A Proposed Approach for Characterizing Large Military Ranges

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Large Ranges Characterization Issues

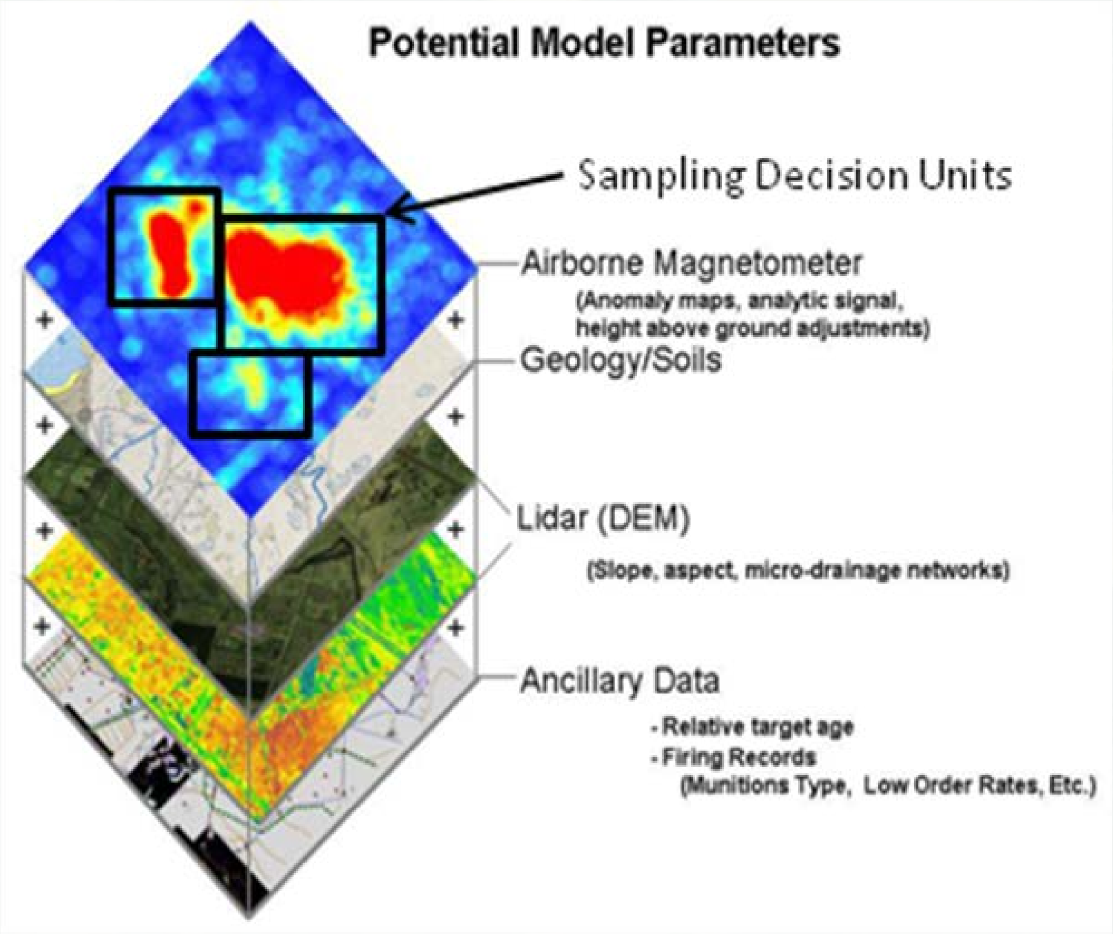
Lack of a systematic approach to evaluate large (> 50 acre) Department of Defense (DoD) ranges for munitions constituents (RDX, HMX, TNT) in a cost effective manner to estimate the source term and soil contaminant loading

Questions/Issues

- What is the utility of Wide Area Assessment (WAA) surveys to locate areas with high density of munitions and explosives of concern (MEC) and munition constituents (MC)
- How to integrate and analyze disparate sensor data, e.g. synthetic aperture radar (SAR), hyper-spectral imaging (HSI), orthophotography, light ranging and detection (LIDAR), digital geophysical mapping (DGM)
- Co-location of MC with high density of MEC, craters, metal fragments, etc.
- How to balance number of soil samples versus cost
- What scale of soil sampling is important
- The applicability of the Incremental Sampling Methodology (ISM)

Possible Approach

Integration of ancillary data, varying sensor modalities, geophysical techniques, and sampling designs such as ISM for effective characterization of MC distribution on ranges



Sensor Technologies

Process:

High-Altitude (LiDar, SAR, HSI, Ortho-Photography)

Low-Altitude (Airborne Magnetometers)

Ground Based DGM (EM-61, MetalMapper)

History:

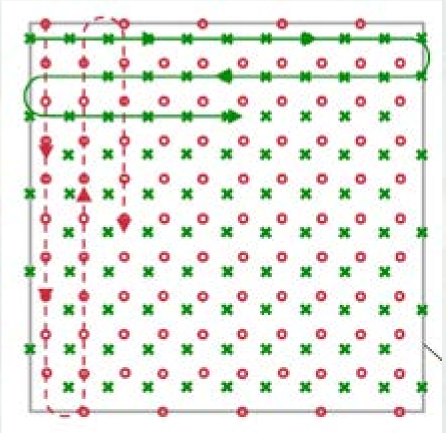
- LIDAR, Orthophoto, Helimag, Digital Geophysical Mapping (DGM) demonstrated to locate MEC directly or indirectly
- Application methodology for WAA established
- Limitations of LIDAR, Orthophoto, Helimag, DGM determined
- Individual sensor data analysis techniques developed

Unknowns:

- Leveraging of WAA tools to infer presence of MC and aid in ISM design
- Utility SAR and HSI to find MEC or infer presence of MC
- Integration and analysis of multi-sensor datasets

Incremental Sampling Methodology (ISM)

Process:



Systematic process to form a representative sample by

- Collecting increments,
- Combining them
- Improved sample processing

History:

- Conventional field sampling and sample preparation methods yield non-reproducible results
- ISM yields reproducible and representative results of the area sampled
- USEPA Method 8330B incorporates sampling and sample preparation changes

Unknowns:

- Appropriate scale of sampling on large ranges
- Appropriateness of current ISM sampling design for large areas
- Scalability of ISM approach
- Co-location of MC with MEC

Wide Area Assessment (WAA)

Wide Area Assessment (WAA)

- Base-Wide Assessment
- Fixed wing platforms
- Definition of Areas of Concern
- Definition of Clear Areas

Helicopter-Based Mapping

- Mapping under favorable conditions
- High resolution total field magnetics
- Target detection and MRS definition

Ground Based Geophysics

- WAA Verification
- MEC Detection
- MEC Characterization
- Target Discrimination

WAA Technology Details

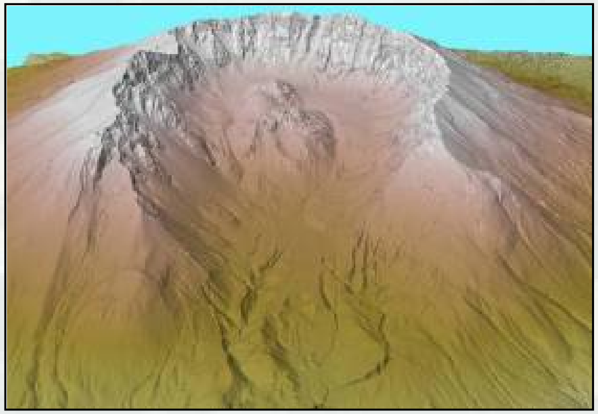
Sensor	Sensor Deployment	Sensor Application	Sensor Limitations
LIDAR	High-altitude WAA	Identify micro-topographic features representative of military munitions activities (i.e., craters/berms and target delineation features)	Dense broadleaf foliation
Visual and Infra-red Orthophotography	High-altitude WAA	Identify man-made features – military munitions related (i.e., access range roads, berms, remnants of bombing targets, and other target delineation features)	Dense foliation
		Discriminate LIDAR features and identify man-made features - unrelated to military munitions activity (i.e., roads, field furrows, tree blow down, and structures)	
SAR	High-altitude WAA	Detect surface metal debris	
HSI	High-altitude WAA	Discriminate surface non-metallic objects	Spectrally similar materials/water saturated materials
HeliMag	Low-altitude helicopter	Detect surface and shallow subsurface metal debris, UXO, and other man-made metallic objects	Terrain, Vegetation height, Ferrous geology
Magnetometry/ EMI	Ground-based	Detect shallow subsurface metal debris, UXO, and other man-made metallic objects	Dense vegetation, Ferrous geology

