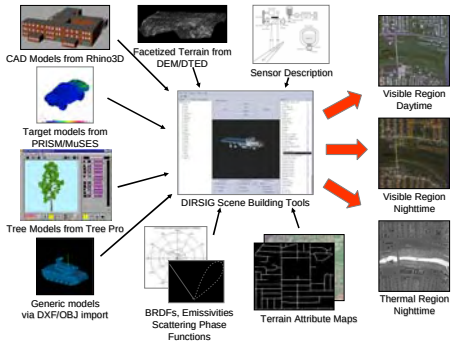
What does a vehicle look like?

- The truck leaves a shadow on the ground
  - The ground is cooler because it has been in the shade.
- You can see a reflection of the hot engine in the asphalt as it drives by.

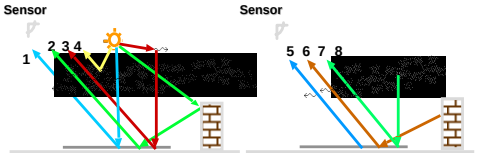
DIRSIG: Applicable Areas

- Sensor Prototyping
  - Construct and test a new sensor in a virtual environment
  - Evaluate design trades
  - Produce example products for customers
- Algorithm Testing
  - Decrease amount expensive field collections
  - Control all the image formation variables
  - Per-pixel truth allows for better evaluation
- Algorithm Training
  - Predict observations that may be found in images to pre-train complex algorithms.
- Analyst Training
  - Create custom training examples
  - Test the sensitivity of the analyst to phenomenology
  - Provide a tool to hypothesis about the nature of phenomenology





Radiometry Submodel: Radiation Sources



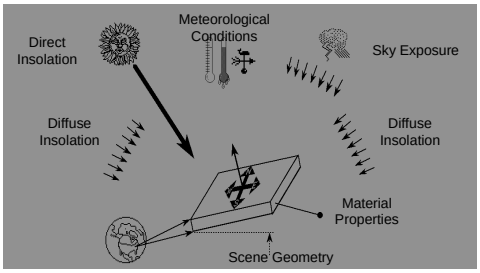
Solar Photons

1 Directly Reflected
2 Background Scattered
3 Skylight
4 Scattered by Atmosphere

Self-Emitted Photons

5 Target
6 Background Reflected by Target
7 Atmosphere Reflected by Target
8 Atmosphere

THERM
Environmental Inputs



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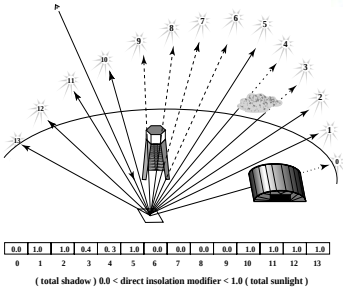
Sun Shadow History



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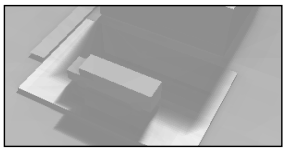
Thermal Submodel:
Phenomenology



"Soft" shadows in the thermal regions resulting from utilizing solar shadowing histories

Radiant "shading" beneath truck and an internal power source (engine)

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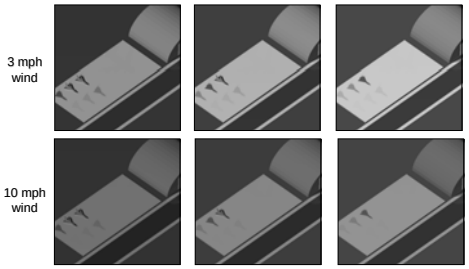
Phenomenology Demonstrations



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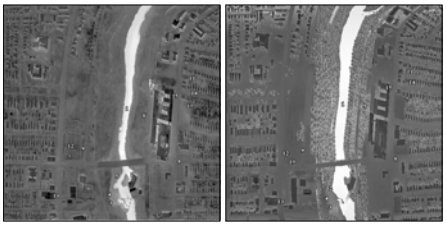
Thermal Simulation:
Rochester NY in Winter at Night



Truth Imagery **DIRSIG Imagery**

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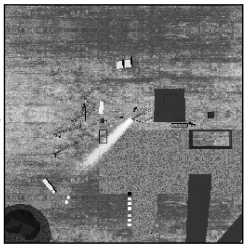
Plume Modeling: Example

- A simulation of a gas plume release at a the Nevada Test Site. The actual plume release was used to validate our simulation.
- If the simulation is accurate, then costly and environmentally unfriendly field releases can be avoided in the future.



