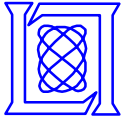


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Potential Payoff of Fusion Between HSI and Other Sensors

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MIT Lincoln Laboratory

19th Space Control Conference

MIT Lincoln Laboratory

4 April 2001

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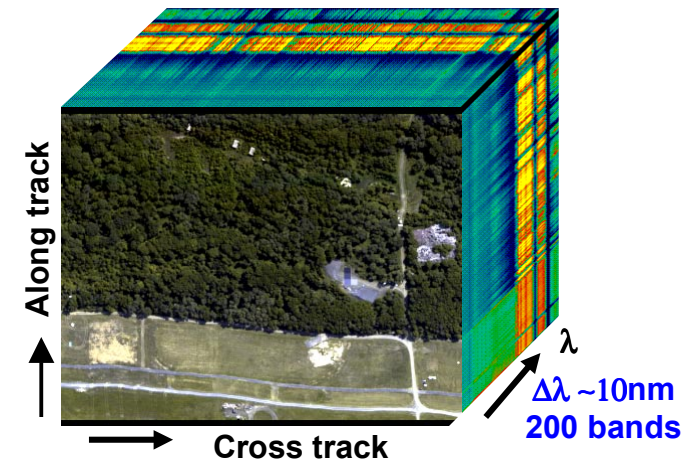
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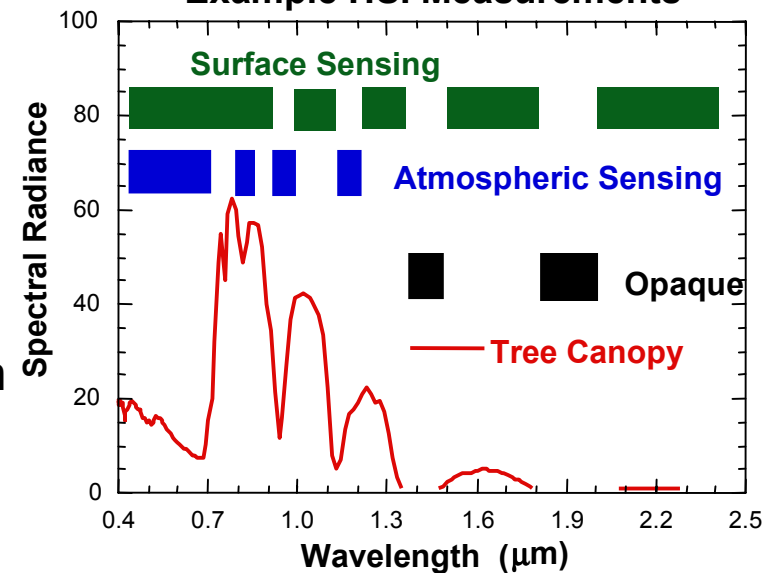
Hyperspectral Imaging (HSI)

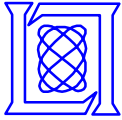
- High dimensionality data
 - High spatial resolution EO imagery
 - Hundreds of co-registered, contiguous, narrow spectral channels ($\lambda/\Delta\lambda \sim 100$)
 - 0.4 to 2.5 μm systems exist, 3 to 12 μm emerging
- Diverse applications
 - Atmospheric characterization
 - Terrain delimitation
 - Target detection
 - Material identification
 - Spatially unresolved object detection

Sample HSI Data Cube



Example HSI Measurements



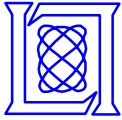


Motivation

- **Combined sensing of HSI with others offers potential for greater payoff**
- **Examples:**
 - **HSI and SAR**

Complementary roles result in surface penetration, false alarm reduction and target identification enhancement
 - **HSI and Panchromatic Imagery**

Enhanced spatial and spectral information for improved background delimitation and better target characterization/identification



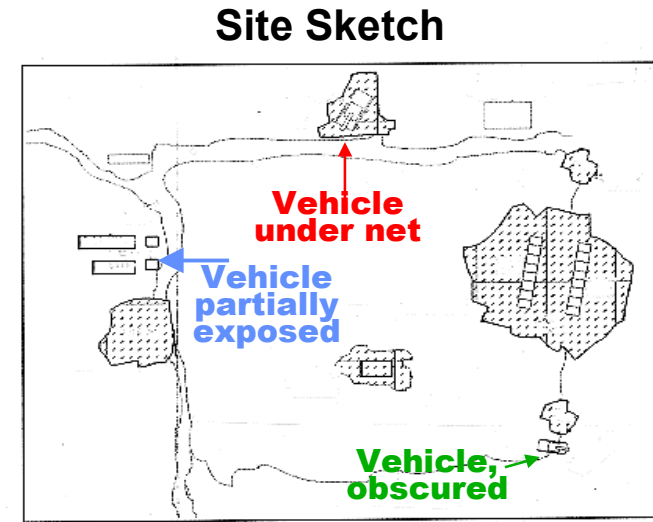
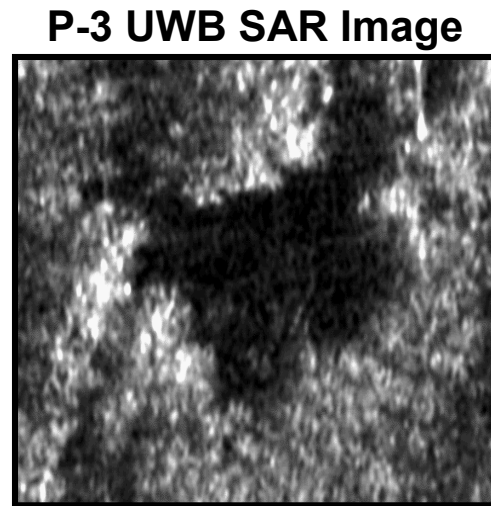
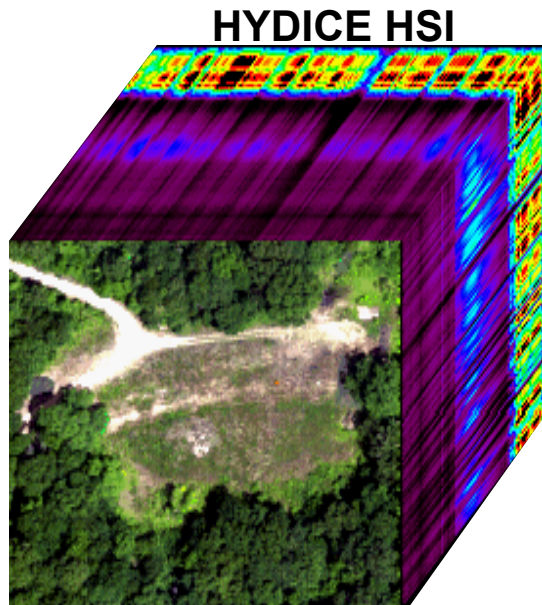
Outline