Light Detection and Ranging (LIDAR)

Optech ALTM 3100 LiDAR

- Defines micro-topography features
- Typical spot densities of 40 – 50 cm
- Precision digital terrain model (DTM) for bare-earth and vegetation canopy models
- Digital elevation model (DEM) & shaded relief map imagery
- Feature Analyst used to detect, locate, and characterize micro-topographic features

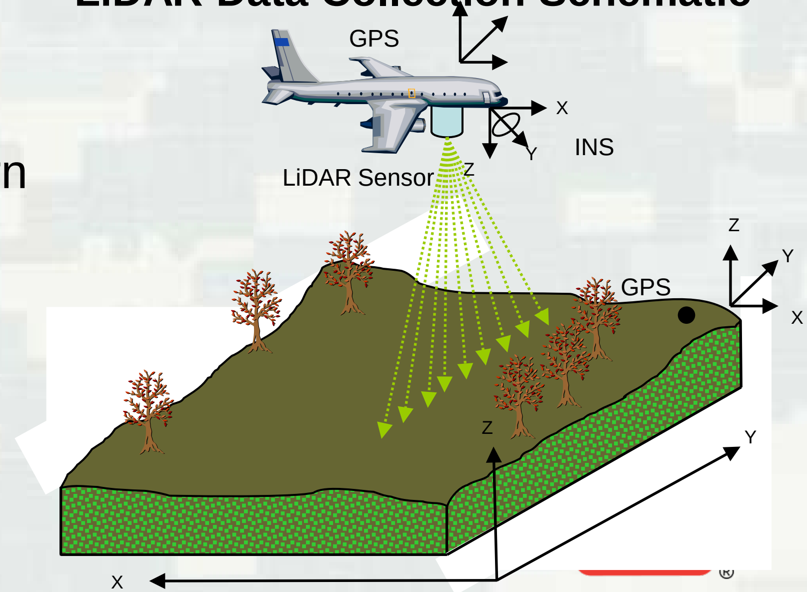
LiDAR from Mt St Helens



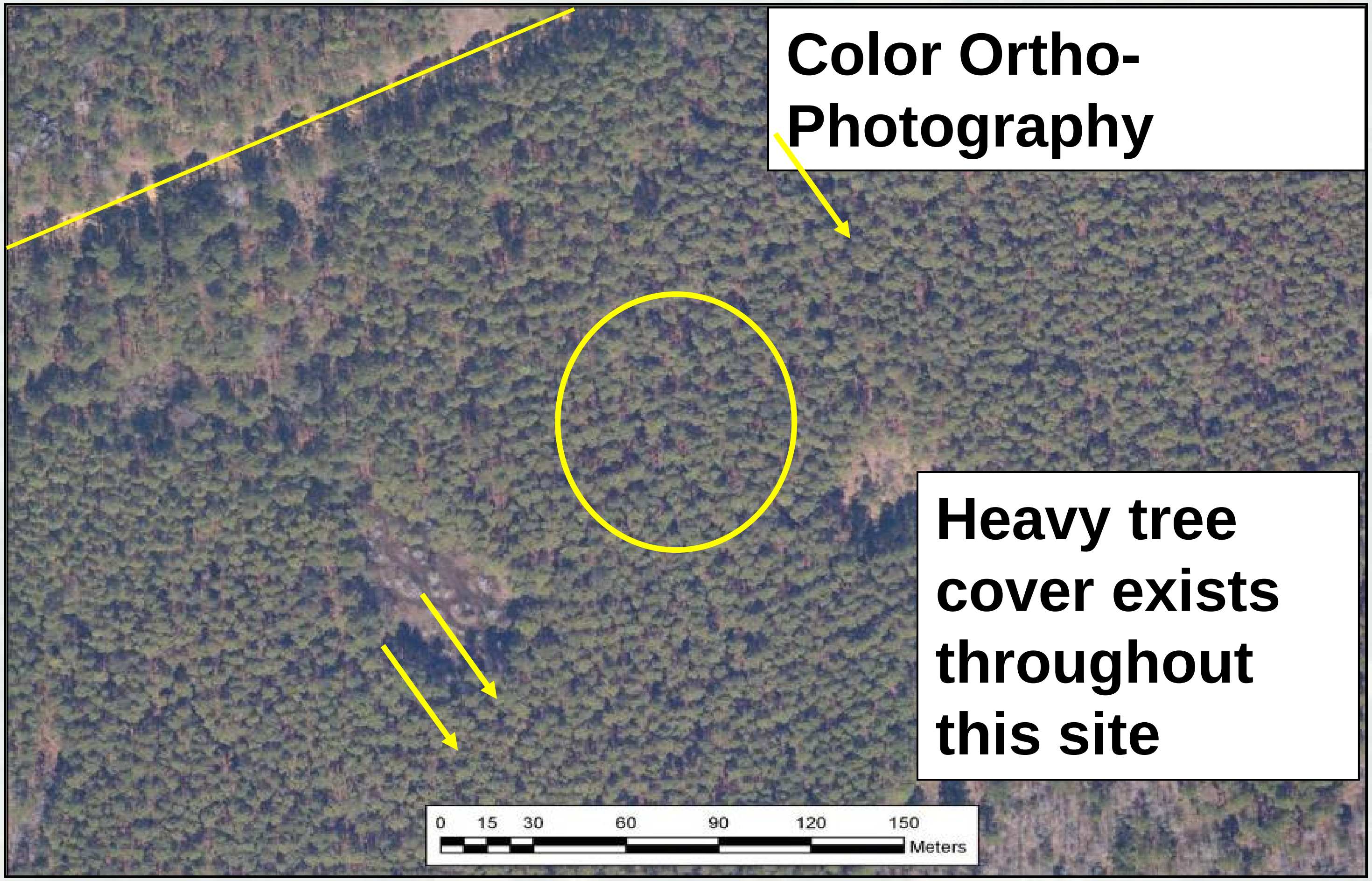
LiDAR Performance

- Up to 100,000 pulses per second
- Records 4 returns per pulse, including last return
- Flight altitudes from 80 to 3500 meters AGL
- Absolute vertical accuracy better than 10 cm
- Absolute horizontal accuracy of ~30 cm
- Point-to-point accuracy approximately 2 cm
- Scan angles +/- 25 degrees
- Scan frequency: variable to 70Hz