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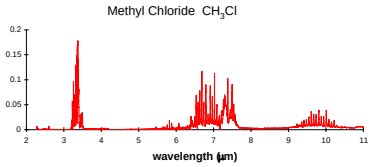
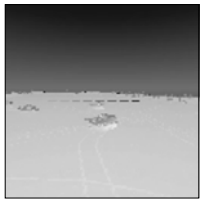
Gas Absorption Database

- Acquired from EPA Laboratory Measurements
- Database ranges from 2.2 - 25 mm at 0.25 cm-1 resolution



3 meter path length at 500 ppm, 298 K

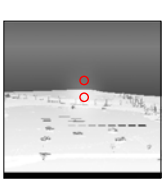
Gas Cloud:
Temporal Behavior

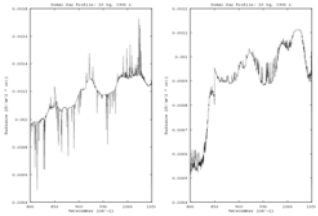


- This movie shows the drift and expansion of the gas cloud over the terrain
  - From 25 ms to 600 ms after release

Spectral Profiles:
Large Payload

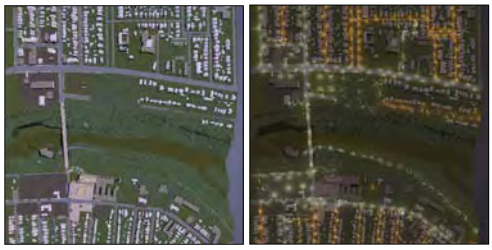
20 kg release, 1500 sec after detonation, against background





Terrain Background Sky Background

Low-Light Images



Daytime Nighttime

Low-Light Images

Low-Light Images

Low-Light Simulation:
Low-Light and Thermal Image Examples

Simulation time = 0200 hours
New Moon Conditions

Low-Light Visible Radiance

Thermal Radiance

Low-Light Simulation:
Fused Image Example

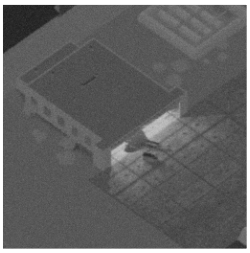
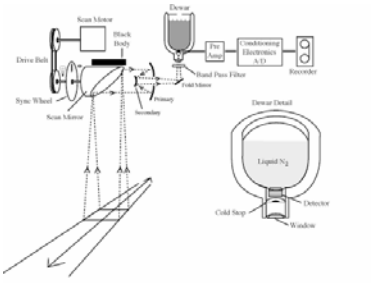


Image fusion of simulated low-light and thermal imagery

Line Scanner:
Optical Geometry

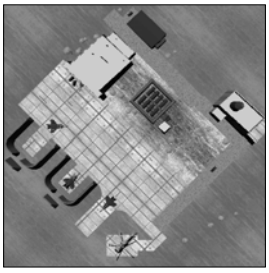


Sensor Modeling:
Geometric Characteristics

```
INSTRUMENT {
    TYPE = FRAMING_ARRAY
}
```

- Radial relief displacement

Sensor Modeling:
Geometric Characteristics



```
INSTRUMENT {
    TYPE = PUSHBROOM_SCANNER
}
```

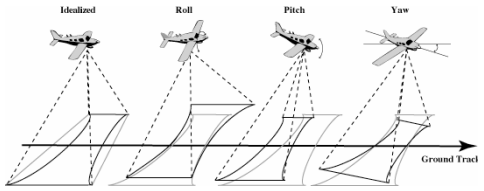
- Cross-track relief displacement
- No tangential distortion

Sensor Modeling:
Geometric Characteristics

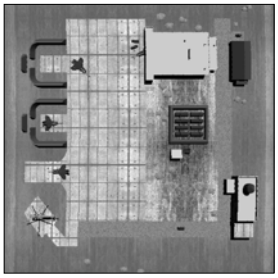
```
INSTRUMENT {
    TYPE = LINE_SCANNER
}
```

