



Combining High Dynamic Range Photography and High Range Resolution RADAR for Pre-discharge Threat Cues

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Project Objective:

- The objective of this project is to develop a joint high dynamic range photography and high range resolution RADAR system on mobile platforms to provide pre-discharge threat warning in urban and mountain environments.



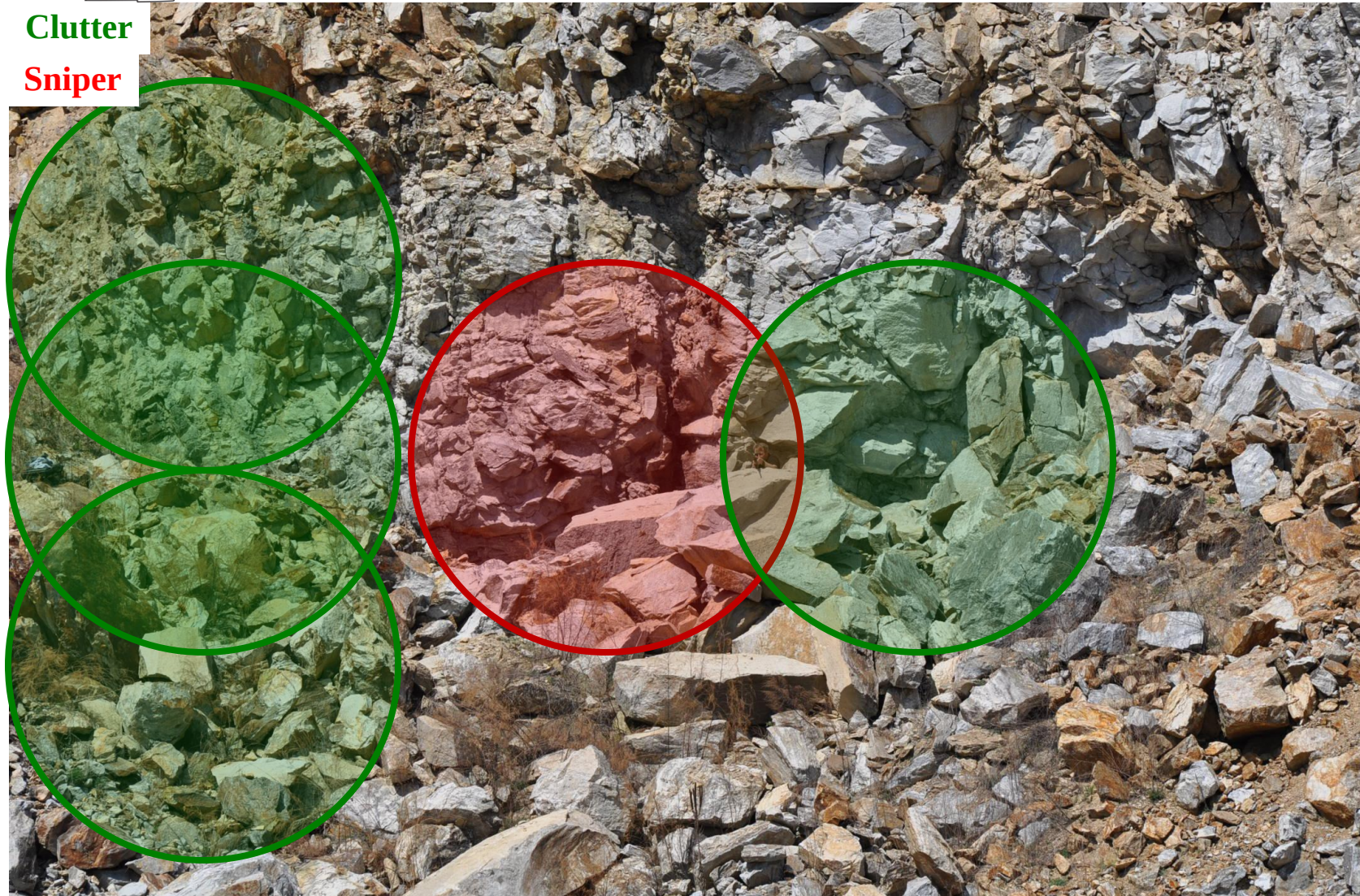
Approach:

- Expand upon the sensor and processing concepts of MTRI Counter RPG and Counter Sniper programs.
 - The expansion of the system will be in the areas of
 - rural, mountainous terrain and threats
 - incorporating cued high dynamic range imagery to the warfighter.
 - Clutter rejection and target detection algorithm variants will be developed
 - develop a parallel aperture high dynamic range optical system along with its attendant signal processing
 - provide confirmatory images of the threat as cued by the RADAR.
 - high dynamic range optical system will be cued by the RADAR in operation
 - Deploy our instrumentation RADAR and optical system at mountainous sites for empirical collections to verify performance
 - Provide a near real-time demonstration of the system.