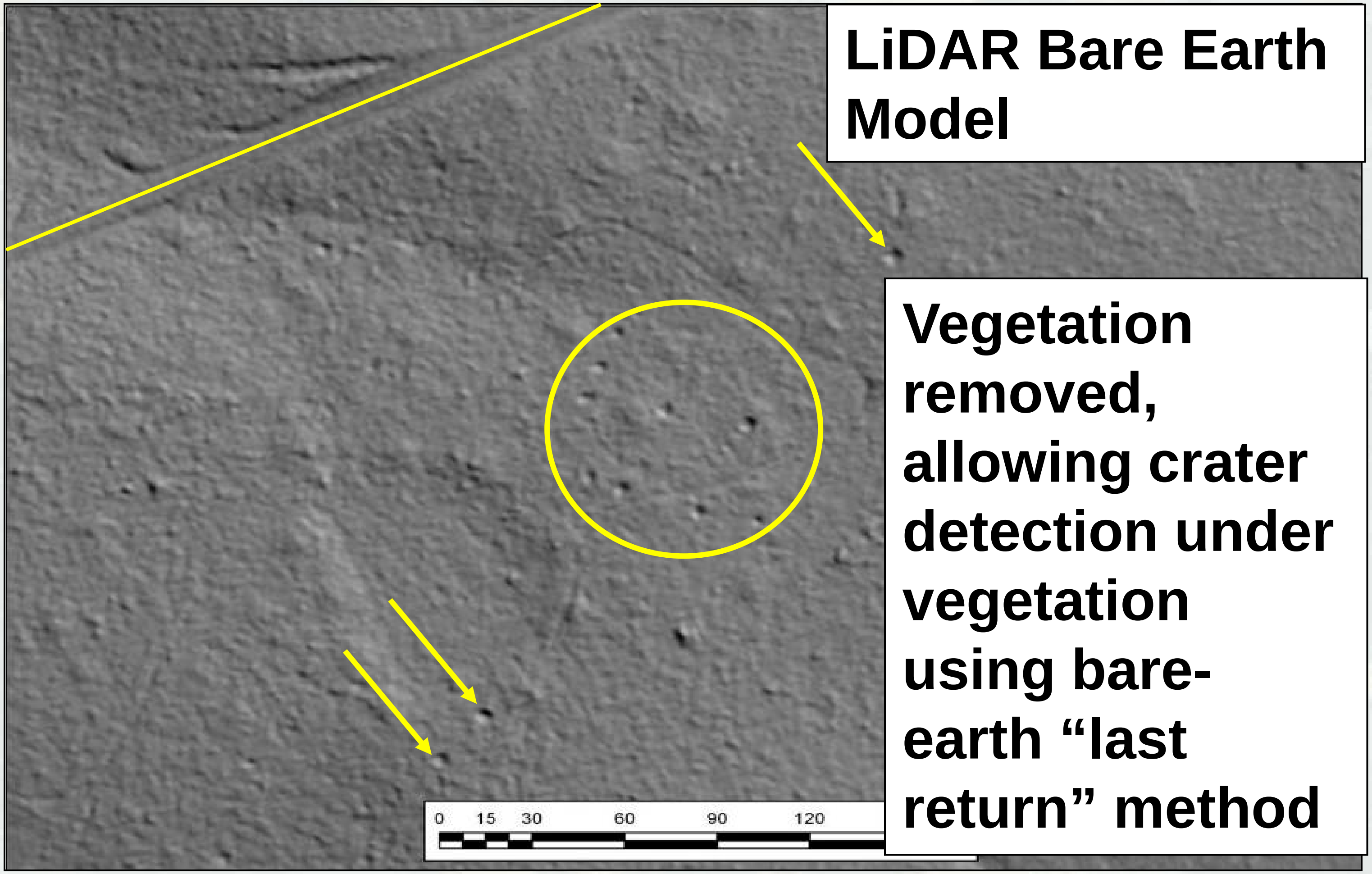
LiDAR Data Collection Schematic



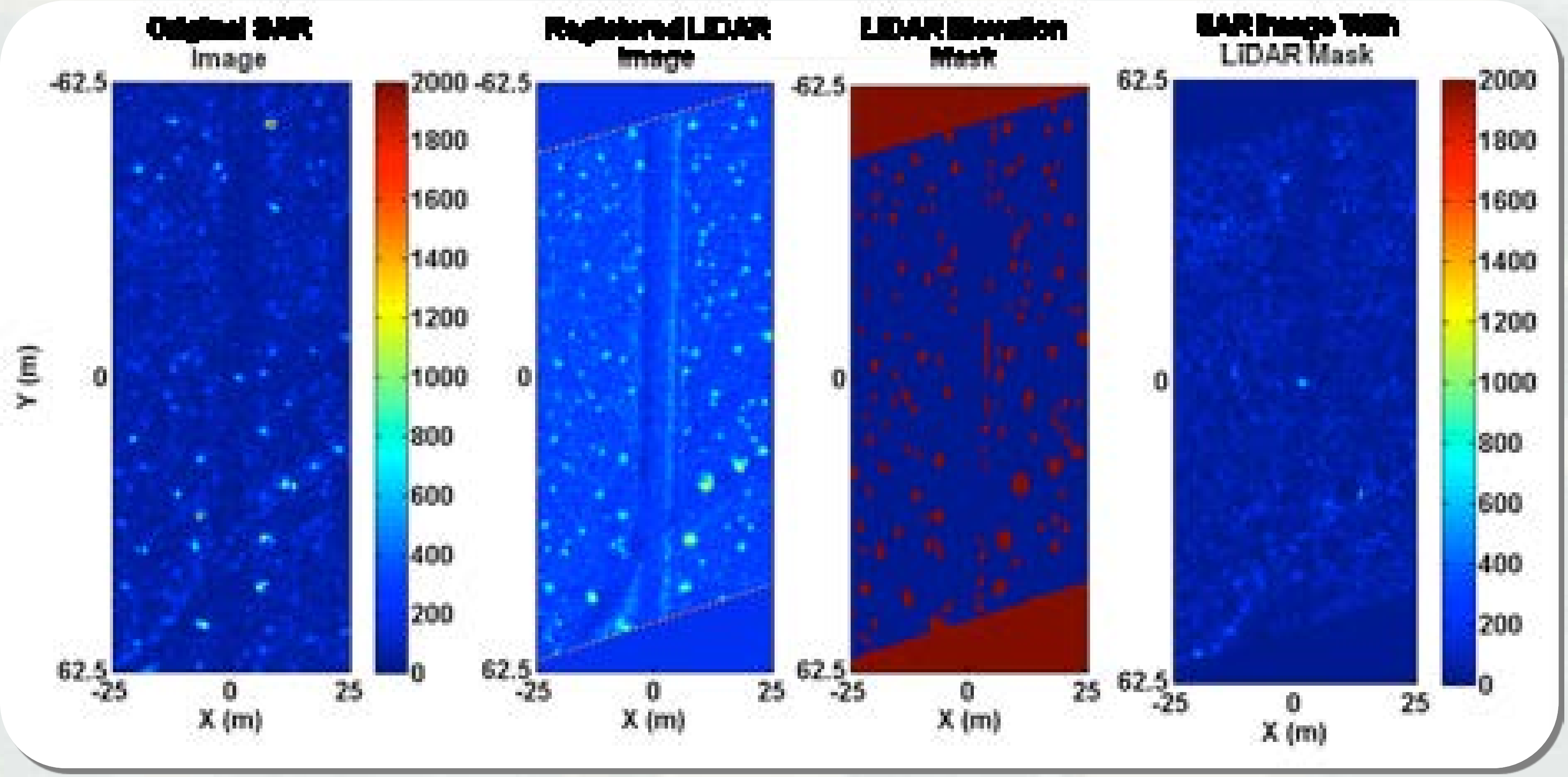
LIDAR: Foliage Example



LIDAR: Foliage Removed



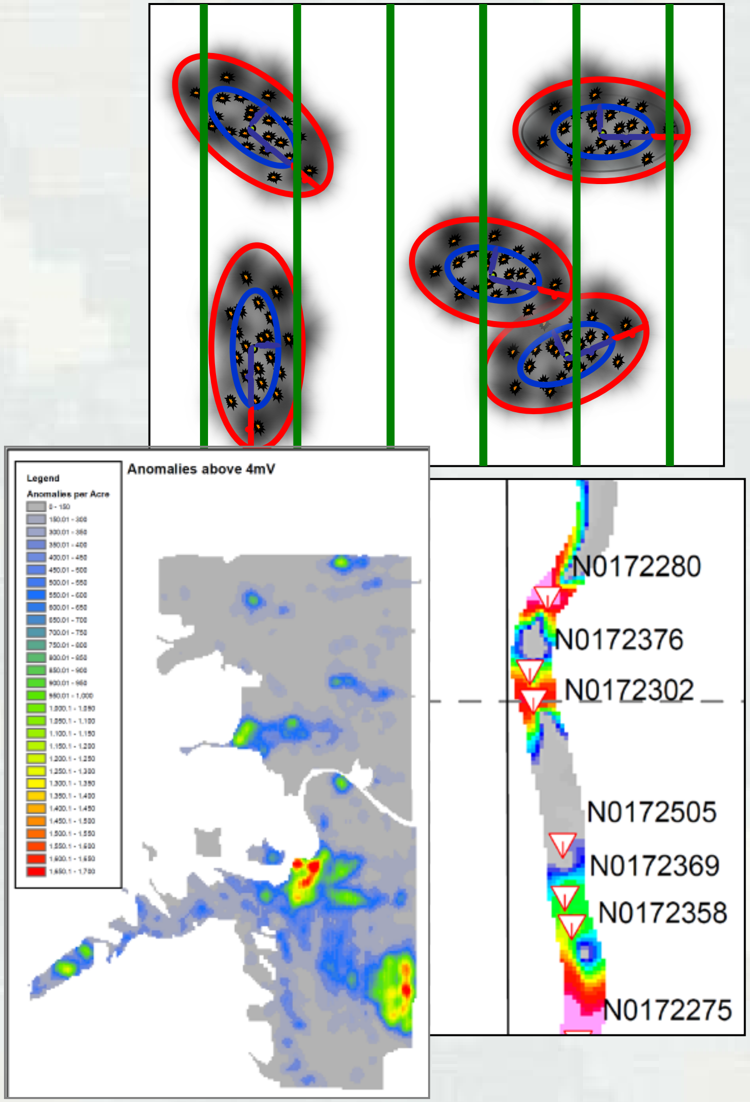
Side Aperture Radar (SAR)



Digital Geophysical Mapping (DGM)

- Man-portable (litter or cart) EM61 or MetalMapper
  - Detects ferrous and non-ferrous munitions down to frag and small arms
  - Transect-based for site-wide anomaly density based on size, shape, and orientation of target areas