- Cross-track relief displacement
- Tangential distortion

Scanning Sensors:
Sources of Geometric Distortion



Sensor Modeling:
Geometric Characteristics



```
INSTRUMENT {
    TYPE = LINE_SCANNER
}
```

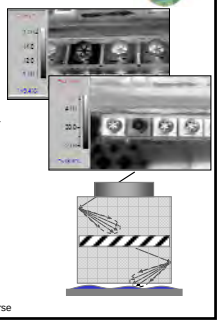
- Cross-track relief displacement
- Tangential distortion
- General flight orientation distortions
  - Gentle role
  - Jitter

Applications and Phenomenology

- Loading Problems
  - Sky, cloud and tree shine problems
- Cavity/Calibration Problems
  - Cavity radiance effects from chambers/cavities with non-ideal surface properties.
- Polarization
  - Full-spectral polarimetric modeling capability
    - Currently heavily limited by available material characterizations
- Water/Littoral
  - In-water scattering/absorption to understand adjacent effects.
- Plume Detection
  - Provide a framework to evaluate instrument designs.
  - Provide a source of data for rigorously testing algorithms.
    - Truth is known for every pixel.

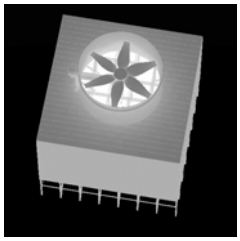
The Cooling Tower Problem

- Problem:
  - Estimate the cooling load (water temperature) from observed radiances.
- The observed radiance is a combination of direct emission from the viewed surface and reflected emission from adjacent surfaces.
- To evaluate the expected variations in the tower leaving radiance, a model of the tower geometry can be constructed.
  - The individual surfaces within the tower can be attributed with unique emissivity and reflectance properties.
- DIRSIG can provide insight into the effect of uncertainties on the tower leaving radiance.
  - Uncertainty in water temperature.
  - Uncertainty in surface temperatures.
  - Uncertainty in surface emissivity.
  - Uncertainty in internal construction.



Cooling Tower Simulation

- DIRSIG Simulation using precomputed surface temperatures.
  - Cannot directly see the warm water in the tower
    - All multiple bounce!
  - Note apparent temperature gradients near fan hub and shroud walls.
  - Small holes are from sampling small grooves in the top “deck”
    - Will be smoothed with PSF



Scene Overview

- Candidate site
  - Irondequoit NY
    - North-east corner of city
- Data Availability
  - Field Collections
    - Close proximity allows for easy and frequent ground collects.
  - Image Collections
    - MISI
    - IKONOS
    - AVIRIS
    - MTI
    - Hyperion
    - Kodak CitiPix

MegaScene1:
Example Images

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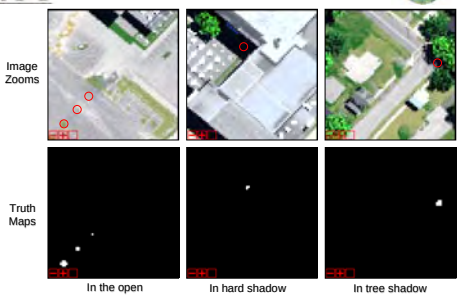
Deployment of Target Panels



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MegaScene #1: Tile #1

A channel from a thermal infrared hyperspectral simulation featuring strong and weak gas plumes.

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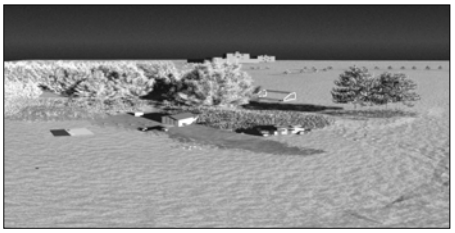
MicroScene1



Near-IR (830 nm) channel from a 70 channel *simulation* of the RIT Modular Imaging Spectrometer Instrument (MISI) imaging a camouflage and concealment experiment.