- **Overview**
 - Objectives
 - Fusion applications
- **Fusion examples**
 - **SAR/HSI**
Explore different phenomenologies
 - **HSI/HPI**
Utilize superior respective spectral and spatial resolutions
- **Summary**

HSI: Hyperspectral Imaging
SAR: Synthetic Aperture Radar
HPI: High-resolution Panchromatic Imaging



HSI/SAR Fusion Example: Dixie-97 Data Collection, 28 May 1997



	HYDICE $0.4 < \lambda < 2.5 \mu\text{m}$	P-3 200 – 700 MHz
Viewing geometry	Nadir viewing	Depression angle $\sim 30^\circ$
GSD	0.76m x 1.1m	0.23m x 0.4m (resampled)

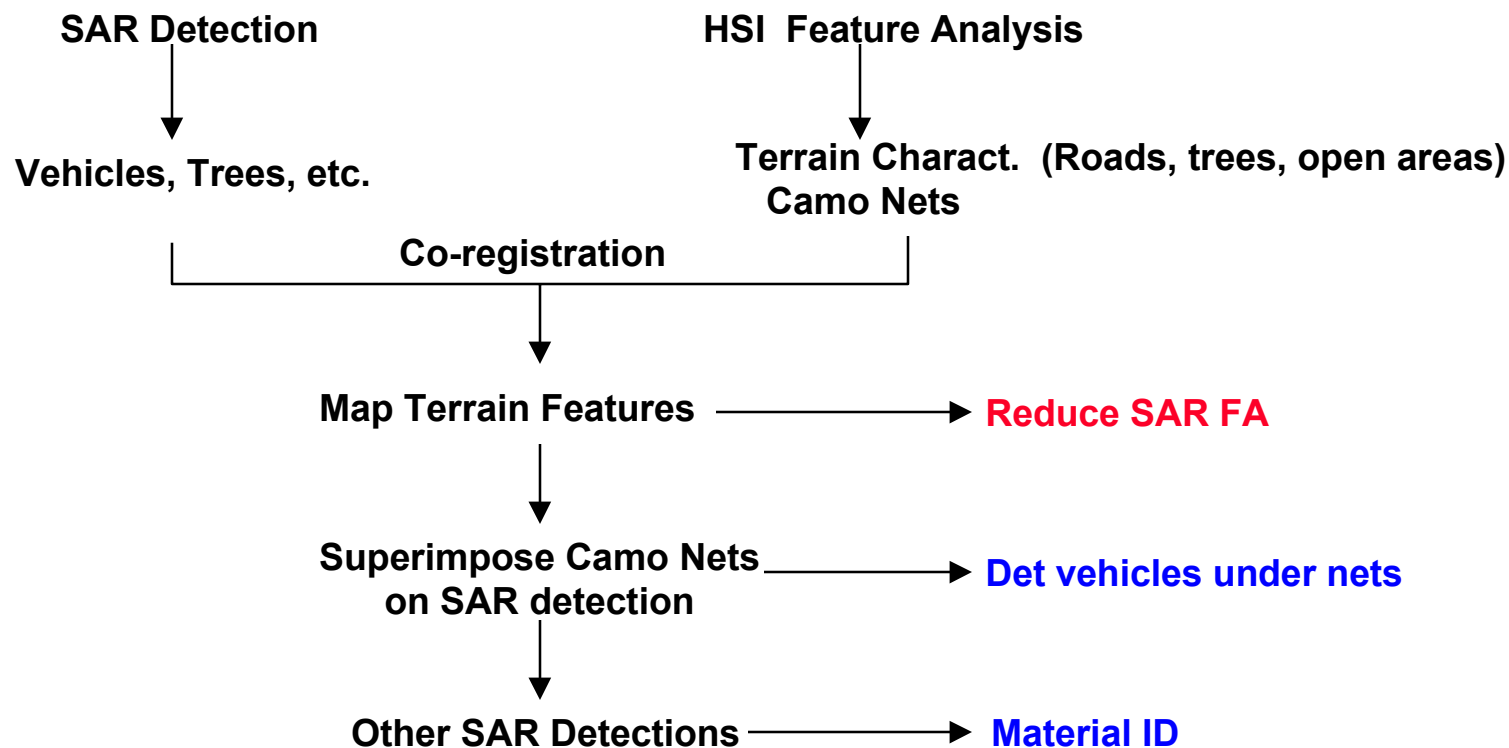
- Forest, roads, open area backgrounds
- Fabric nets, exposed and concealed vehicles
- Overlapping coverage for HSI and SAR fusion