  - Grid-based for detailed target area characterization

Ground Base Geophysics

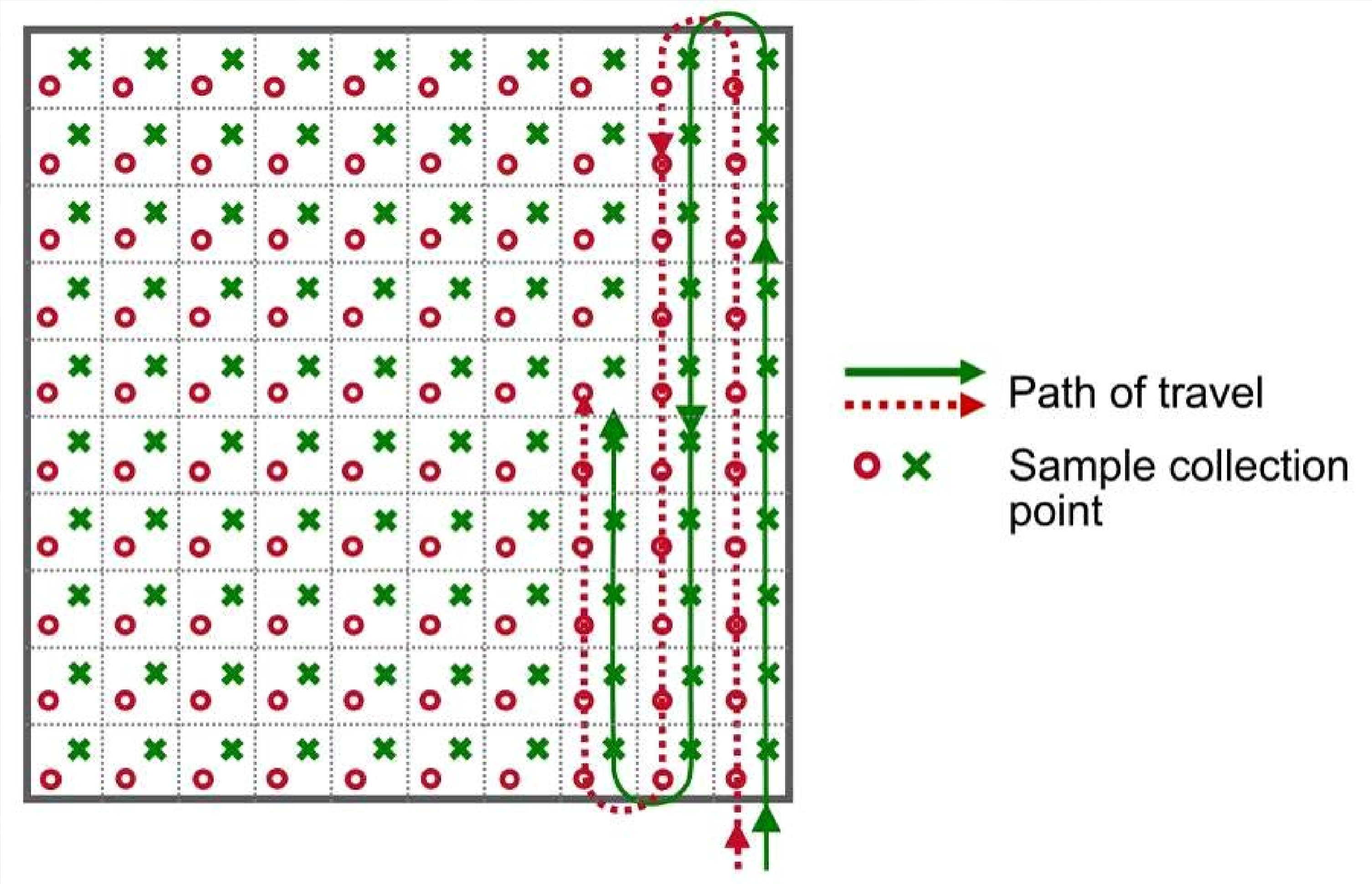


- Parameter estimation techniques
- Discrimination between targets (MEC) and non-targets (metallic debris, magnetic geology, other)
- Anomalies detected along transects
- Anomaly densities between transects interpolated through kriging
- Analysis using Geosoft Oasis Montaj™, UX-Detect, ARCGIS, VSP

