Knowledge Aided Clutter Prediction And Comparison With Measured Data

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Outline

- Simulation Capabilities for Predictive Modeling
- Simulation Performance Verification
- Radar/Clutter Simulation and Modeling Capabilities
- Current Hardware Test Equipment and Facilities
- Future Development of SAR Laboratory
- Problems for Laboratory Investigation
- Problems for Investigation and Solution Development
- Evaluation of Clutter Mitigation Methods
- Knowledge Assisted Processing

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Simulation Capabilities for Predictive Modeling

- Raytheon Has Developed a High Fidelity Simulation Program to Predict the Performance of Pulse-Doppler and SAR Systems
- The Simulation Allows the User to Define the Important Platform and Sensor Parameters Through an Easy to Use Graphical Interface
- Internal Physical Models
  - Physical Optics Based Ray-Trace Algorithms
    - Polarization
    - Meteorological Effects
  - Detailed Facet Models
    - Vehicles (Tanks, Trucks, SAM Battery, Etc.)
    - Foliage (Trees, Shrubs, Grasses, Etc.)
    - People (Soldiers with Various Types of Equipment)
  - Clutter Calculations
    - DTED (Any Level)
    - DFAD (28 Surface Types)
    - Limited Set of Cultural Databases

Simulation Performance Verification

- MMW ISAR Measurements for a T72 Tank Target and MSTARS Model Data set
  - Model Differed from Actual Tank
    - Surface Details were Missing from Model (Tread Fenders, Small Protrusions)
    - Surface Material was Modeled as Perfect Conductor
  - Correlation Values of 50-70% Required for ATA/ATR
  - Significantly Better than Equivalent X-Patch Results
- Clutter Predictions
  - Compared Simulated Data to MIT/LL (Billingsly) Measurements for Cochrane, Alberta Canada
    - Tall Grass Features
    - DTED Level 1 Topographic
    - Fixed Radar Scans
  - Clutter σ_0 Mean and Probability Density Function Compared Favorably Between MIT/LL Measurements (Repeat Sector) and TKMOD

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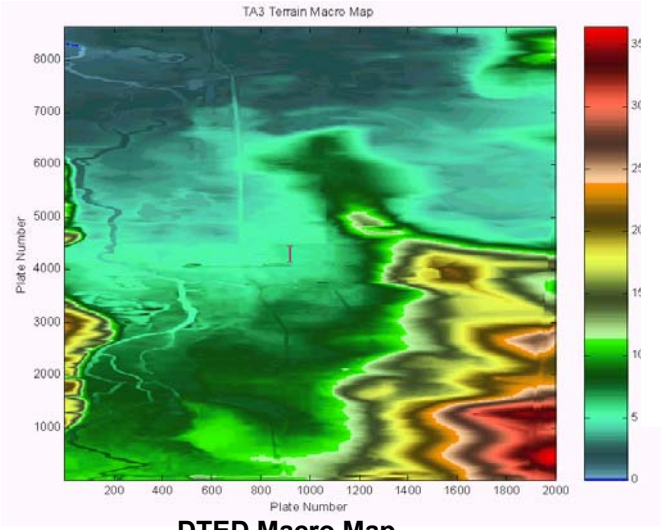
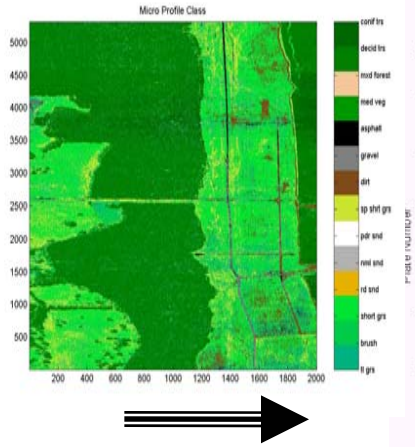
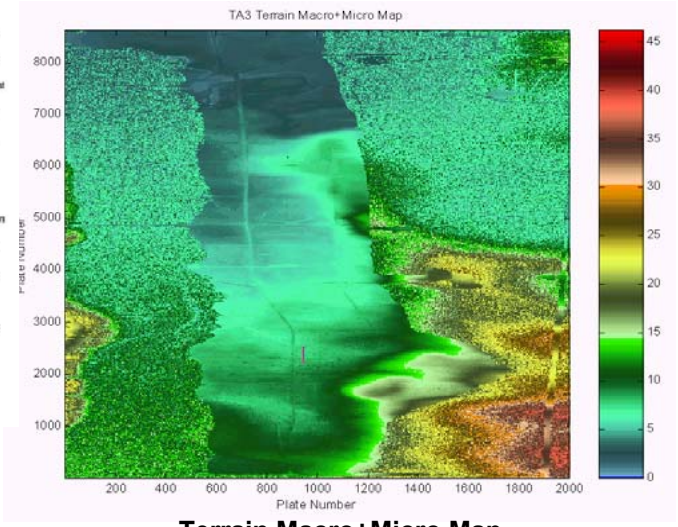
Simulation Clutter Model Generation Examples