SAR/HSI Detection Comparison and Sample ID Fusion Approach

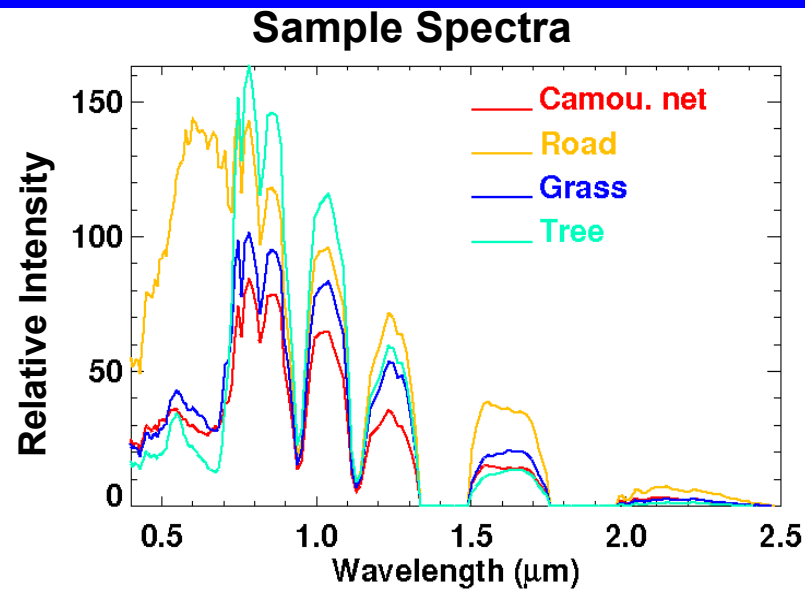
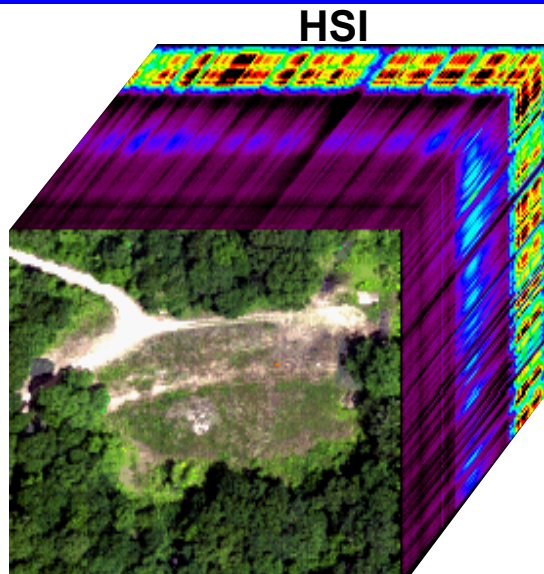
	Trees	Grass	Roads	Camo Nets	Vehicles
UHF SAR	FA	Low Signal	Low Signal	No Det	Det
HSI	ID	ID	ID	Det in open	Det in open