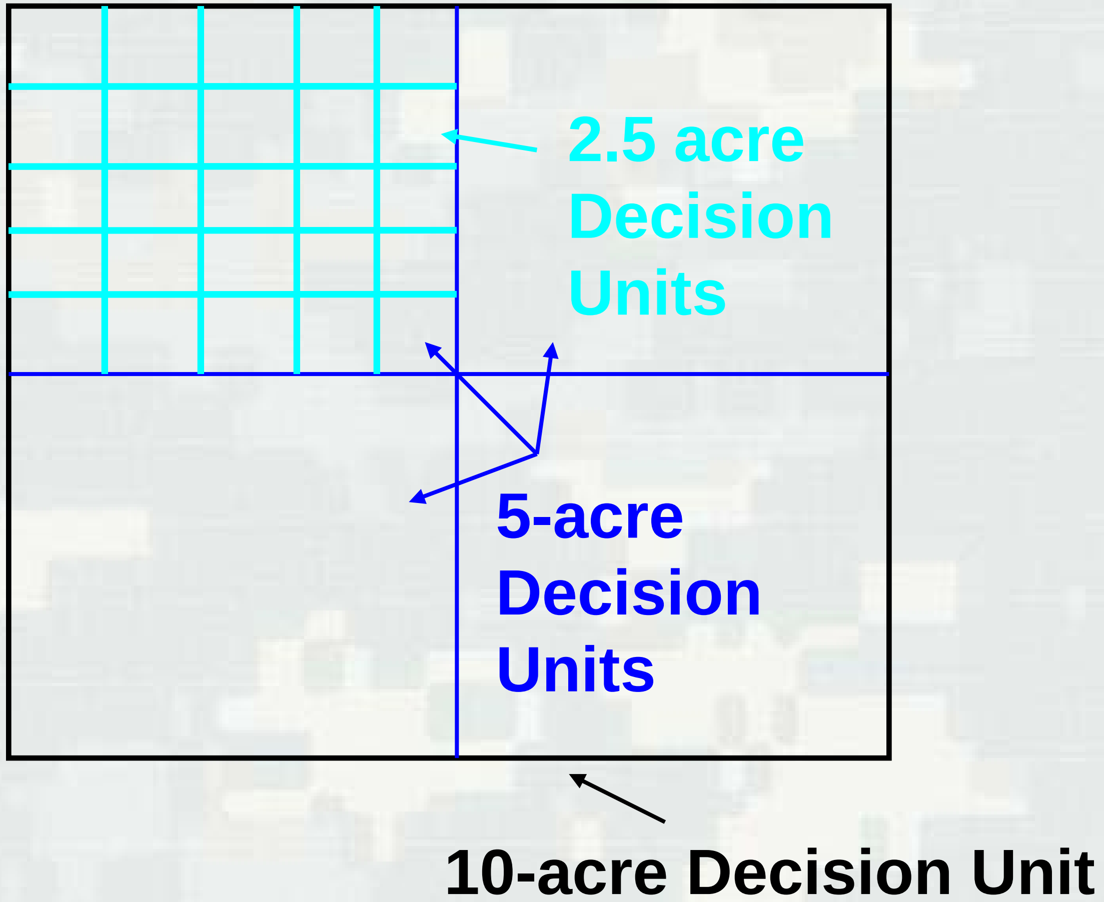
Decision Unit (DU) Selection

- Select “high value” anomalies within areas of “high” anomaly density
- Map density of munitions
- Differentiate between surface MEC, high-order detonation debris, and low-order detonation debris
- Combine with WAA information
- Select soil sampling Decision Units

Incremental Sampling Methodology (ISM)



Possible Decision Unit (DU) Layout



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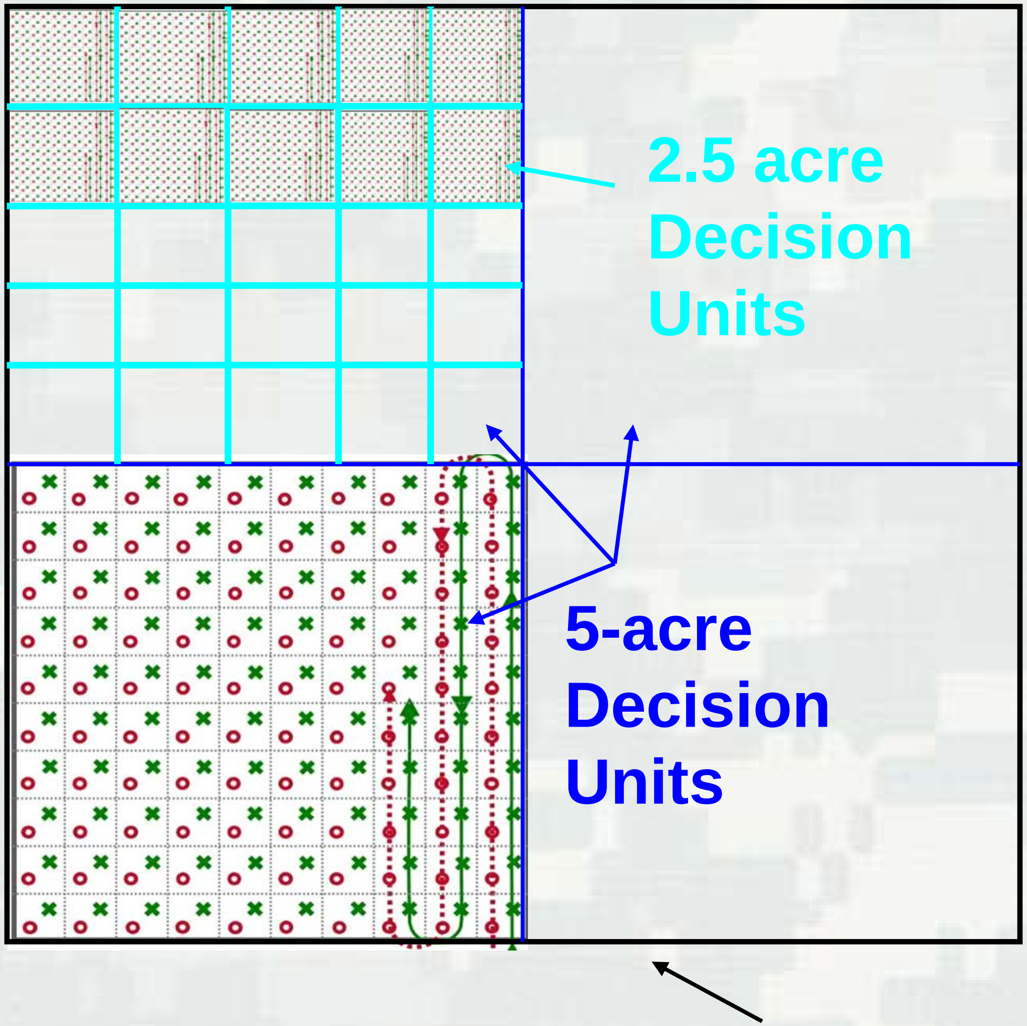