Optical Difficulty: Find the Shooter



Radar Locates Potential Threat



* Chart is Animated in Slide Show Mode

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Shooter is Located



Impacts of Mountain/Rural Clutter

- Moving from “Sniper in Building” to “Sniper in Mountainous Terrain” – significant differences

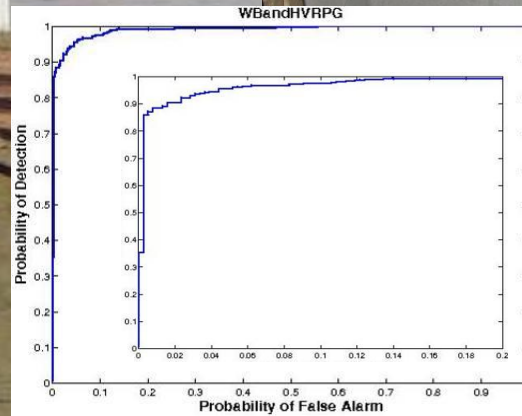
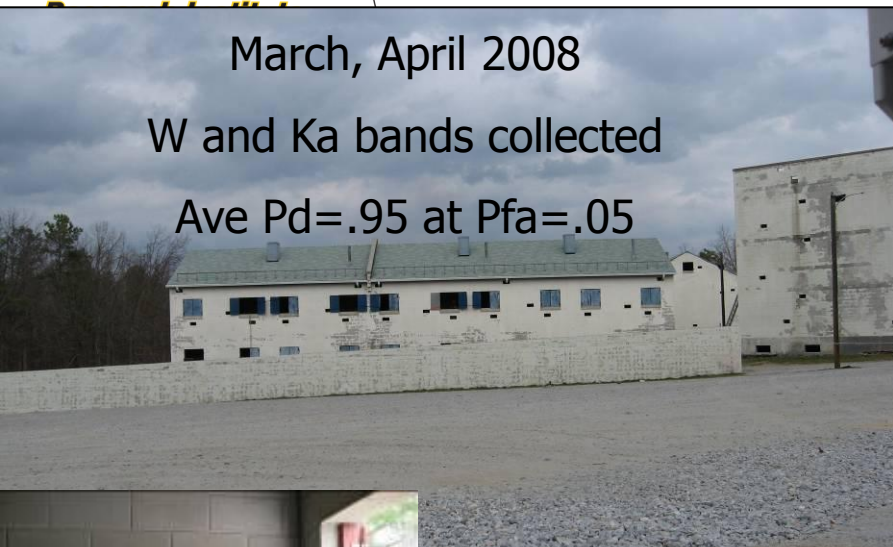
Urban	Mountainous
Bright and more localized discretes	Diffuse and distributed scatters
Fast changes in spatial clutter	Slow to moderate changes in spatial clutter
Predominance of flat surfaces (walls/furniture)	Distribution of rocks and vegetation
More control of incident angles	Wide variety of incident angles
Clutter = combination of several discretes	Clutter = variety of distribution of scatterers (moderate to heavy-tailed)
Polarimetric – known distinct differences between targets/clutter	Polarimetric – expect differences but less distinct between targets/clutter
Weapon variety – mod variability	Weapon variety – more variable
Focused Scan Area (windows, roofs, edges of buildings)	Larger Scan Area (more possible locations)

Ft. Pickett Collection Campaign

March, April 2008

W and Ka bands collected

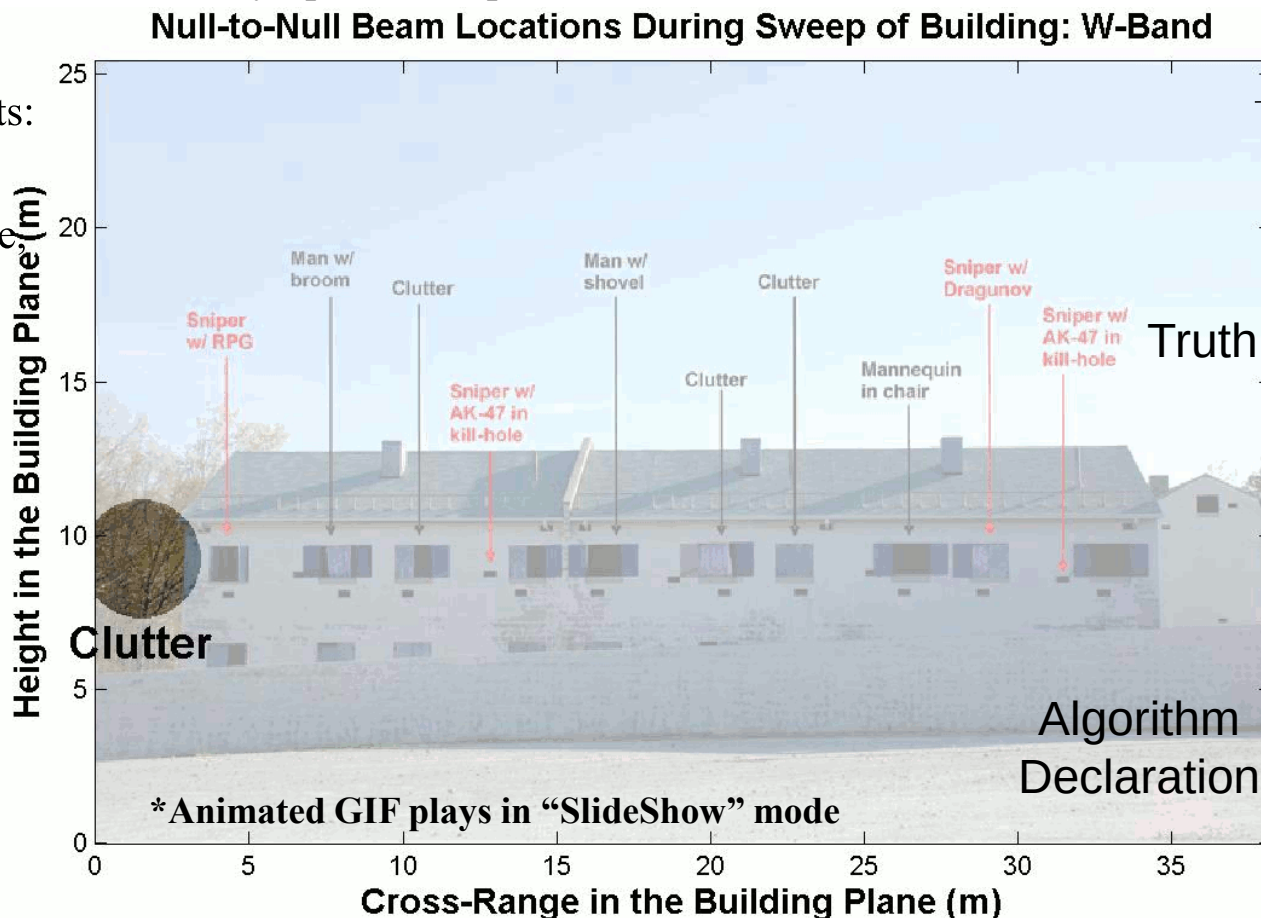
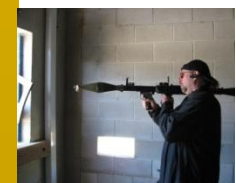
Ave Pd=.95 at Pfa=.05