FA = False Alarm
ID = Identification
Det = Detection

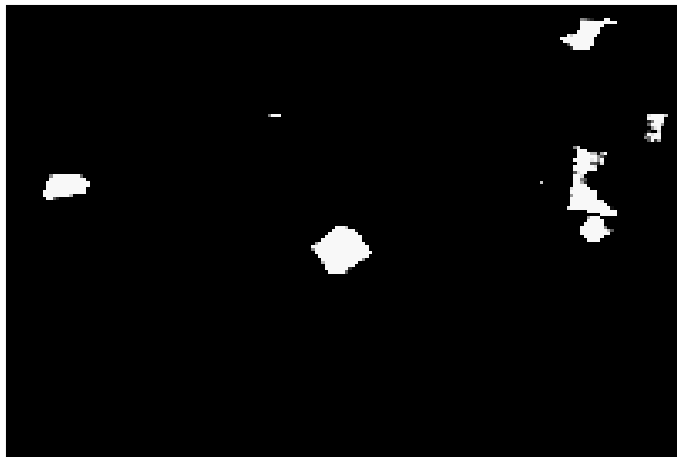




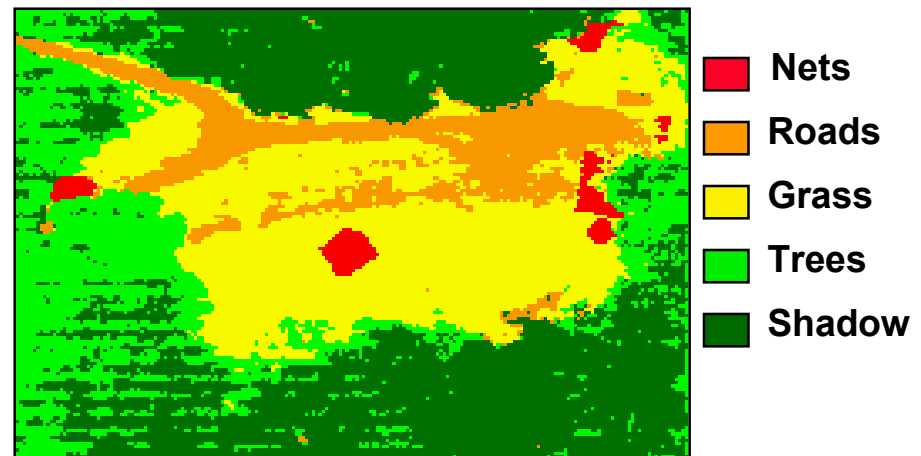
HSI Analysis Results



Net detection



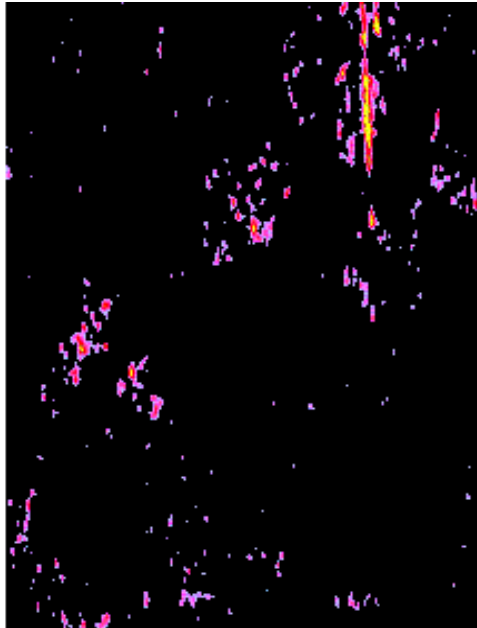
Background characterization





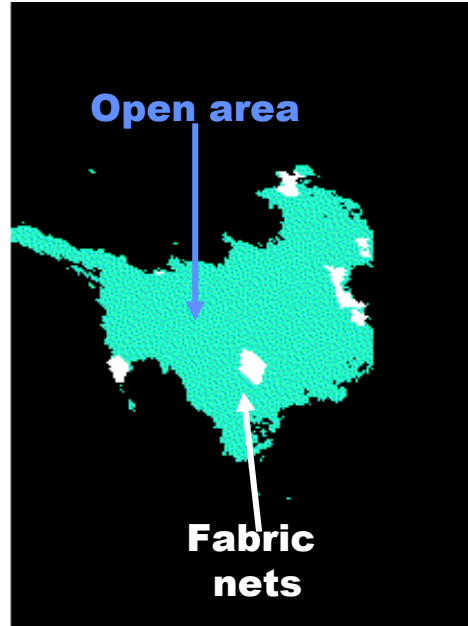
Fusion of SAR/HSI Detections

P-3 UHF SAR
6 dBsm Thresholded

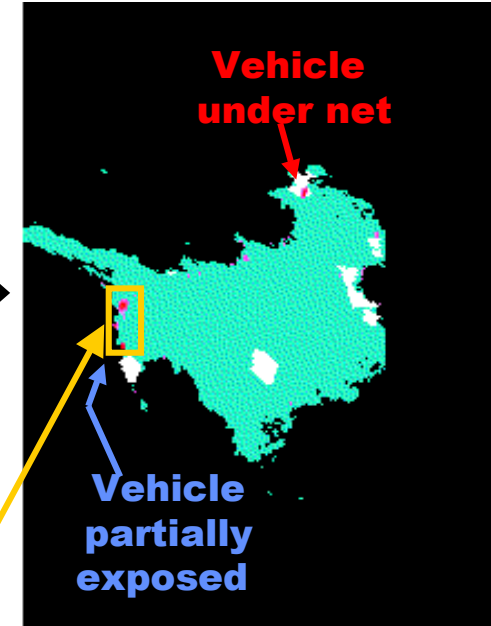


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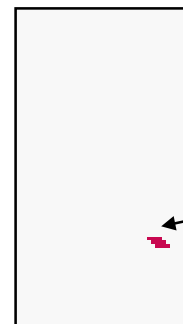
HYDICE HSI
Open area/Fabric net
Detection



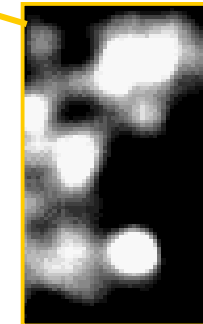
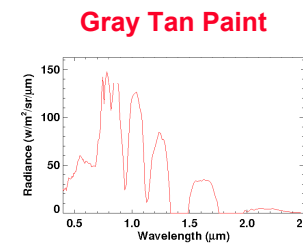
Combined SAR/HSI Data
Vehicle under Net
Identified



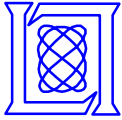
**SAR detection
confirmed and
material identified
using HSI**



HSI Chip



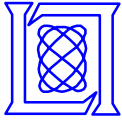
SAR Chip



SAR/HSI Fusion Summary

- **Common data set identified**
 - Dixie-97 with forest background
 - Fabric nets, vehicles, vehicle under fabric net
- **HSI data detected fabric nets not seen by SAR**
 - Terrain characterization also established
- **SAR/HSI image co-registration accomplished**
- **Fusion of SAR/HSI data results in:**
 - Detection of vehicle under net
 - Reduction of SAR false alarms
 - Confirmation of SAR detection and material identification

➡ Complementary roles between HSI and SAR illustrated



Outline

- Overview
 - Objectives
 - Fusion applications
- Fusion examples
 - SAR/HSI
 - **HSI/HPI**
 - Enhanced spatial-spectral analysis**
- Summary

HSI: Hyperspectral Imaging
SAR: Synthetic Aperture Radar
HPI: High-resolution Panchromatic Imaging



Motivation for Fusion of HSI and Panchromatic Imagery

- HSI and high resolution EO sensors often co-exist in measurement platforms (Space, A/C, and UAV)
- Spatial resolution for Pan typically 3-8 times better than HSI

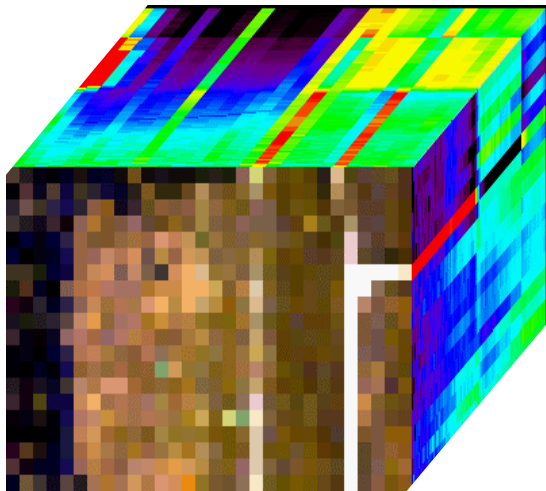
Example Space Platforms

Satellite	EO-1 (NASA)	Warfighter-1 (Air Force)	NEMO (Navy)
HSI Spectral	0.4 - 2.5 μm 220 bands	0.4 - 2.5 μm 200 bands	0.4 - 2.5 μm 210 bands
Scene Size	7.5 km x 100 km	5 km x 20 km	30 km x 200 km
HSI IFOV	30 m	8 m	30 m
Co-incident Pan (Visible band)	10 m	1 m	5 m



Fusion of Hyperspectral and High Resolution Panchromatic Images

Hyperspectral Image Cube
8 m resolution



(HSI)

Panchromatic Image
0.8 m resolution

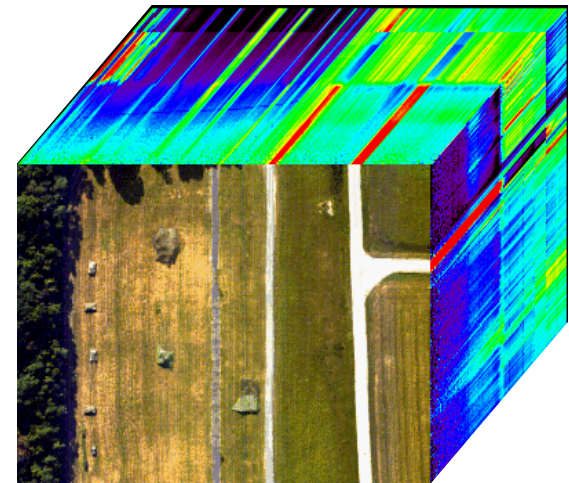


(HPI)