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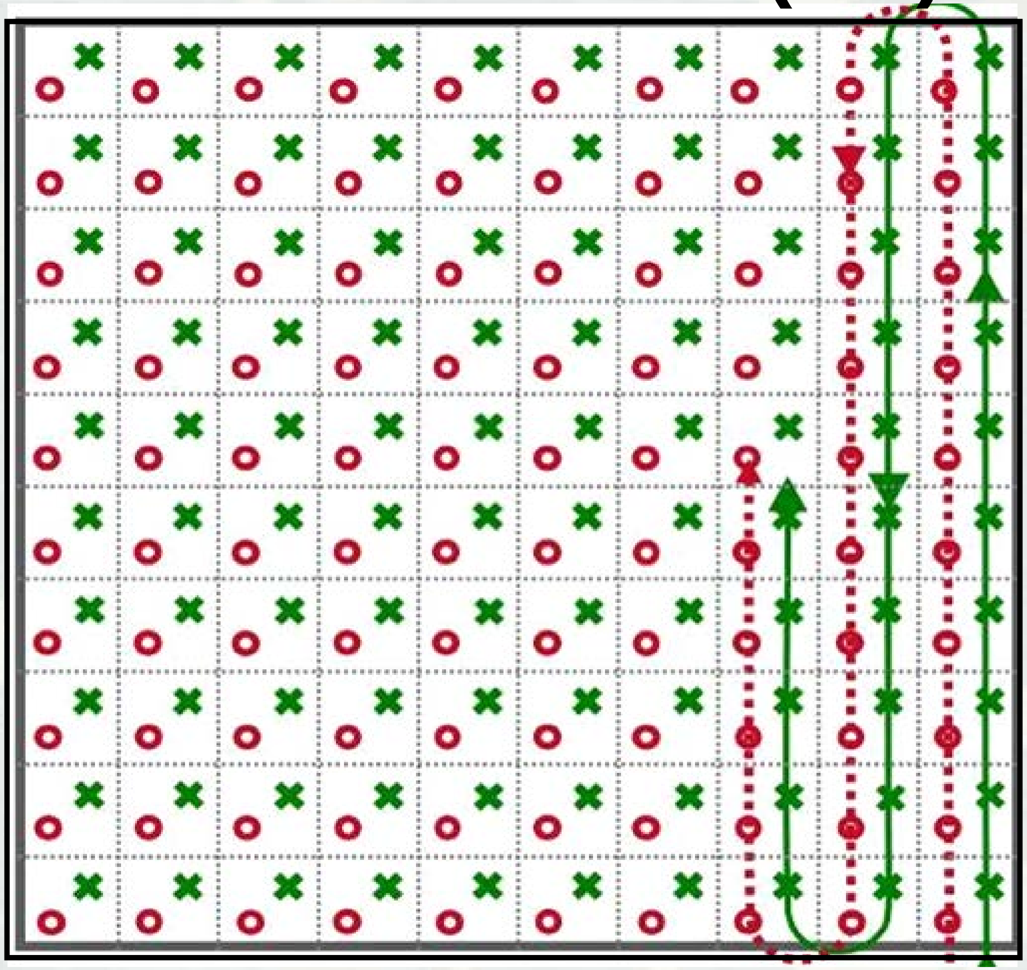
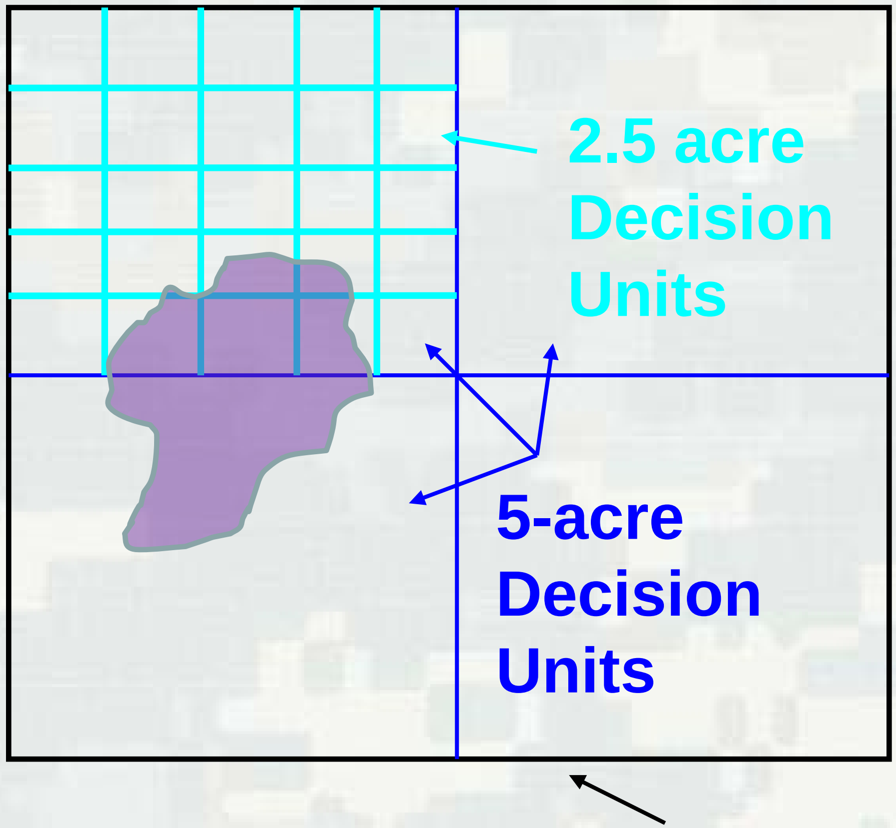


10-acre Decision Unit

Possible Decision Unit (DU) Layout



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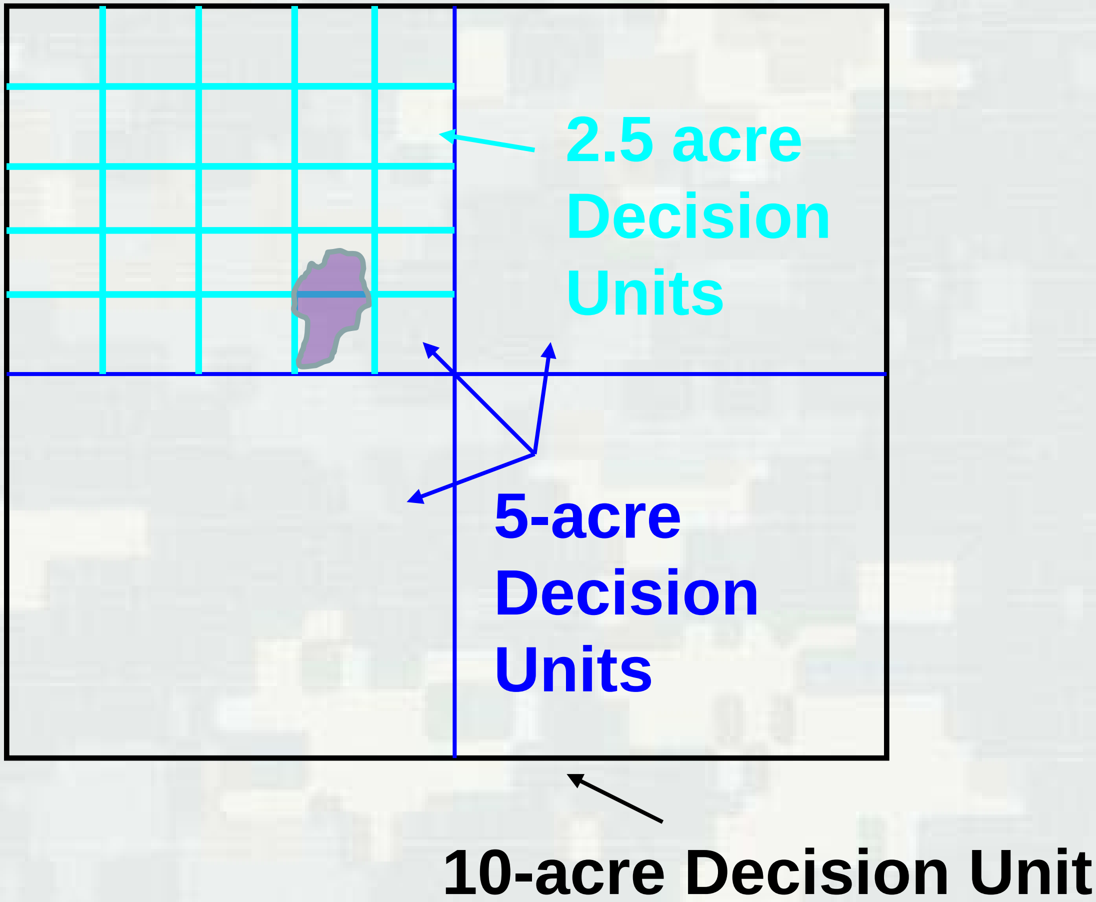


