# Demonstration of Wide Area Assessment Technologies to Characterize Munitions Density

## Closed Castner Firing Range
## Fort Bliss, TX

Technical Project Planning Meeting 3
16 June 2010

URS

# Agenda

- Review project objectives
- Helicopter-borne Magnetometry Results
- Ground-based Geophysics Results
- Data Overlays
- Intrusive Investigation
- Explosives Site Plan
- Schedule Update & Questions
- Introduction to Incremental Sampling
- Questions & Wrap -Up

# Project Objectives

# Characterization Challenge

- Millions of acres of closed ranges in MMRP site inventory
- Many acres do not contain UXO
- Need methods to cost effectively:
  - Focus characterization efforts on areas used for munitions related activities
  - Eliminate areas with no indication of munitions use

# Full Coverage: "Mag and Flag"

# Project Purpose

- Field test the WAA methods and conclusions included in the *Wide Area Assessment Cost-Benefit Analysis: Active Army Military Munitions Response Program* (USAEC 2009)
- Collect site characterization data using a variety of WAA methods in a manner to ensure usable data for subsequent MMRP investigations (i.e., RI/FS)

# Objective

Demonstrate non-traditional technology applications for detecting munitions on Army property

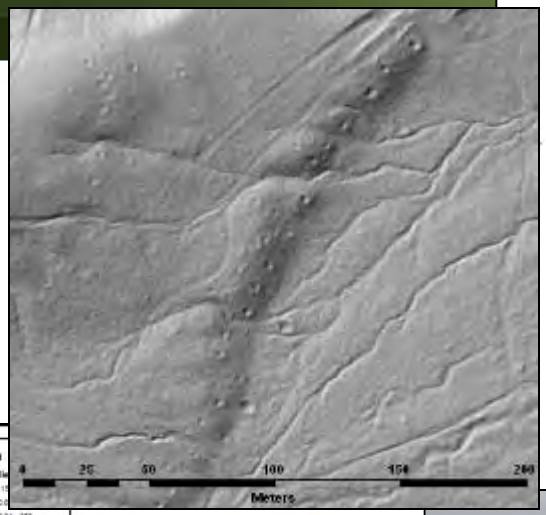
- Determine areas with evidence of past military munitions use
- Determine relative density of anomalies across these areas
- Determine areas with minimal evidence of past military munitions use

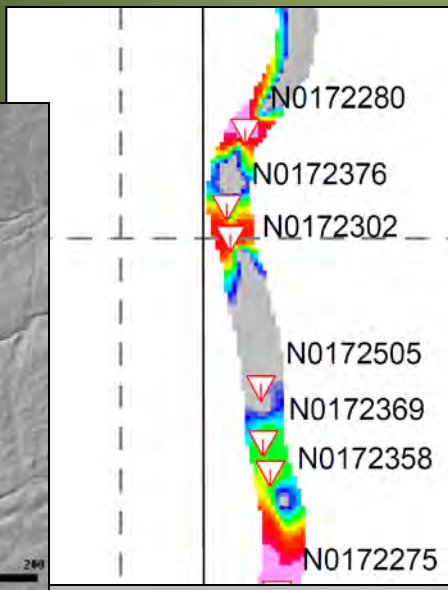
# What is not included…

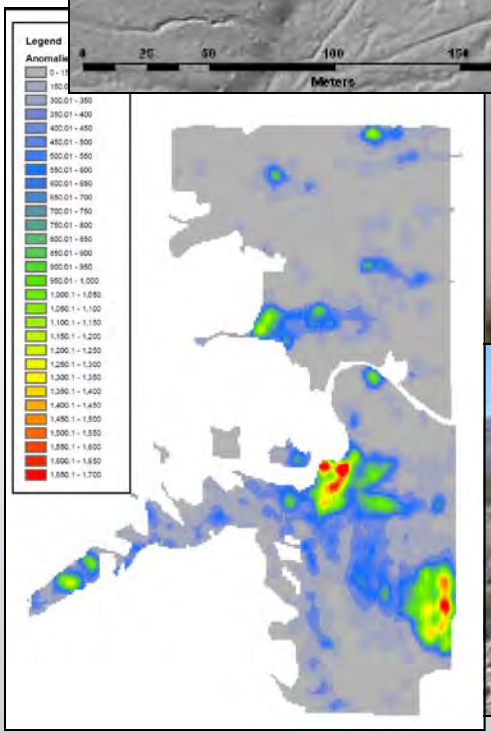
- Remedial Investigation
- Decisions about future land use
- Decisions about transferring the property
- Decisions about developing the property
- Decisions about mapping individual ordnance items
- Decisions about cleaning-up all the munitions

# What is included…

- Collecting data about the distribution and density of munitions on Closed Castner Range
- Demonstrating costs and benefits of applying proven technologies in innovative ways





# Project Scope

- Site Reconnaissance
- Lidar & Orthophotography
- Site Prep
  - Survey
  - Run VSP
  - Mark Transects
  - Install IVS

Complete. Results discussed at TPP 2.