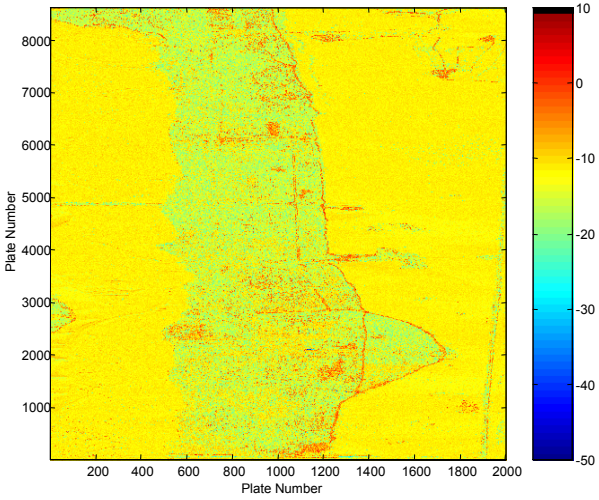
DTED Macro Map



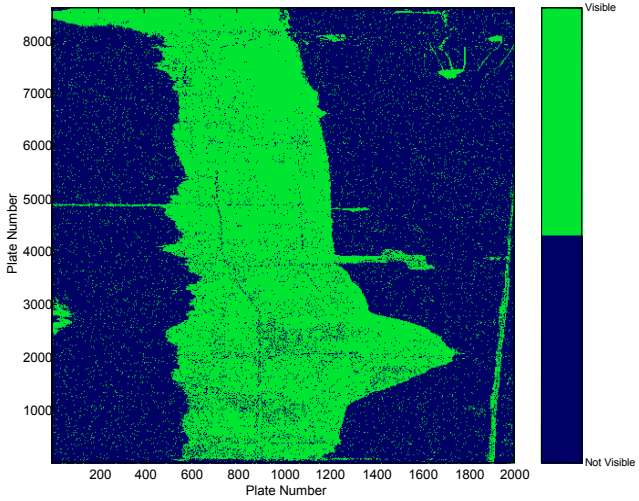
Micro Structures



Terrain Macro+Micro Map

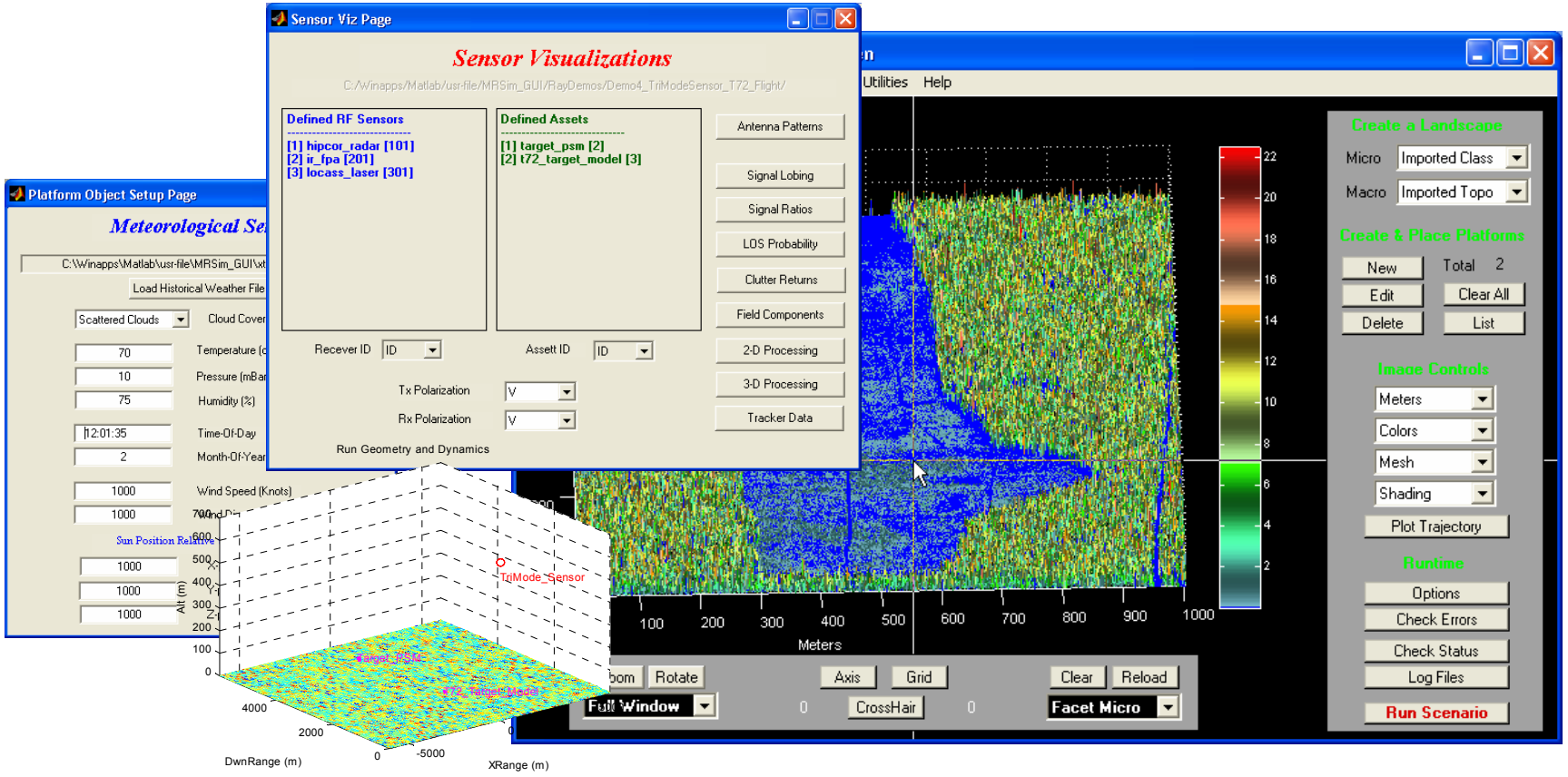


Computed Clutter Map