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Camouflage Level of Detail

Digital photo at real scene | DIRSIG simulation

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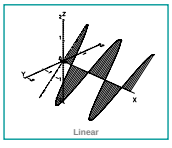
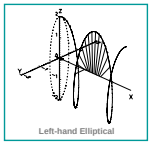
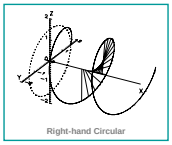
Polarization States

- Polarization due to relationships between the magnitude and phase of the orthogonal electric field components
  - Random
  - Linear
  - Circular
  - Elliptical







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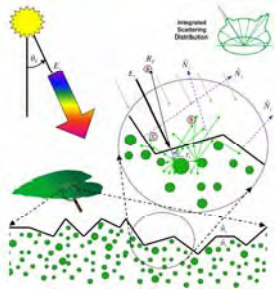
"Real Material" Reflectance

- Real materials are complex, with two basic reflectance components
  - Surface
  - Volume
- Surface reflectance highly color neutral
- Volume reflectance → color
- Umov's effect: *DOP* and brightness inversely proportional



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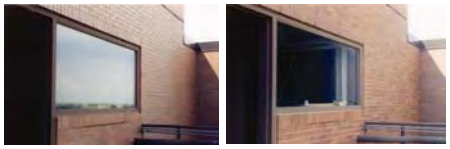
Demonstration of Polarization



Vertically Polarized Filter **Horizontally Polarized Filter**

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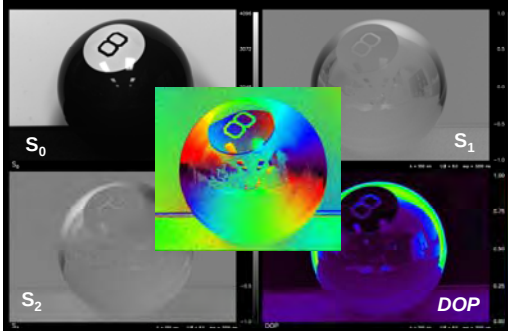
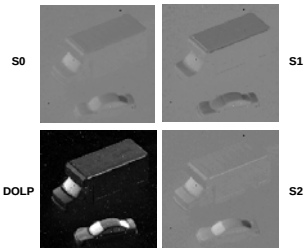
Imaging System Demonstration: "Magic 8-ball"



AFRL Polarimetric Images



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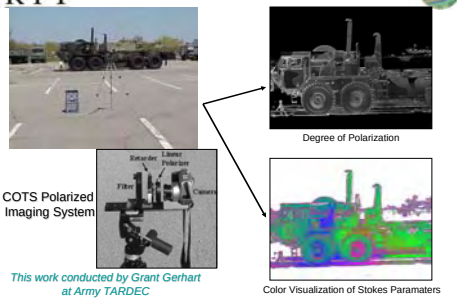
Army TARDEC Collections



This work conducted by Grant Gerhart at Army TARDEC

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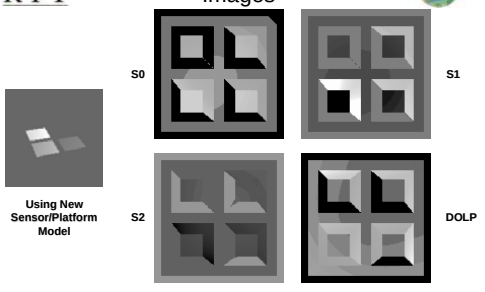
First DIRSIG Polarimetric Images



Using New Sensor/Platform Model

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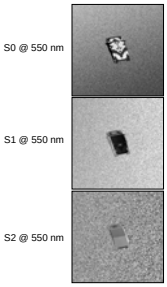
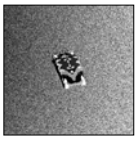
LM, RIT and AFRL Partnership




RGB Color


Degree of Polarization

- A simple, polarized scene simulation
  - Vehicle BRDF modeled using AFRL's multi-parameter, polarized BRDF model.
  - Grass modeled using RIT's Shell Background model.
  - No sensor noise or MTF effects.