- Helicopter-borne Magnetometry
- Ground-based Geophysics (towed array & man-portable EMI)
- Analog Data Collection

Complete. Results discussed today.

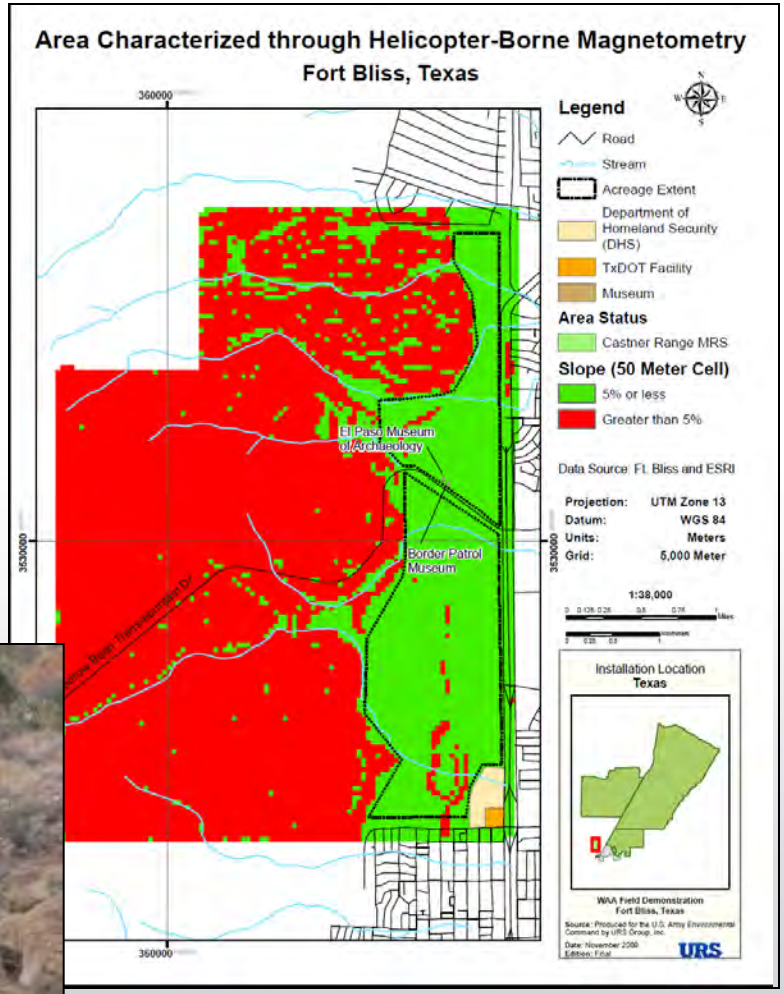
- Intrusive Investigation
- Project Reports
  - WAA Field Demonstration Report for Castner Range
  - Revised WAA Cost-Benefit Analysis: Active Army MMRP
  - WAA Cost Estimating Equations

Yet to do.

# Helicopter-borne Magnetometry

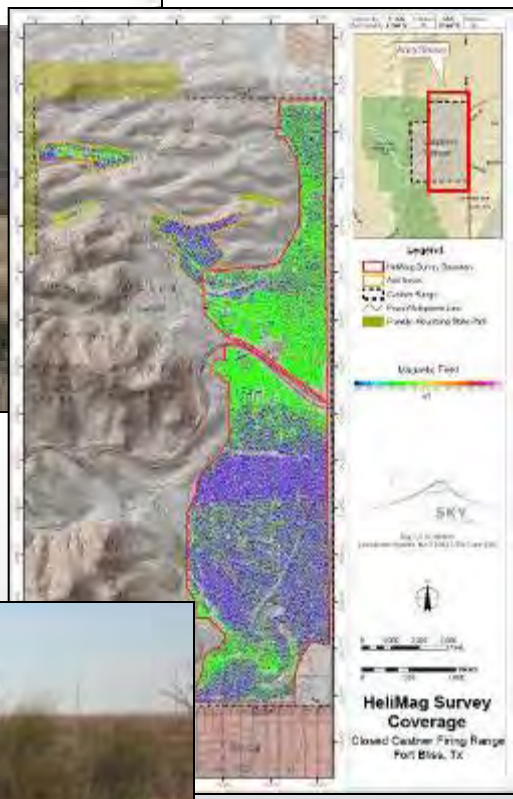
# Helicopter-Borne Magnetometry

- Objective: Map relative densities of ferrous metals
- Fly 1-3m above ground surface
- 7 sensors spaced 1.5m apart; provide swath width of approx 9m
- Flight lines 7m apart provide for 2m overlap
- 100% coverage of survey area (approx 1,577 acres; < 5% slope)
- Approx 300 - 500 acres/day
- 11 - 14 January 2010