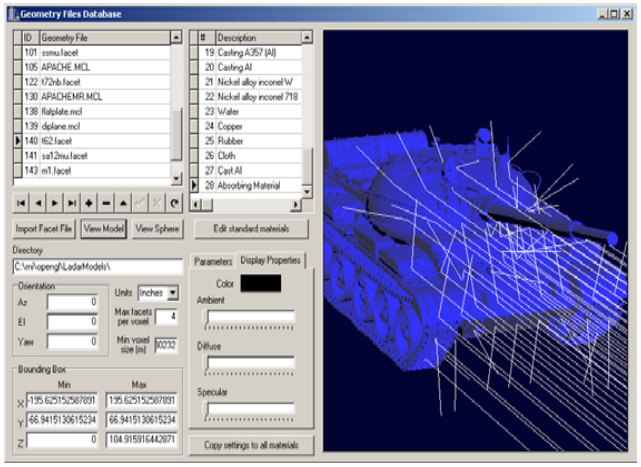
LOS Overlay Map

Radar/Clutter Simulation User Interface

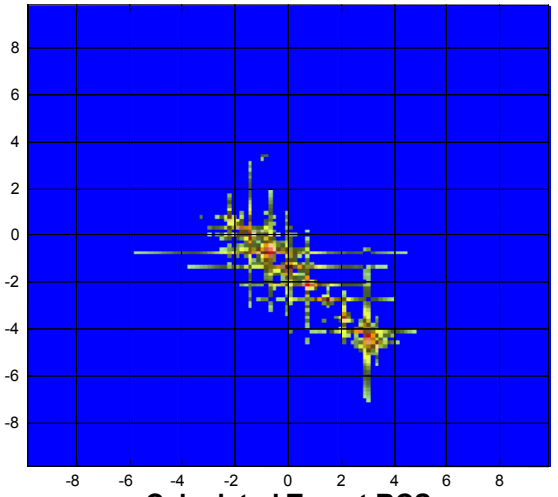


- **Provides Parameter Setups and Output Visualizations (Including In-Process)**