+



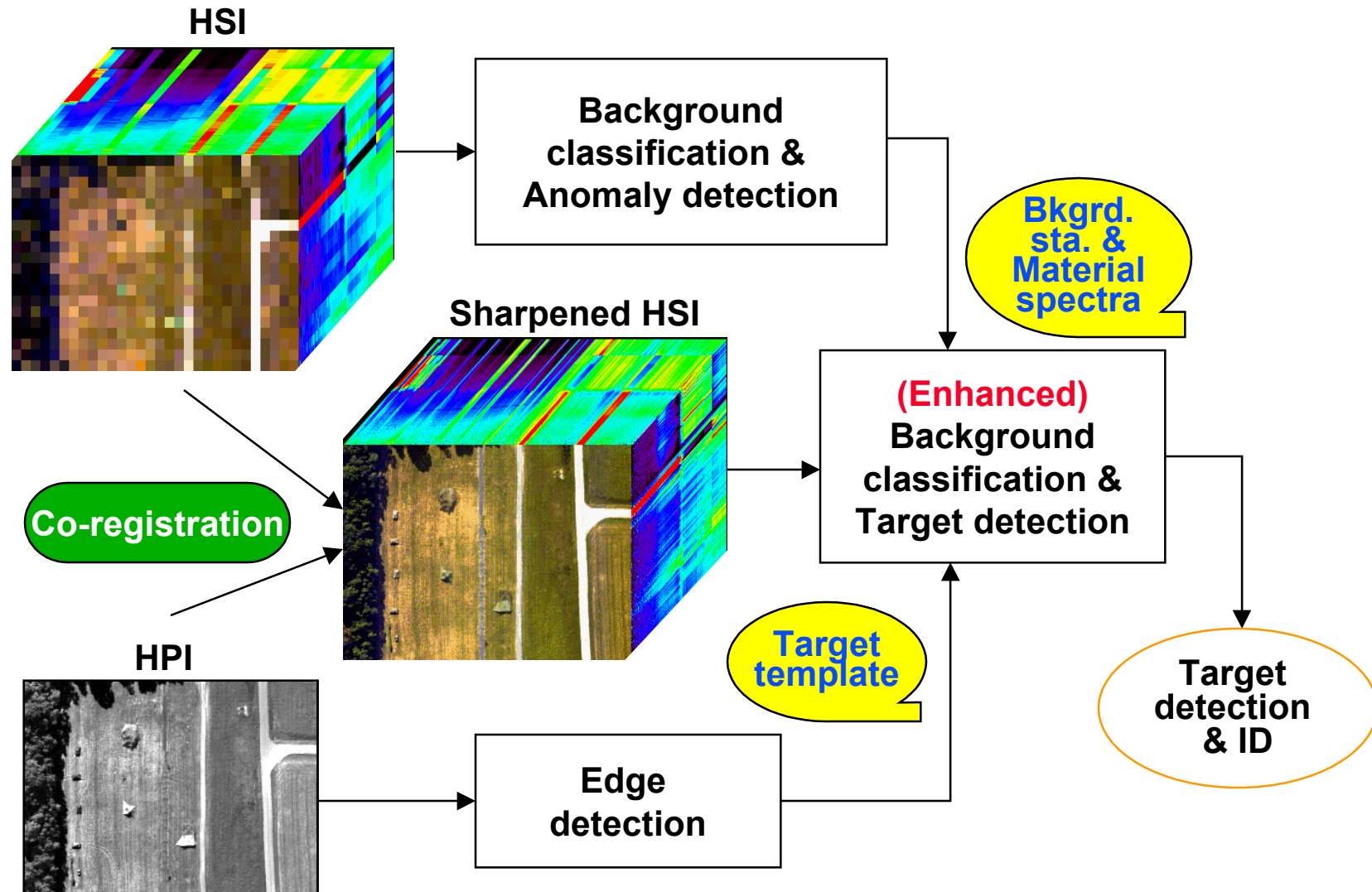
Reconstructed HSI
0.8 m resolution



- Combined spatial and spectral information from high resolution data for enhanced background characterization and target detection / identification