Blind Test Results Show Detectable Signatures in Clutter

- Radar scanned across building with blind target deployment
 - Complex clutter in room including holes in walls, steel furniture and large wooden ladder
 - Deployed behind fully open, half open windows and “kill hole”
- System

- Real Threats:
AK-47,
Dragonov
Sniper Rifle
RPG-7



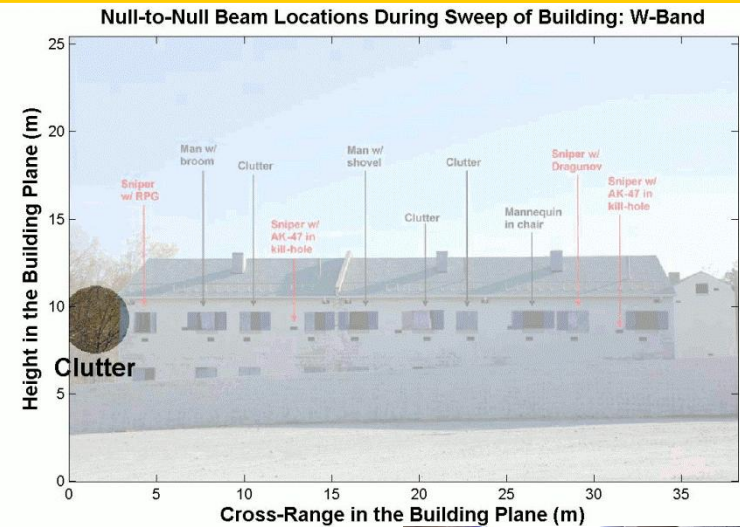
False Threats:

- Broom
- Shovel
- Ladder



RADAR Demonstration Structure

- Scan set #1
 - False alarm testing
 - Scan #1: building with confuser targets
 - Empty rooms, people, people with implements
 - » Positioning of people determined on site with government
 - Scan #2: completely empty building, shutters open
 - Scan #3: empty building with shutters closed
- Inspection of processing results
- Scan set #2
 - Detection testing
 - 3 Scans
 - 4 Weapons
 - RPG-7, Dragunov, AK-47, AR-10
 - Positioning of target determined on site with government
 - Confusers added as resources permit



Demo April 2010

Detection Results – tp9042

Scenario

Munitions

- Dragunov
- AK47
- RPG
- AR10

Confusers

- Person with Tripod
- Person with Broom

Results

- Dragunov, AK47, RPG, and AR10 detected as weapons
- Person+Tripod declared as clutter
- Person+Broom declared as clutter