- **Includes a Number of Utilities for Data Visualization and Virtual Prototyping**

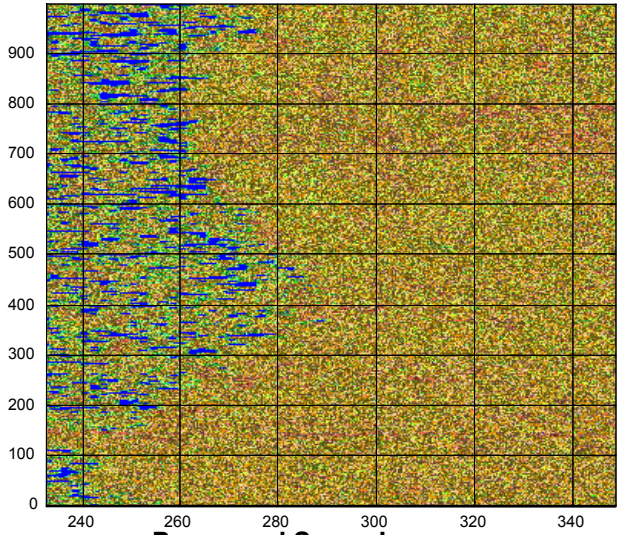
SAR Components: Target Selection & Scene Combination