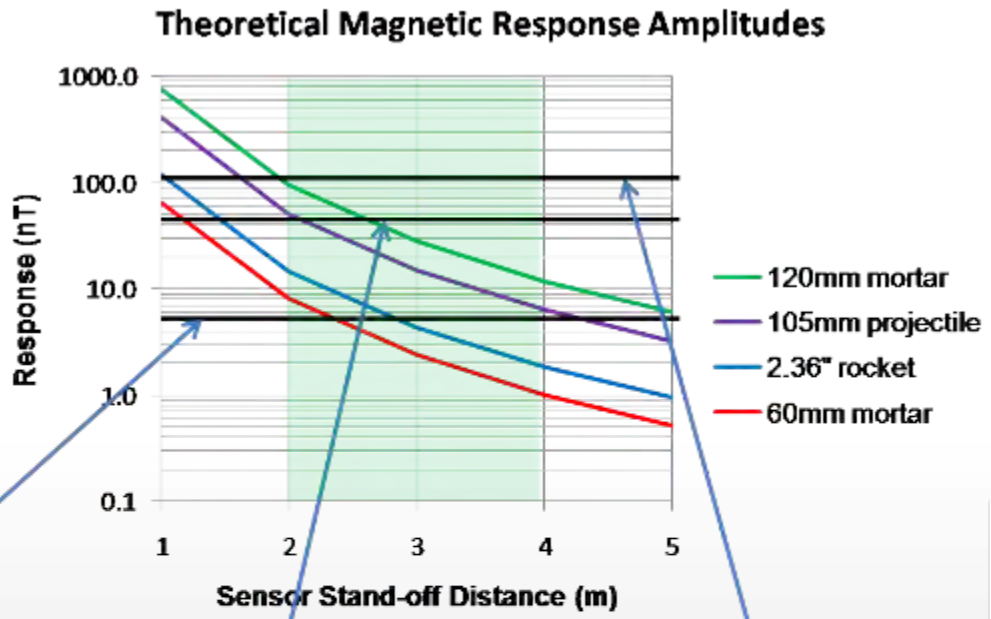
# Helicopter-Borne Magnetometry: Preliminary Results

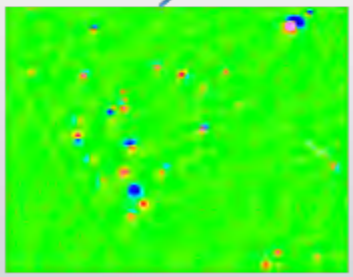
- Production rate higher than expected; flew 500-700 acres/day
- Site conditions limited utility of helicopter-borne magnetometry
  - Magnetic geology more extensive than expected (created noise)
  - Vegetation more problematic than terrain (high altitude, low pd)
- Data do not support conclusions about density and distribution of ferrous material at the site



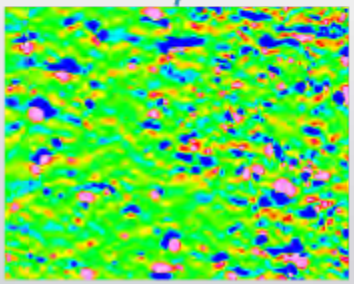
# Effect of Background Noise

Detection is a function of target size, altitude, and background noise.