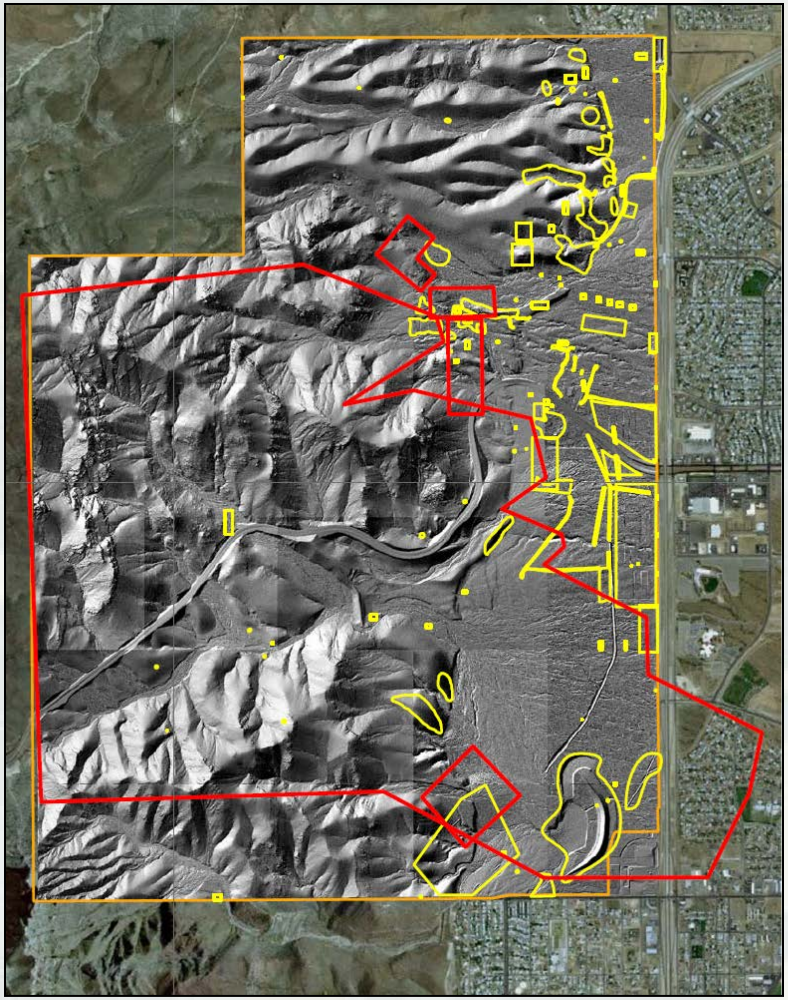
Soil Sampling

- Collect surface soil samples from locations identified as possible areas of interest based on WAA data
- Fifty soil samples collected from each of three anomalous zones (high, medium, and low density)
- Samples targeted to anomalous locations for specific sensors and combination of sensors
- Collect samples using standard ISM approach

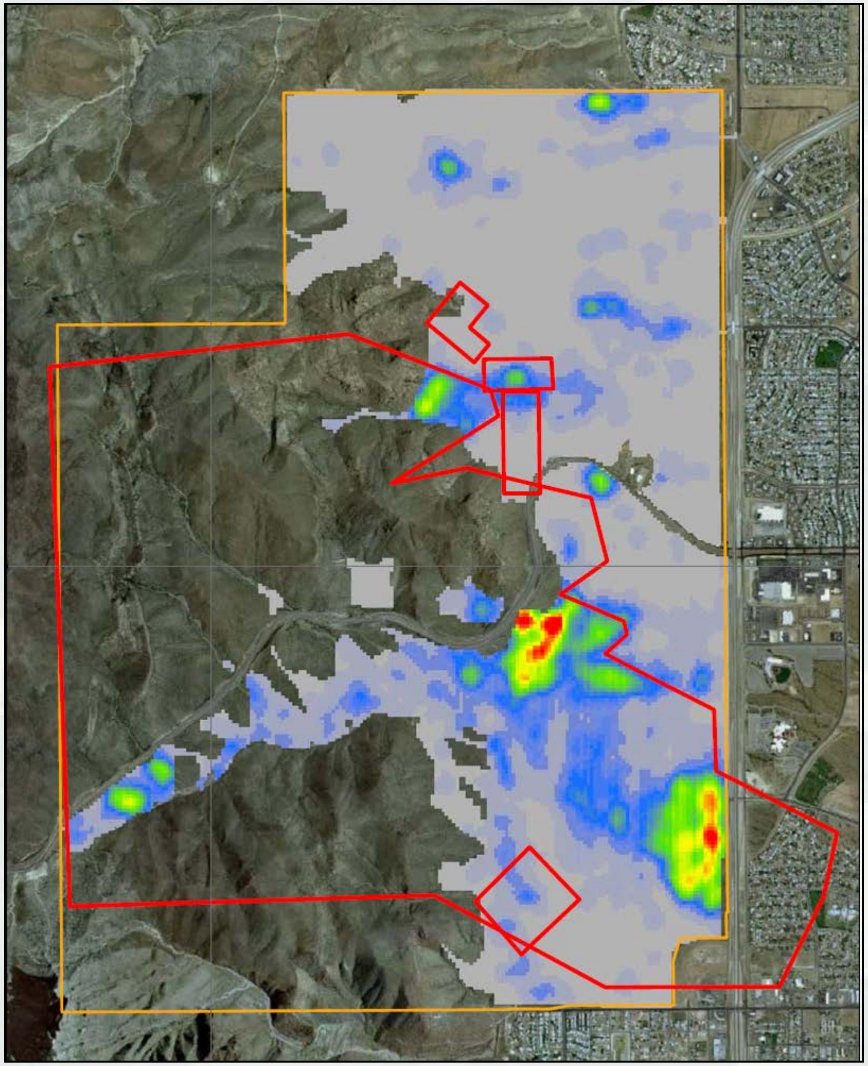
Extrapolation from Sampled DUs to Unsampled DUs

- Approach involves separating a range into high, medium, and low probability of MC
- Within each category establishing DUs
- Random selection of 59 DUs for sampling
- If no MC detection then 95% probability that MC is not present in unsampled DUs
- If MC detected in 1 DU then unsampled DUs will need to be sampled or the sampling approach re-evaluated

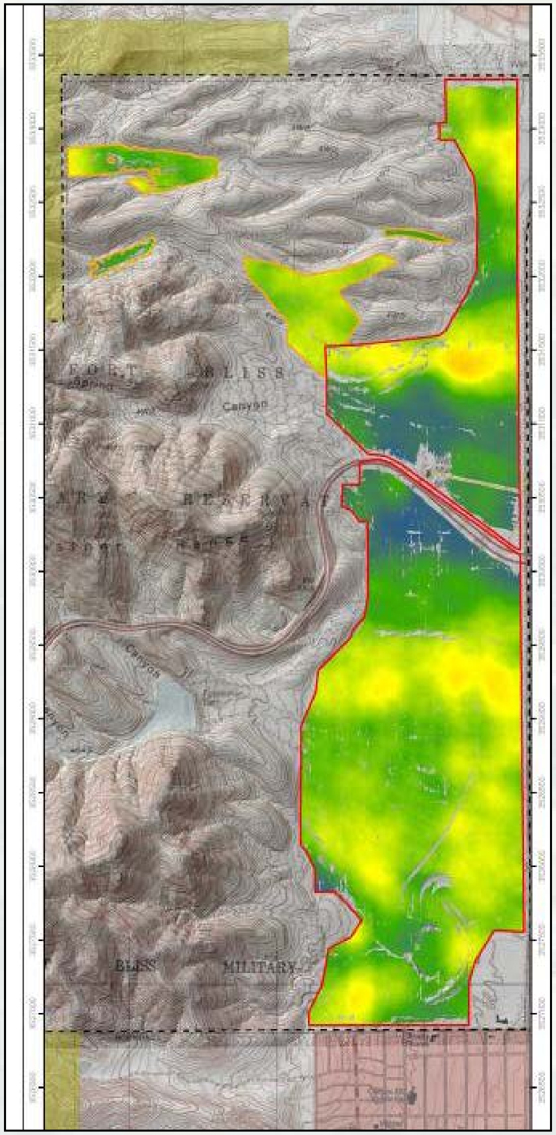
Data Fusion – Site Information Integration