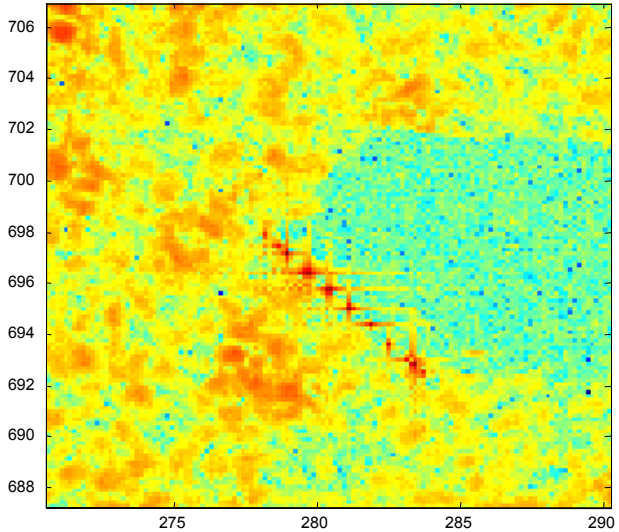
GUI Target Model Selection



Calculated Target RCS



Processed Scene Imagery



Combined Image, Target, and Additive Noise

Current Hardware Test Equipment and Facilities

- The Raytheon Tucson, AZ Site has Built a Rooftop SAR Rail Test and Development Facility
  - Located on a Building Adjacent to a Semi-Desert Area
    - Terrain Elevation Standard Deviation ~ 1m
    - Natural Vegetation: Mesquite, Cactus, Small Leafed Trees
    - Features Include Fences, Poles, Corner Reflectors, Nearby Highway
  - Sensor Motion
    - Produced by Wheeled Motor Assembly on Permanently Attached Rail Track
    - Position, Orientation, and Velocity are Monitored and Recorded
  - Radar is a Ka-Band Monopulse T/R Module
- SAR Observation Ground Patch
  - Primary Site is Located 300m from Radar System
  - Effective Patch Area is Approximately 40m x 40m
  - Small SAR Image Cell Area

Laboratory Advantages: Repeatability, Reproducibility, Cost, Time

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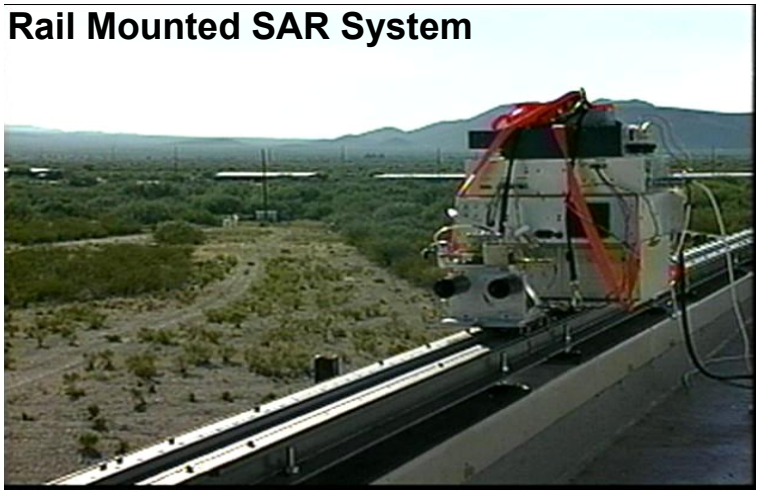
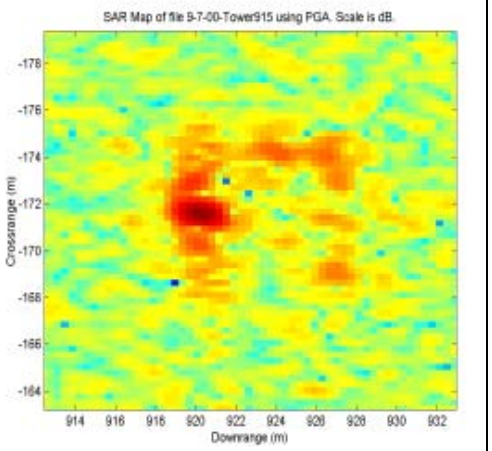
Rooftop SAR Facility and Sample SAR Images