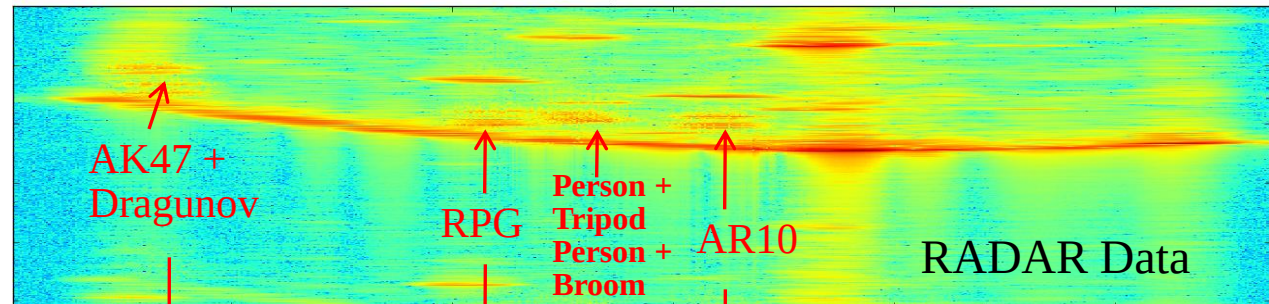
Notes

- AK47 and Dragunov in same room



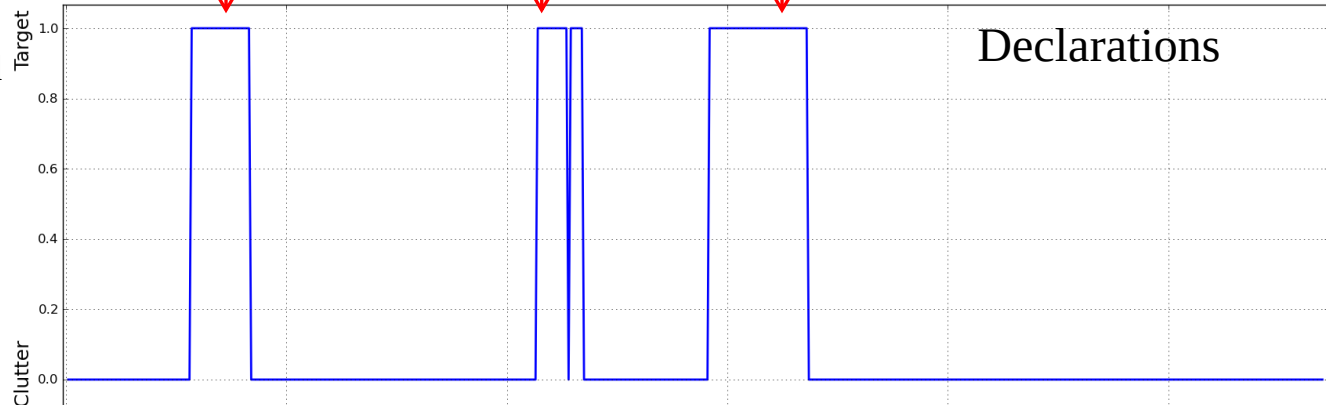
tp9042

Range ↑



Sweep Number →

Target
Clutter



Sweep Number →

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Summary: Algorithm Declarations

	Window 1	Window 2	Window 3	Window 4	Window 5	Window 6	Window 7	Window 8	Window 9	Window 10
Clutter Test, Windows Open										
Clutter Test, Windows Open	Person		Person		Person				Person	Person
Clutter Test, Windows Closed										
Detect Test 1		Dragunov			RPG	Person + Tripod	AK47			AR10
Detect Test 2		RPG			Person + Tripod	AK47	AR10			Dragunov
Detect Test 3	AK47 + Dragunov			RPG	Person+ Tripod Person+ Broom	AR10				

Detection

**Missed Detection/
Outside Search Area**

False Alarm

Confuser

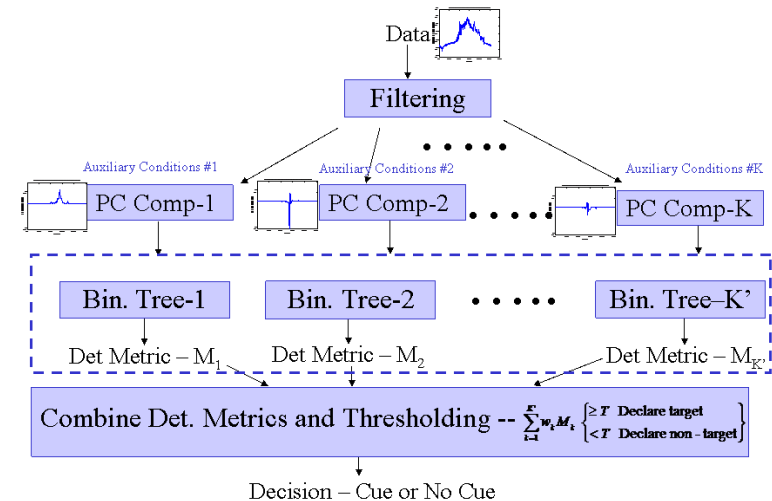
Correct Declaration

Incorrect Declaration

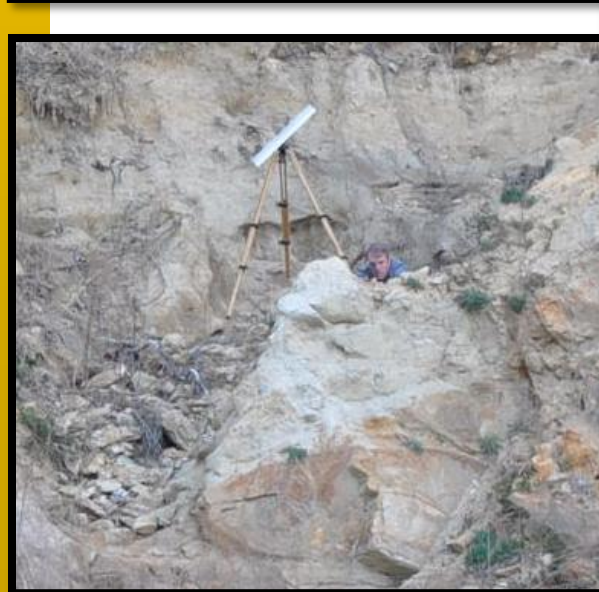
- ❖ All weapons within search range of system were detected
- ❖ No false alarms
- ❖ Automated algorithm used 4 minutes for declarations (non-real time code)

Nonparametric Boosting Classification: Discrimination of Output Cues

- Nonparametric boosting-based rule ensembles
 - Flexible to new operating conditions
 - Doesn't assume Gaussianity
 - Needs relatively moderate amounts training data
 - Robust to over fitting
 - Computationally efficient
 - Approximately optimal (Bayesian Neyman-Pearson Detector)