DIRSIG BRDF Model

- Sample Imagery (Color Renderings)
  - Color Images: Red (S0: 650nm), Green (S0: 550nm); Blue (S0: 450nm)
  - 3 Viewing Angles (Forward, Side and Backscatter)

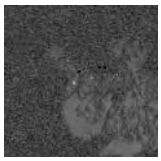

Back Scatter (RGB)


Side Looking (RGB)


Forward Scatter (RGB)

DIRSIG BRDF Model

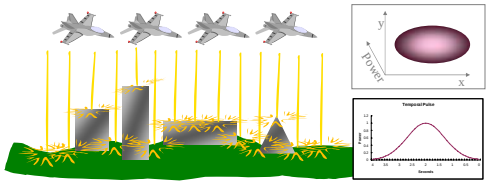
- Sample Imagery
  - DOLP Images (650nm)
  - 3 Viewing Angles (Forward, Side and Backscatter)


Back Scatter (DOLP)


Side Looking (DOLP)

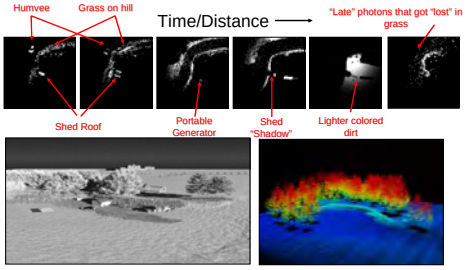

Forward Scatter (DOLP)

LADAR/LIDAR

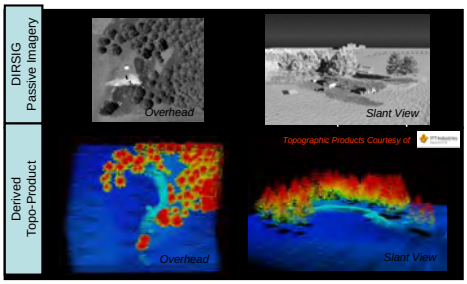


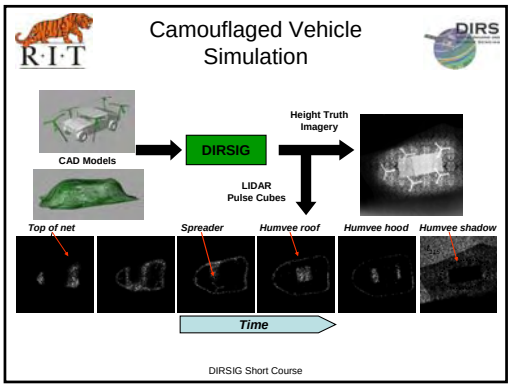
- The scene is stimulated with a pulsed beam that has a spatial, spectral and temporal shape.
  - The goal is to produce a simulation environment that can simulate as much physics as possible and provide a tool for design trade studies and algorithm testing.

LIDAR at MicroScene1



Topographical LIDAR Demo




Camouflaged Vehicle Simulation
CAD Models
DIRSIG
LIDAR Pulse Cubes
Height Truth Imagery
Top of net
Spreader
Humvee roof
Humvee hood
Humvee shadow
Time
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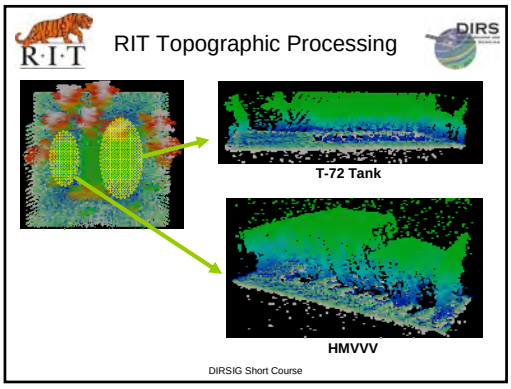
RIT Topographic Processing
T-72 Tank
HMVVV
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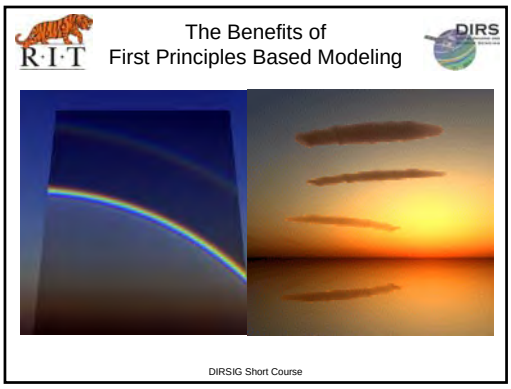
The Benefits of First Principles Based Modeling
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