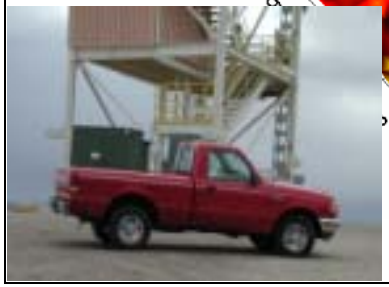
Rail Mounted SAR System

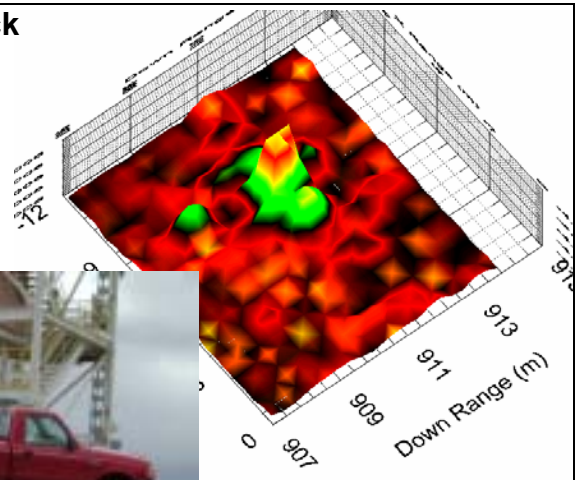


RF Tower

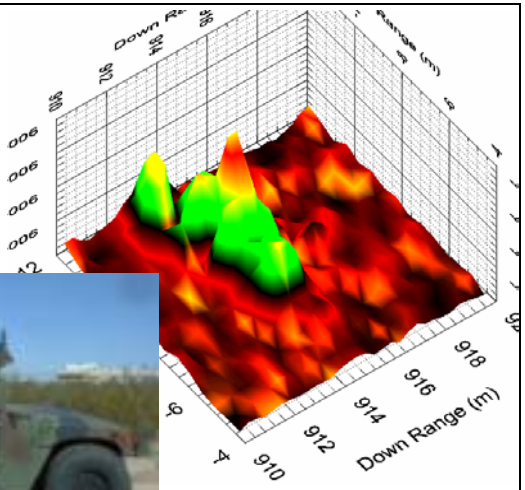


Small Truck





HumVee



Future Development of SAR Laboratory

- Verify Radar/Clutter Simulation Results
  - Initially with Very Accurate Survey Data
  - Comparisons of Results with DTED and DFAD Only Information
  - Measurements Performed in Various Non-Uniform Terrain Areas
- Move The Current Instrumentation to Nearby Mountain Sites Overlooking Regions of Rugged Terrain
- Develop of Next Generation Test Systems
  - Other Frequency Bands
  - Different Types of Transmitter/Receiver Equipment
    - Multichannel Receiver Arrays
    - DPCA / ADPCA
    - Along-Track Interferometric SAR
  - Improved Sensor Platforms

Problems for Laboratory Investigation

- Comparisons of Measured and Modeled Target / Clutter Signals
  - Determine Differences Under Controlled Repeatable Conditions
  - Evaluate Reasons for Significant Differences
  - Verify and Improve Radar/Clutter Simulation Models
- Investigate Hardware/Software Tradeoffs
  - Improved Measurement Accuracy:
    - Transmitter and Receiver Stability
    - Kinematics Determination Using Differential GPS/INS
  - Adaptive Signal Processing Methods for Error Estimation and Reduction

Evaluation of Clutter Mitigation Methods

- Waveforms
  - Multiple Resolution
  - Target Adaptive
  - Time Reversal Focusing
  - Radar Signal Precursors
- Raytheon Developed Adaptive DPCA Processing
  - Model Calculations Predict Clutter Cancellation Reduction
  - Limited Test Results Have Demonstrated Predicted Clutter Cancellation
- Along-Track Interferometry for Direct Velocity Measurements
- Coherent Change Difference of Sequential SAR Images
- Polarization Variations
  - Circular
  - Dual Linear Polarization (HH, VV, HV)

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Knowledge Assisted Processing

- Using DTED Only:
  - Improved Accuracy for SAR Image to Geographical Map Transformations
  - Identification of Shadow Regions
  - A Priori Motion Probability Maps to Aid Detection and Tracking
    - Identification of Open Continuous Regions that can be Used for Roads
    - Identification of Areas Containing Rugged Terrain Unlikely to Contain Movers
- Using the Clutter Simulation with DTED, DFAD, Cultural, and Meteorological Databases
  - Intelligent Secondary Covariance Matrix Sample Selection
  - Deterministic Nulling of Discrete Clutter
- Quantify Performance Improvement for Different Scenario Conditions
  - Terrain
  - Urban / Rural Locations
  - Meteorological