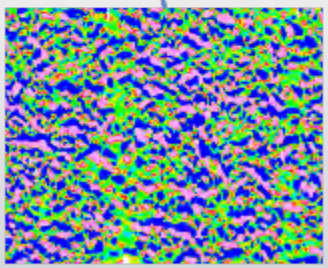


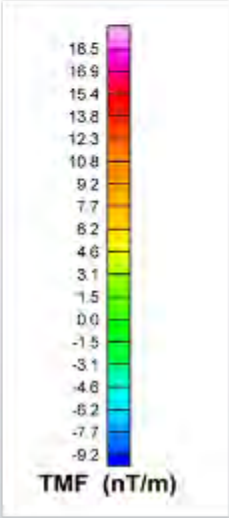
Ideal geology



Area 2

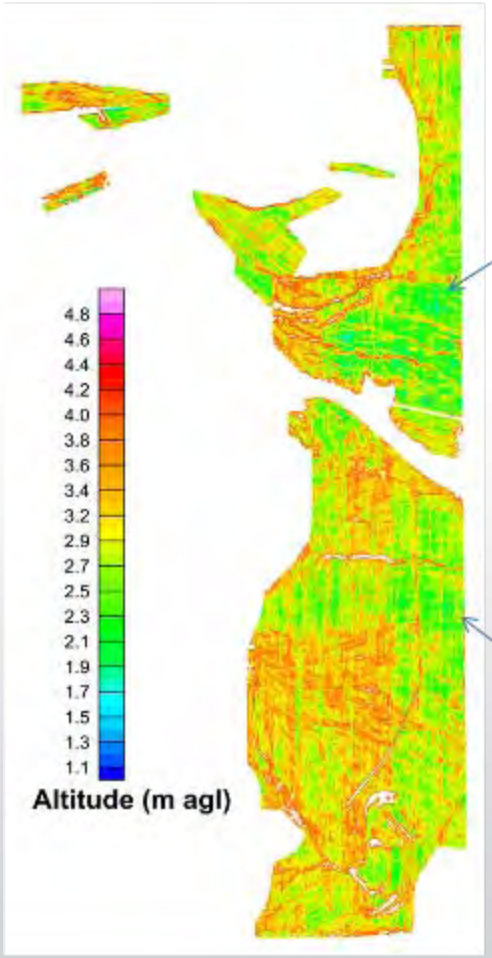


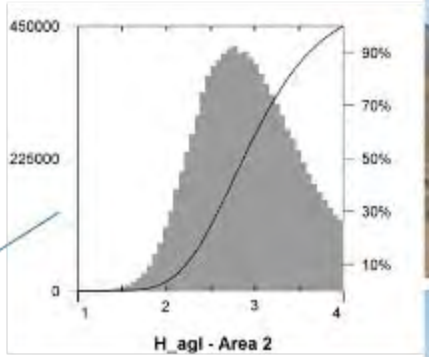
Area 5



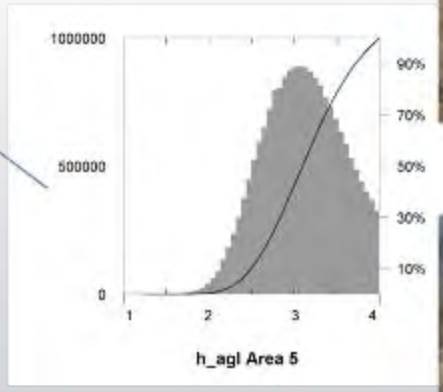