Mountainous Surrogate: Quarry at Ft. Pickett, VA



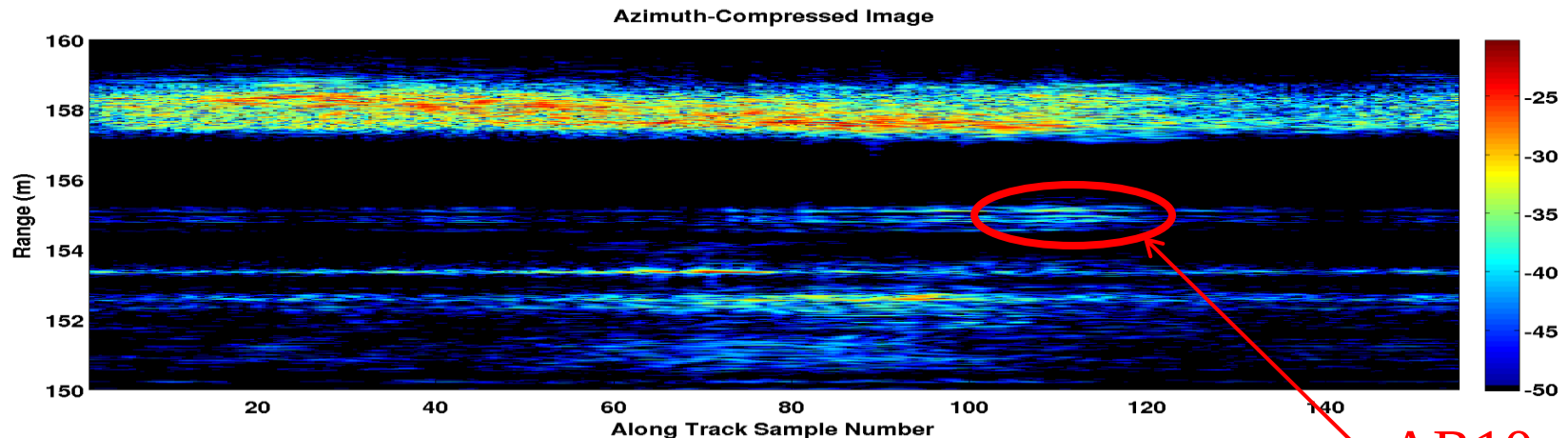
Mountainous Surrogate: Ft. Pickett, VA





Algorithm Declaration After SAR Processing

- Algorithm searched for target over all ranges
- Azimuth compression eliminates false alarm (clutter is localized in azimuth)



AR10

AR10 Metric 3 of 5 Voting AR10PtCompAllRanges

AR10 Declaration

Clutter Declaration

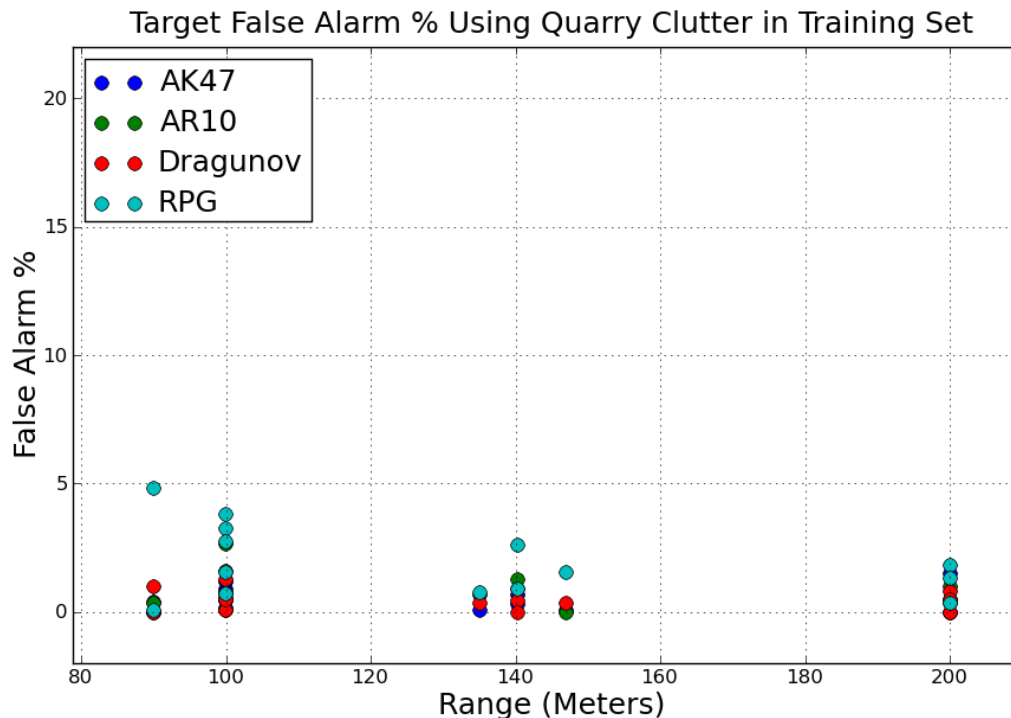
Sweep Number

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Quarry Clutter Scans Processed Using Training Sets