Spatial and Spectral Analysis Approach



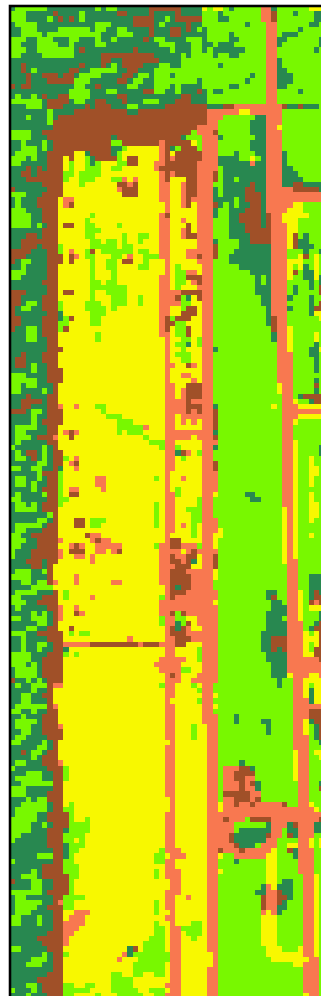


Background Classification and Anomaly Detection on HSI

RGB

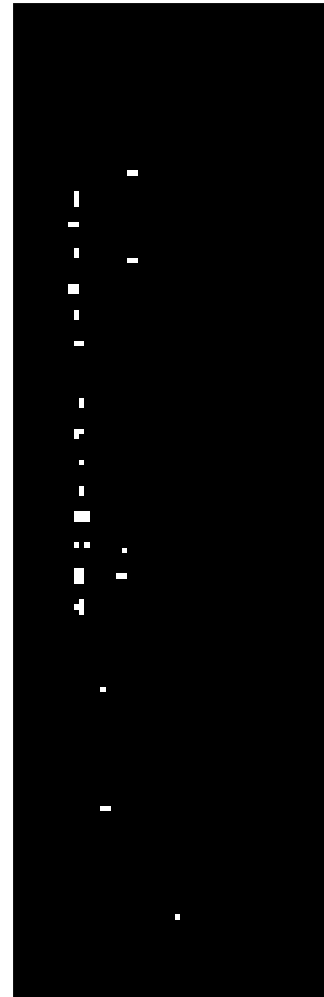


Background
classification



- Road
- Ground
- Vege.
- Dk. Vege.
- Shade

Anomaly detection

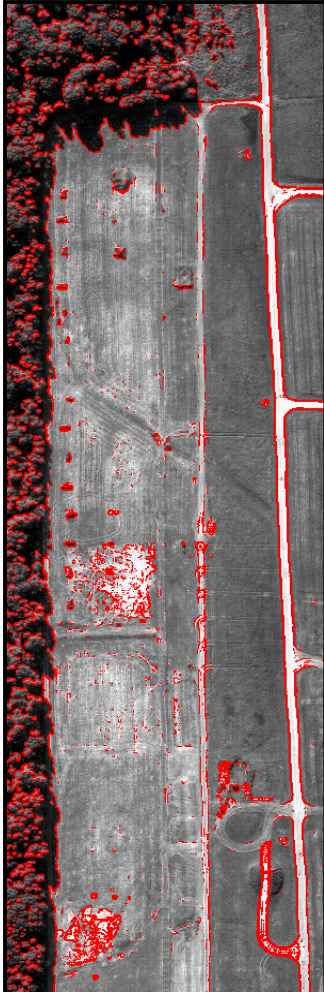


- Background map from unsupervised classification
- Anomaly detection also accomplished



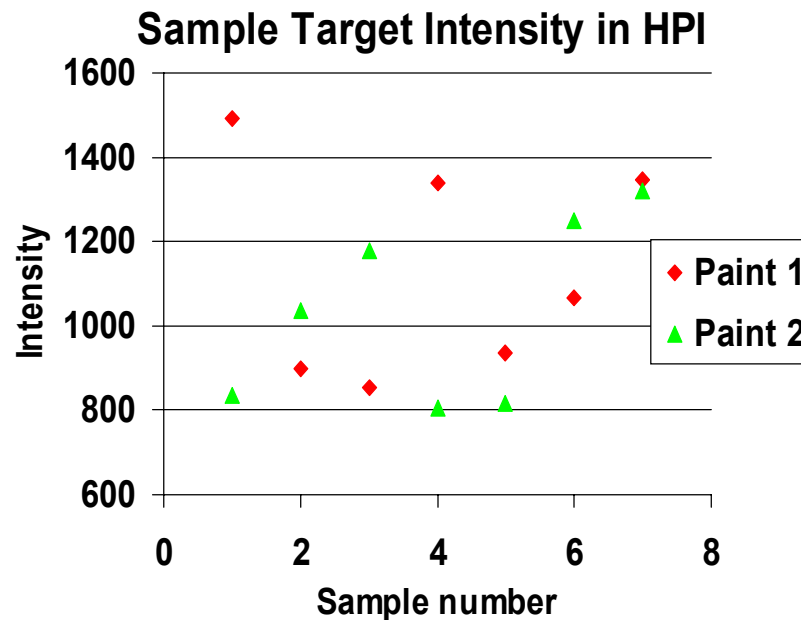
Spatial Processing on HPI

Panchromatic
image with edges



Sobel operator:

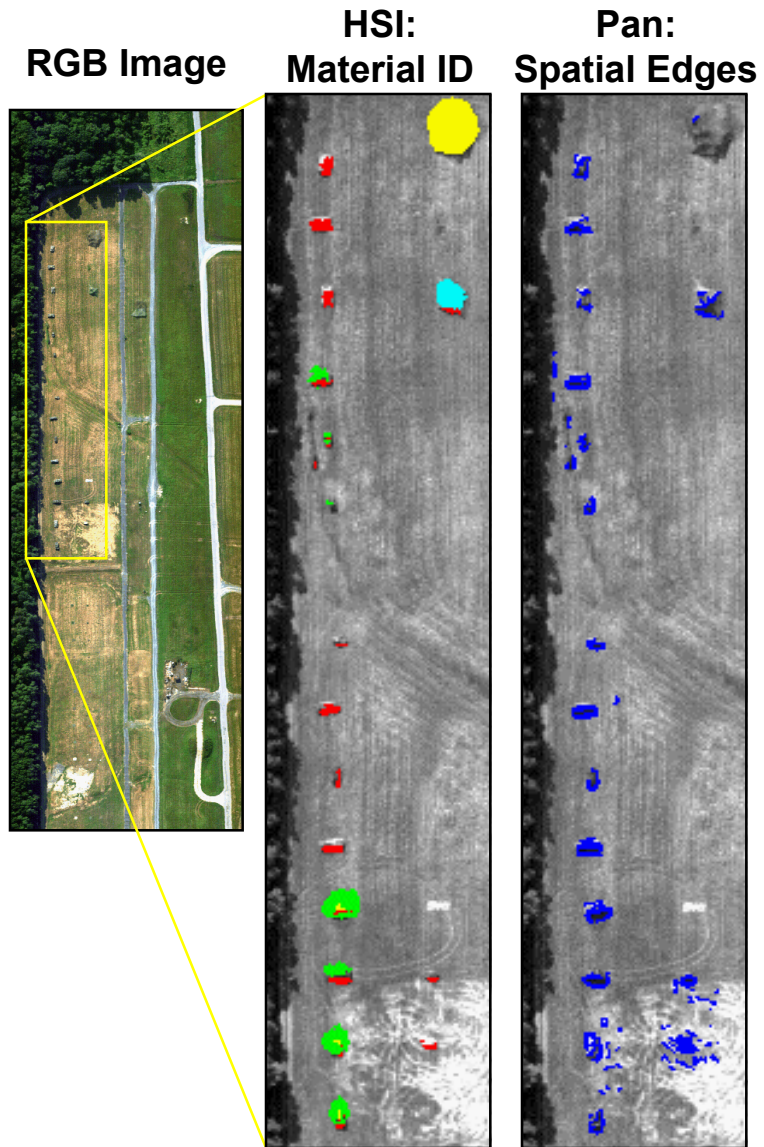
$$S_{x,y} = \begin{vmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{vmatrix} + \begin{vmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{vmatrix}$$



- Edge detection obtained with application of Sobel operator
- No apparent separation in HPI intensity between sample material classes