# Altitude Performance

Helimag Ft Bliss 2010 - Altitude Performance




Mean 2.9 m




Mean 3.1 m

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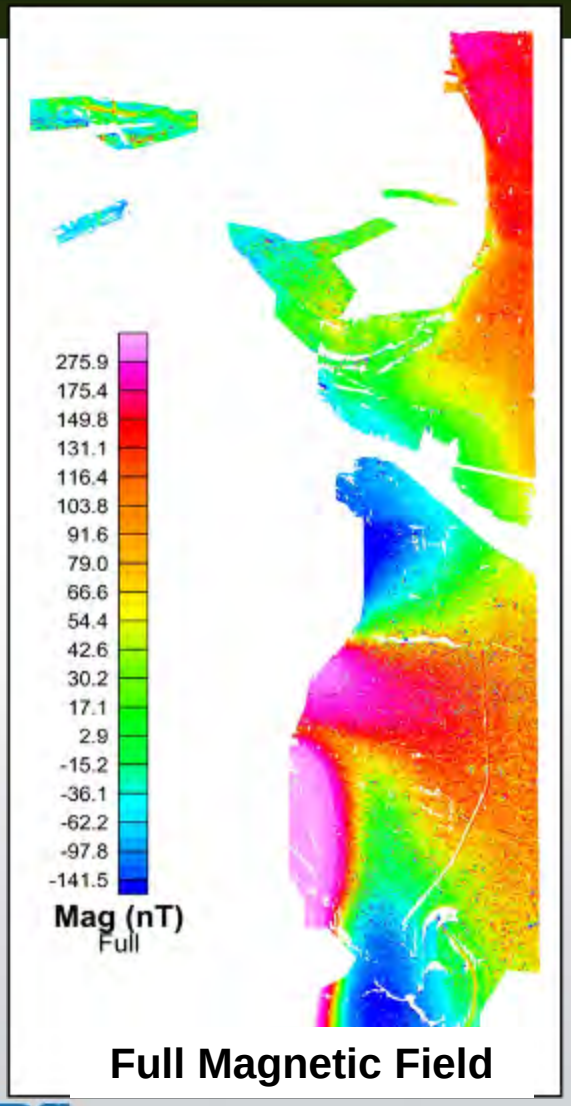
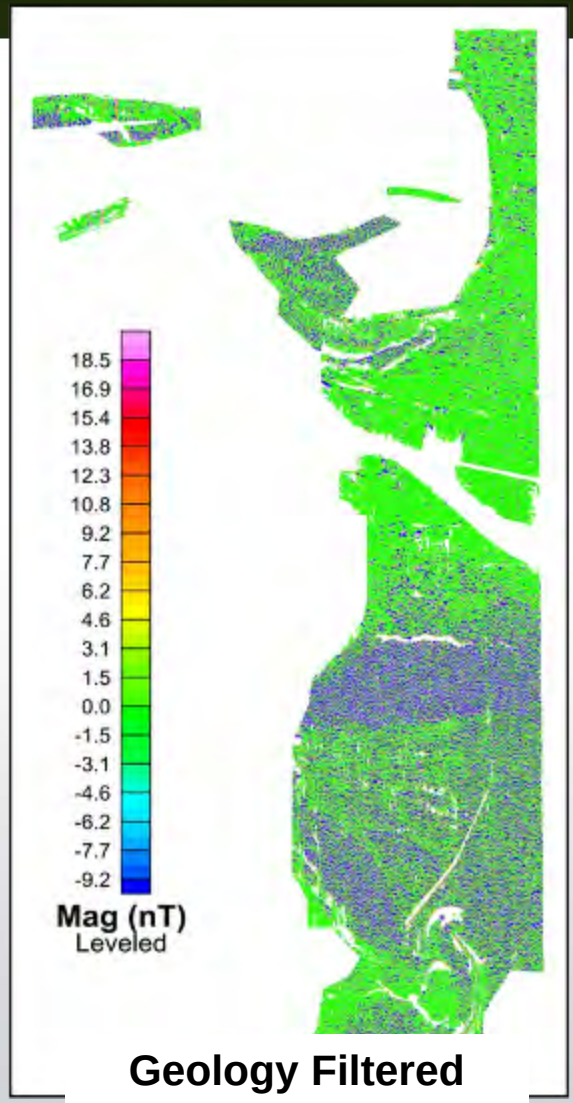
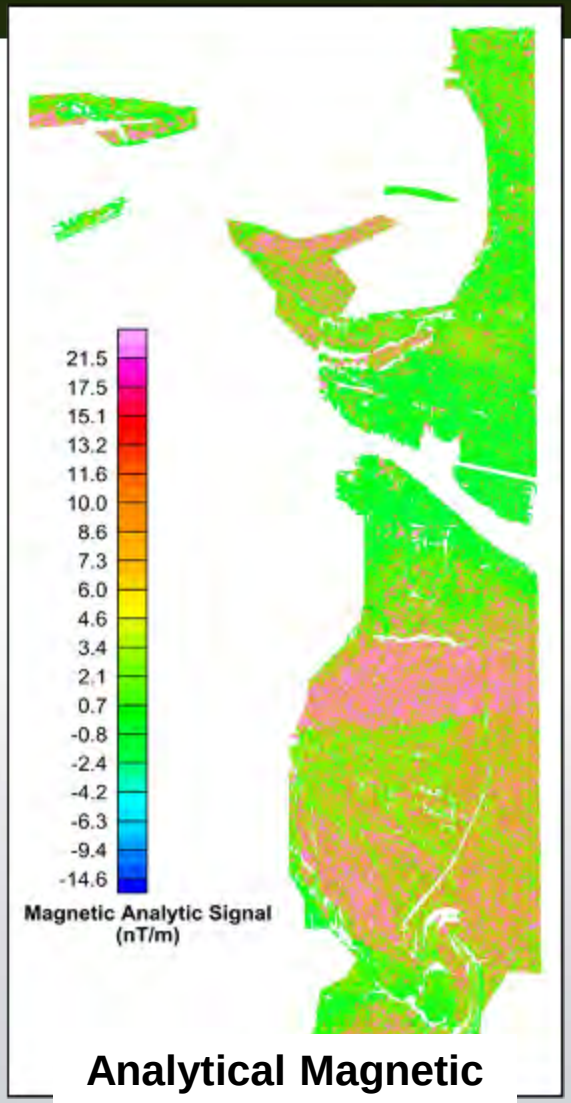
# What did we see?