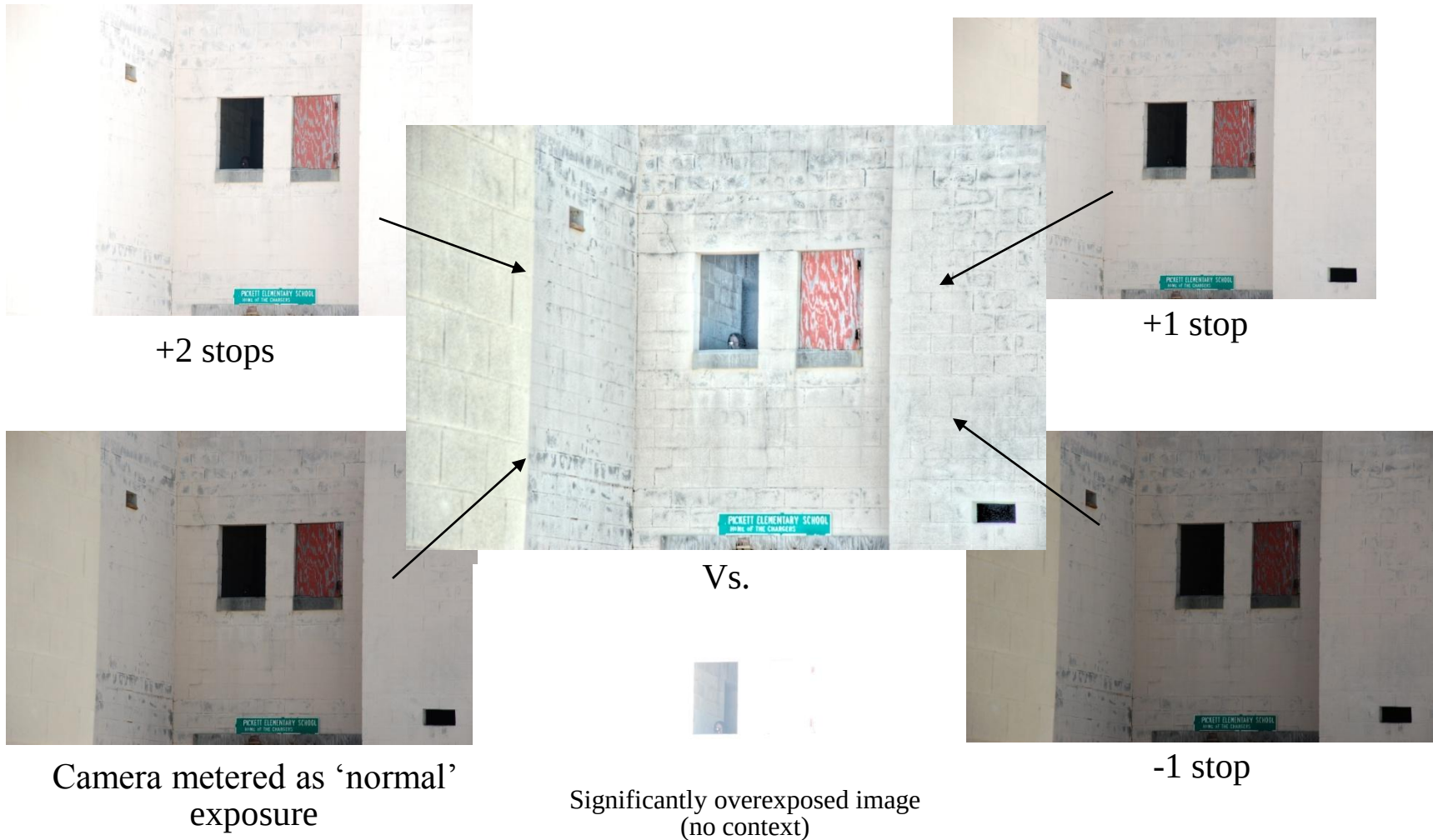
- Training sets created from urban target and quarry clutter
 - Training sets are HV, so testing sets are also HV
- Test data was quarry clutter scans



- Expectation that false alarms would decrease with better clutter match was verified

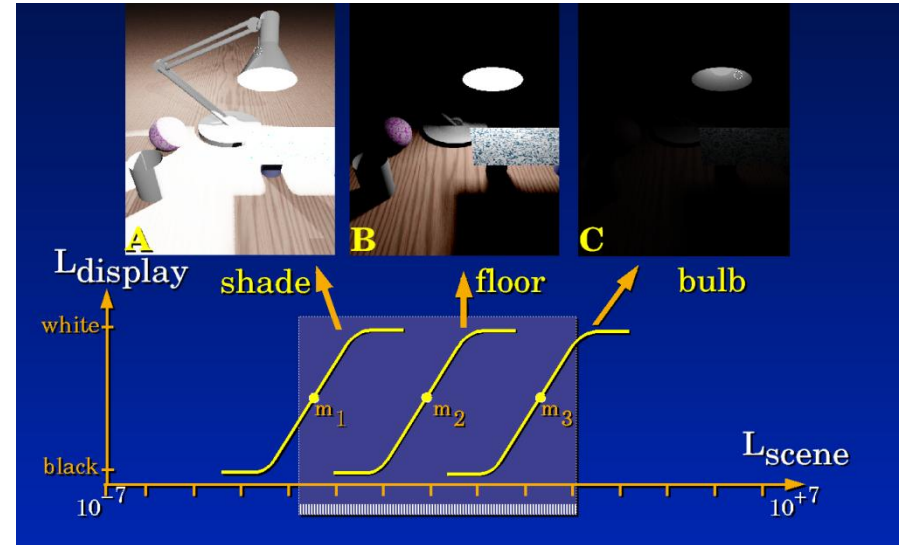
High Dynamic Range Photography

Combination of 4 moderately exposed images



High Dynamic Range Photography

- Linear Combination of over/under exposed images to increase dynamic range
 - Maximum likelihood
- Tone mapping optimally maps high dynamic range data onto display
 - Local operator using the zone method (local dodging and burning)