Data Fusion – WAA Integration



Data Fusion - DGM



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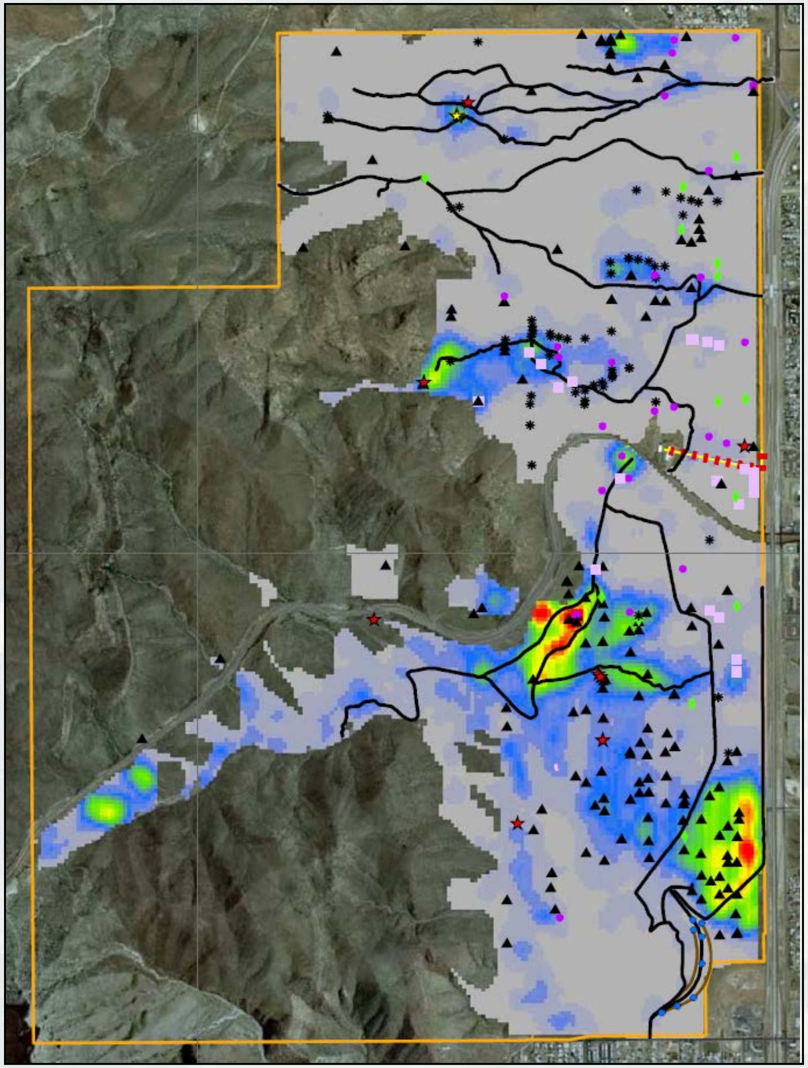
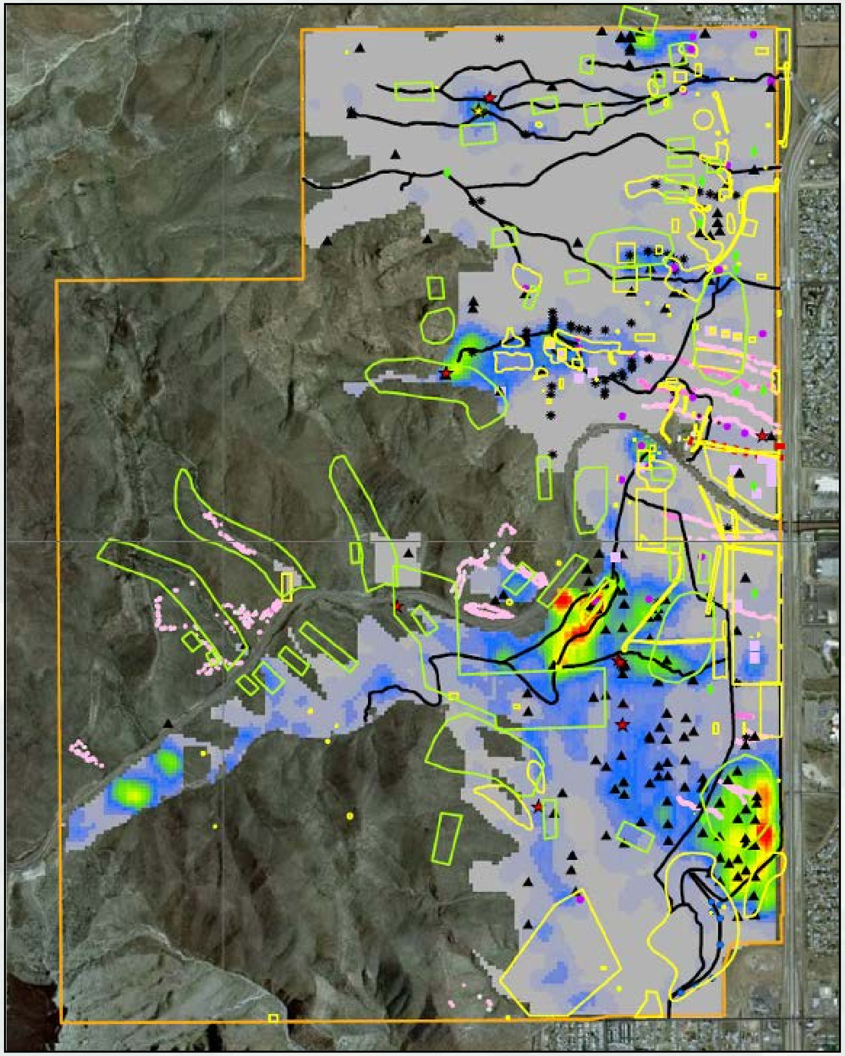
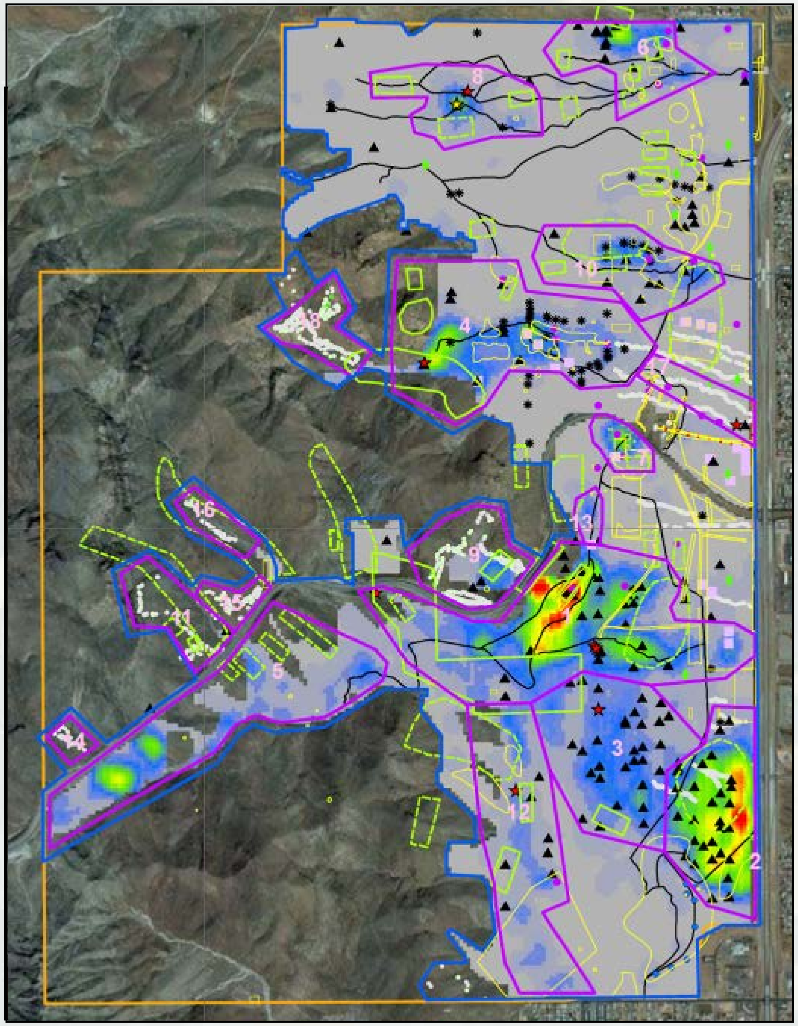
Data Fusion – MEC Locations



Data Fusion – Range Boundaries



Data Fusion – Decision Unit (DU) Selection



Conclusions

- An approach for evaluating MC on large ranges involves integration of site specific cultural data with WAA and DGM sensor data
- Identification of low, medium, and high MEC/MC zones
- Data fusion for selection of DUs within each zone
- Extrapolation approach for assessment of unsampled DUs
- Collection of surface soils using ISM