Full Magnetic Field

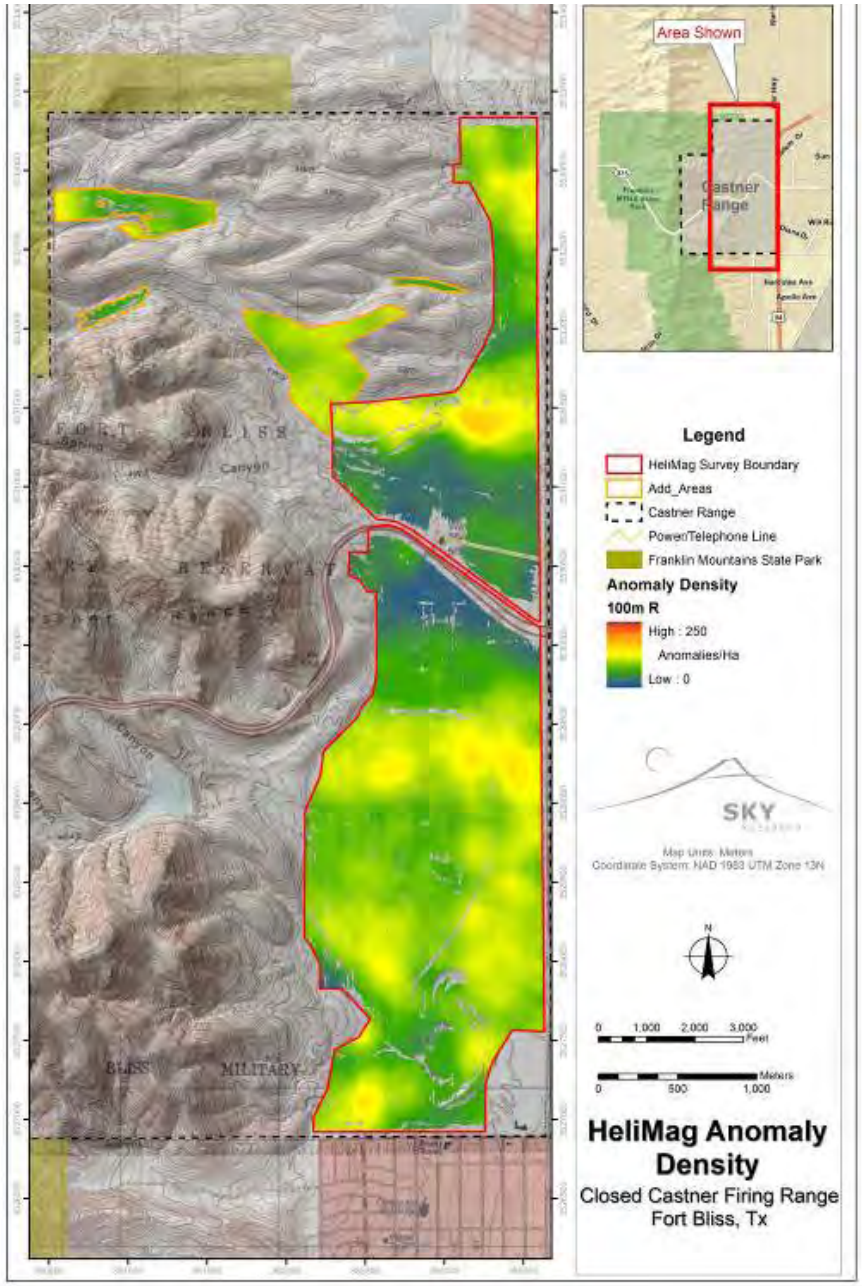



Geology Filtered Magnetic Field




Analytical Magnetic Signal

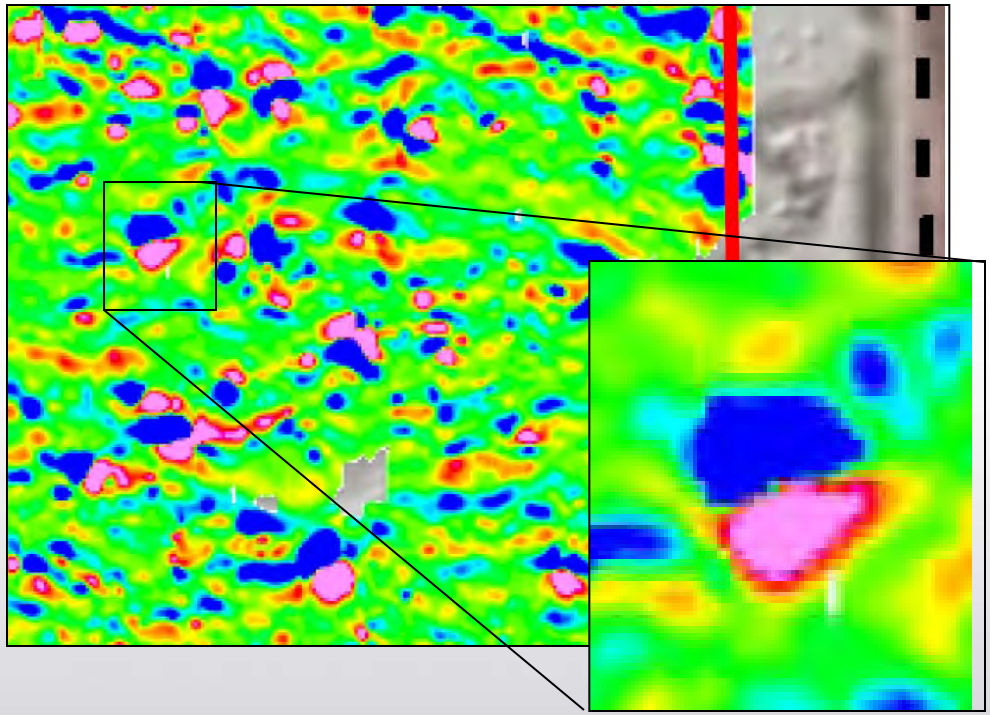
# Helicopter-Borne Mag Anomaly Density



# What are we detecting?

Dipoles

- Not necessarily munitions
- Positive and negative magnetic fields associated with a ferrous object (like + and – poles of a magnet)
- Have distinguishing characteristics:
  - Size
  - Depth
  - Orientation