$$L_d(x, y) = \frac{L(x, y)}{1 + V(x, y; s)}$$

$V(x, y, s)$ - local average over scale s

HDR System



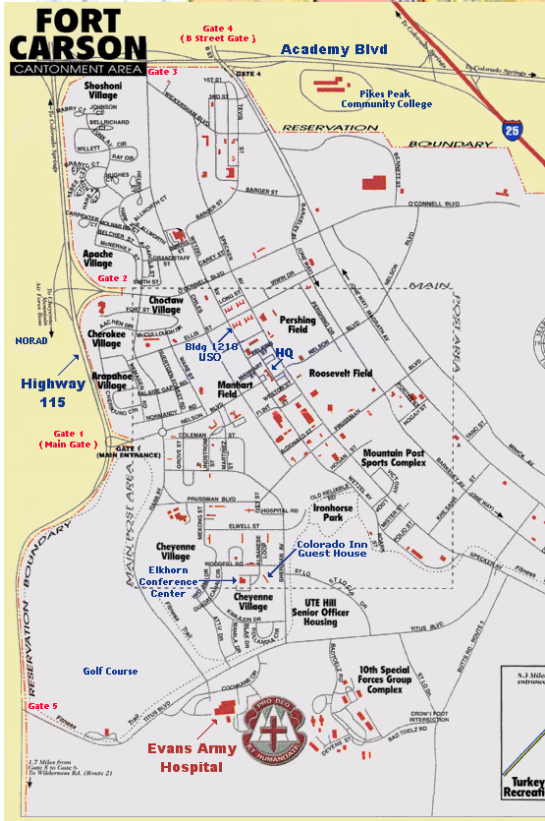
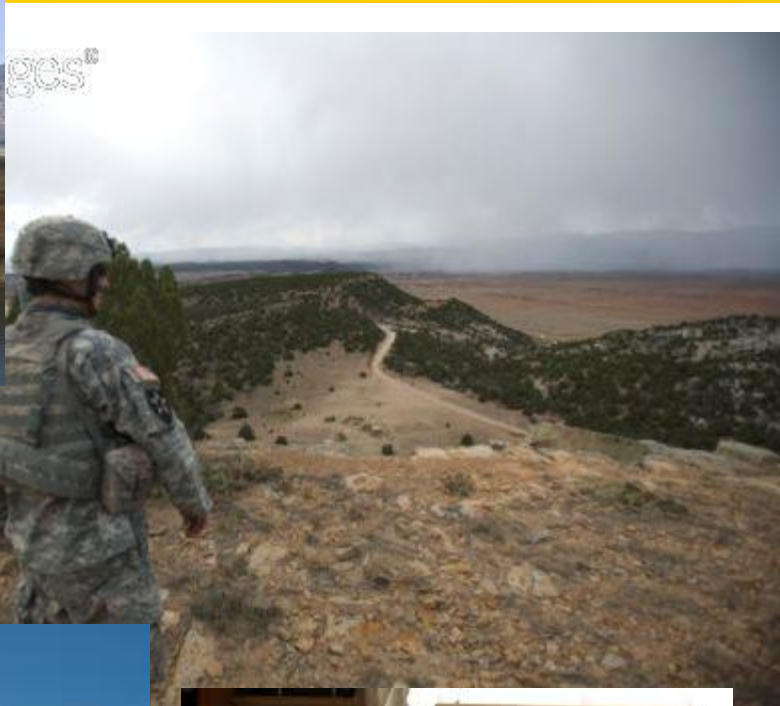
Local Mapping Example



Fattal (2002) – Localized gradient based method
[1 alpha, .8 beta, 1 saturation, no noise reduction]