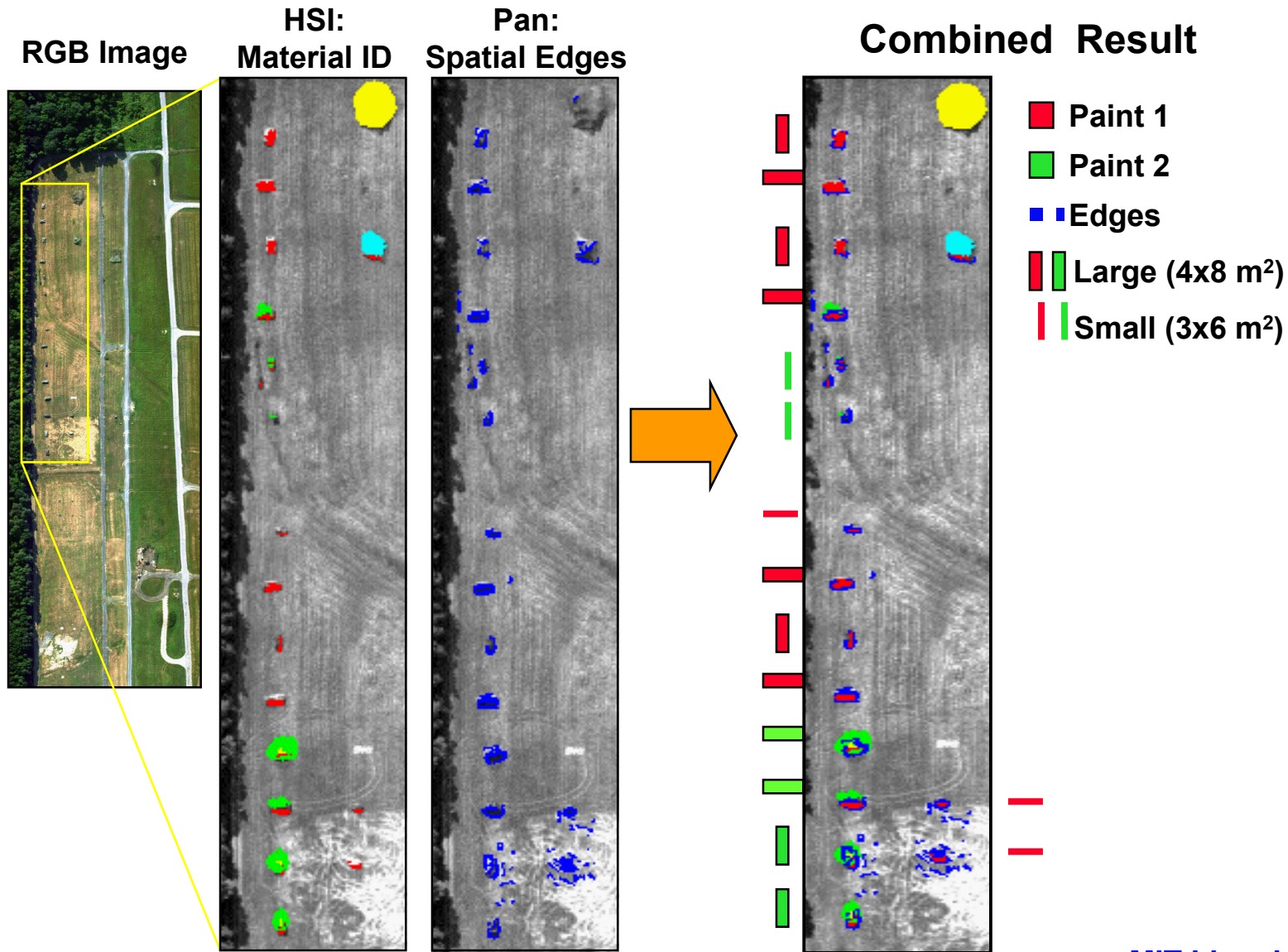


Target Identification: Fusion of HSI and Panchromatic Imagery



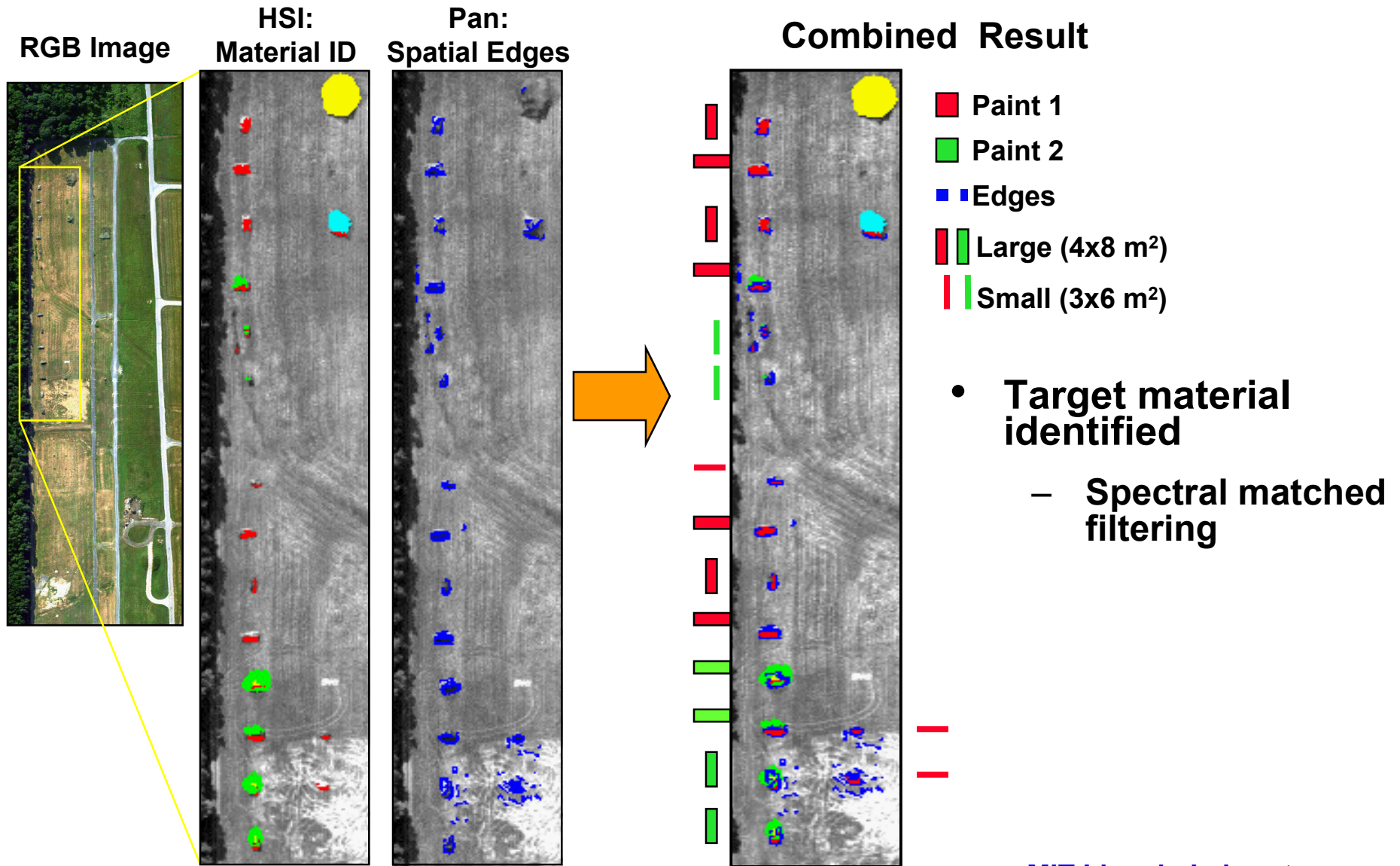


Target Identification: Fusion of HSI and Panchromatic Imagery



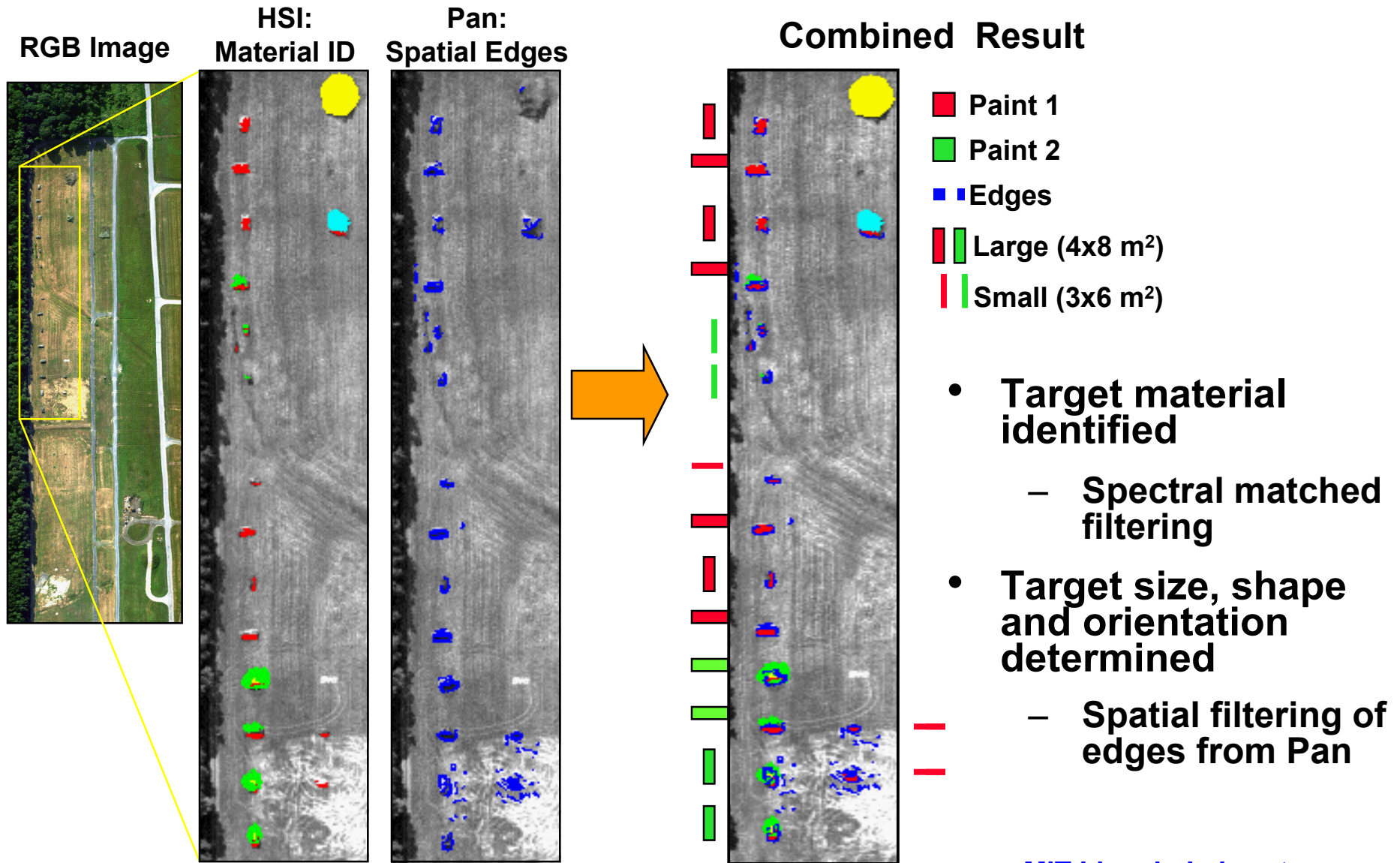


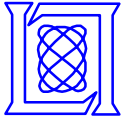
Target Identification: Fusion of HSI and Panchromatic Imagery





Target Identification: Fusion of HSI and Panchromatic Imagery





HSI/HPI Fusion Summary

- **Simulated data generated**
 - Measured data from high resolution HSI as “truth”
 - HPI data by band integration
 - HSI data by spatial degradation
- **Methodology developed for combined spatial/spectral analysis**
- **Fusion of HSI/HPI data results in:**
 - Enhanced background classification
 - Better target characterization and identification

➡ **Product enhancement illustrated by HSI/HPI fusion**