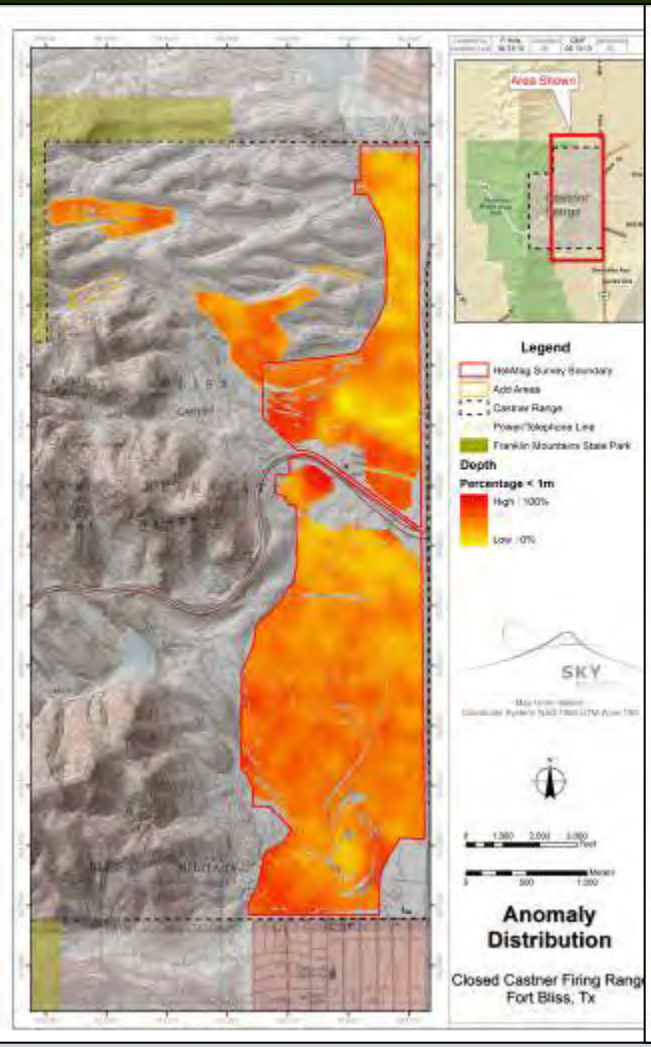
**One Strong Distinct Dipole**

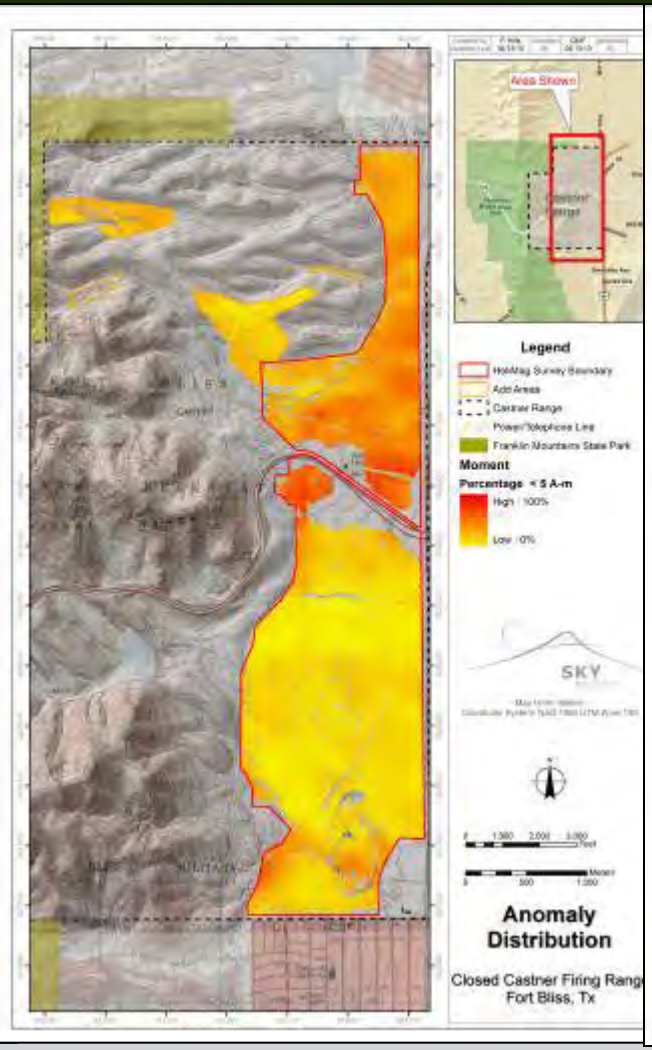
# …but which are UXO?