Mountainous Site: Ft. Carson, CO

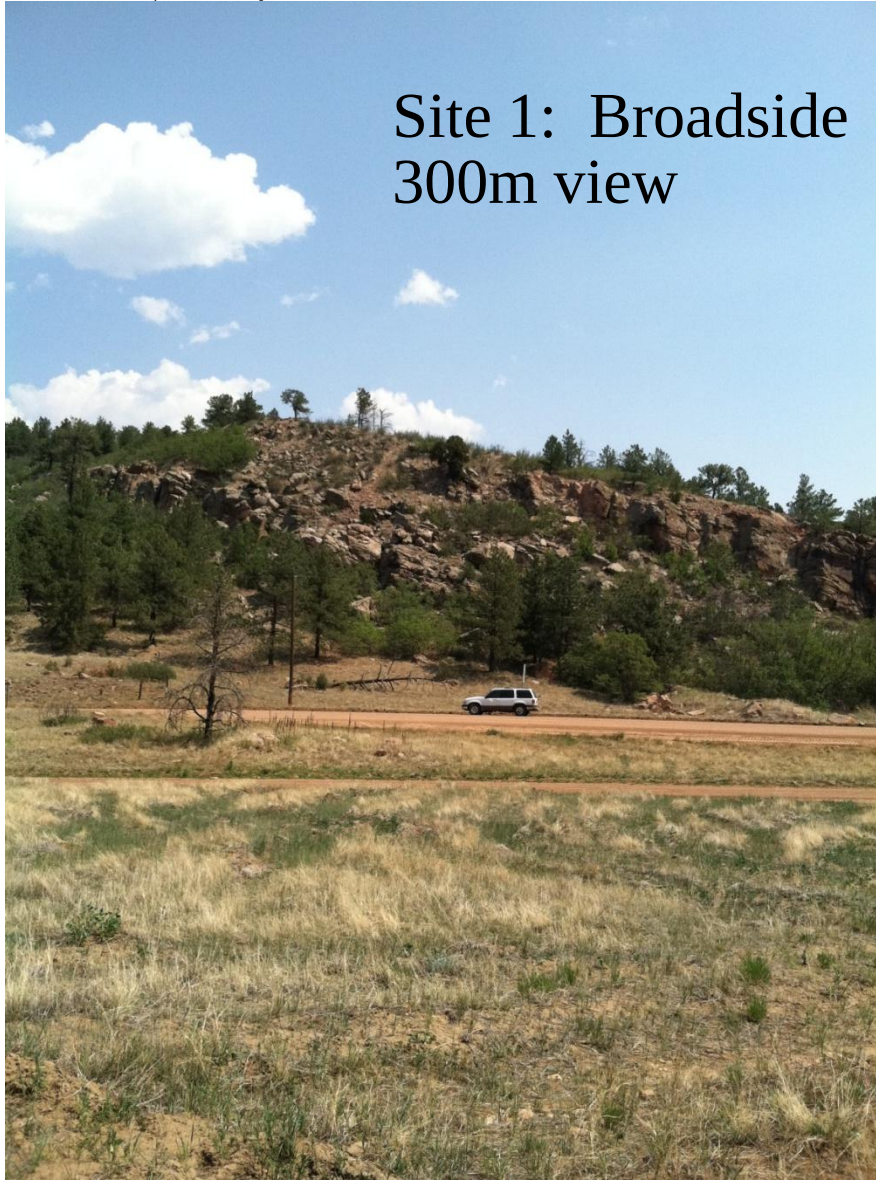


**Fort Carson
and
Evans U.S. Army Hospital**

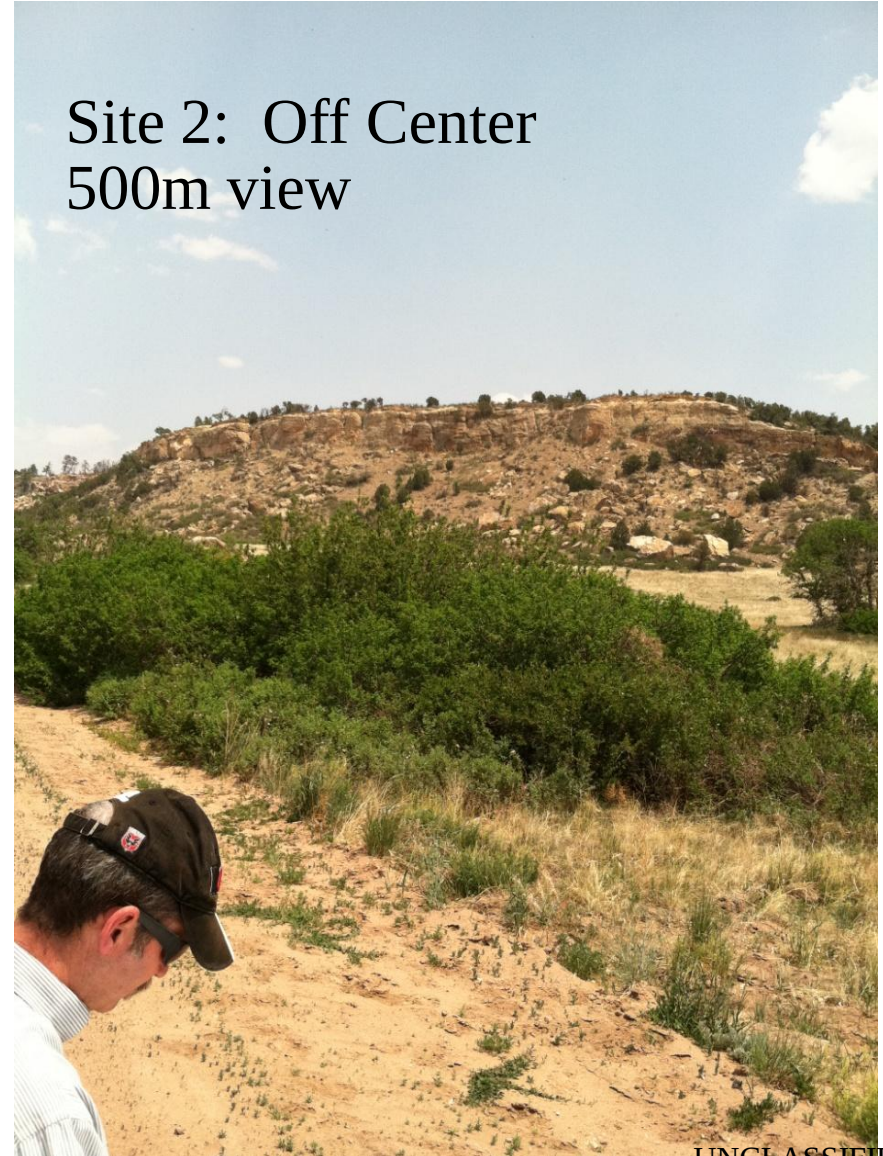


Ft. Carson Site 1

Site 1: Broadside
300m view



Site 2: Off Center
500m view





Summary

- Initial results from Ft. Pickett are very promising
 - With minimal training on new data, detection/FA results are quite good
 - $P_d=1$, $P_{fa}<5\%$
- Including EO imagery provides actionable imagery to commander
 - RF provides cues
 - HDR alleviates shadowing while maintaining context
- Ft. Carson campaign to commence in early August
 - Much larger data set
 - True mountainous terrain
 - Using both EO and Radar in the collection

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