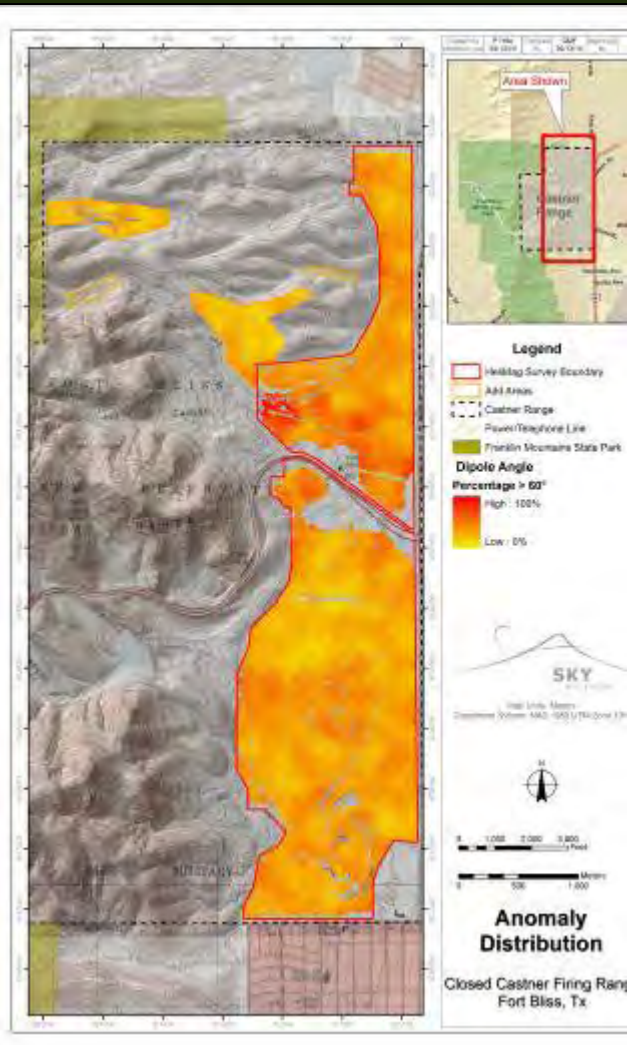
Dipoles associated with MEC tend to be:

- Small (<5 Am2),
- Shallow (<1m depth), and/or
- Low magnetic remanence (dipole angle <60 degrees)

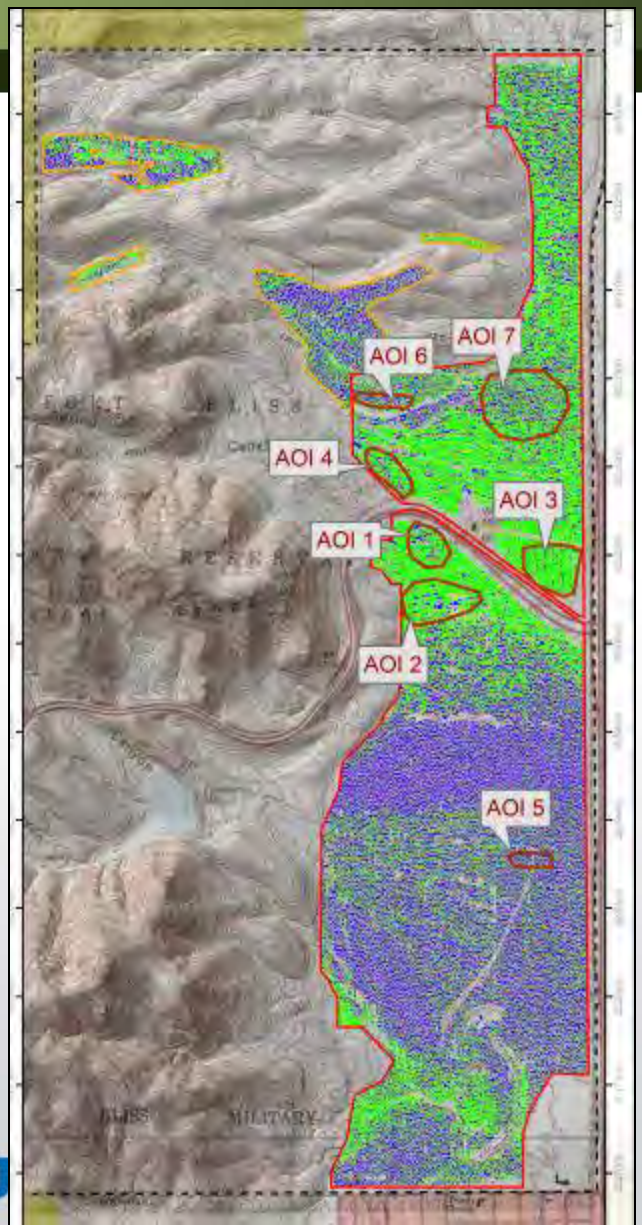
# Anomaly Distribution: Depth, Size, and Orientation

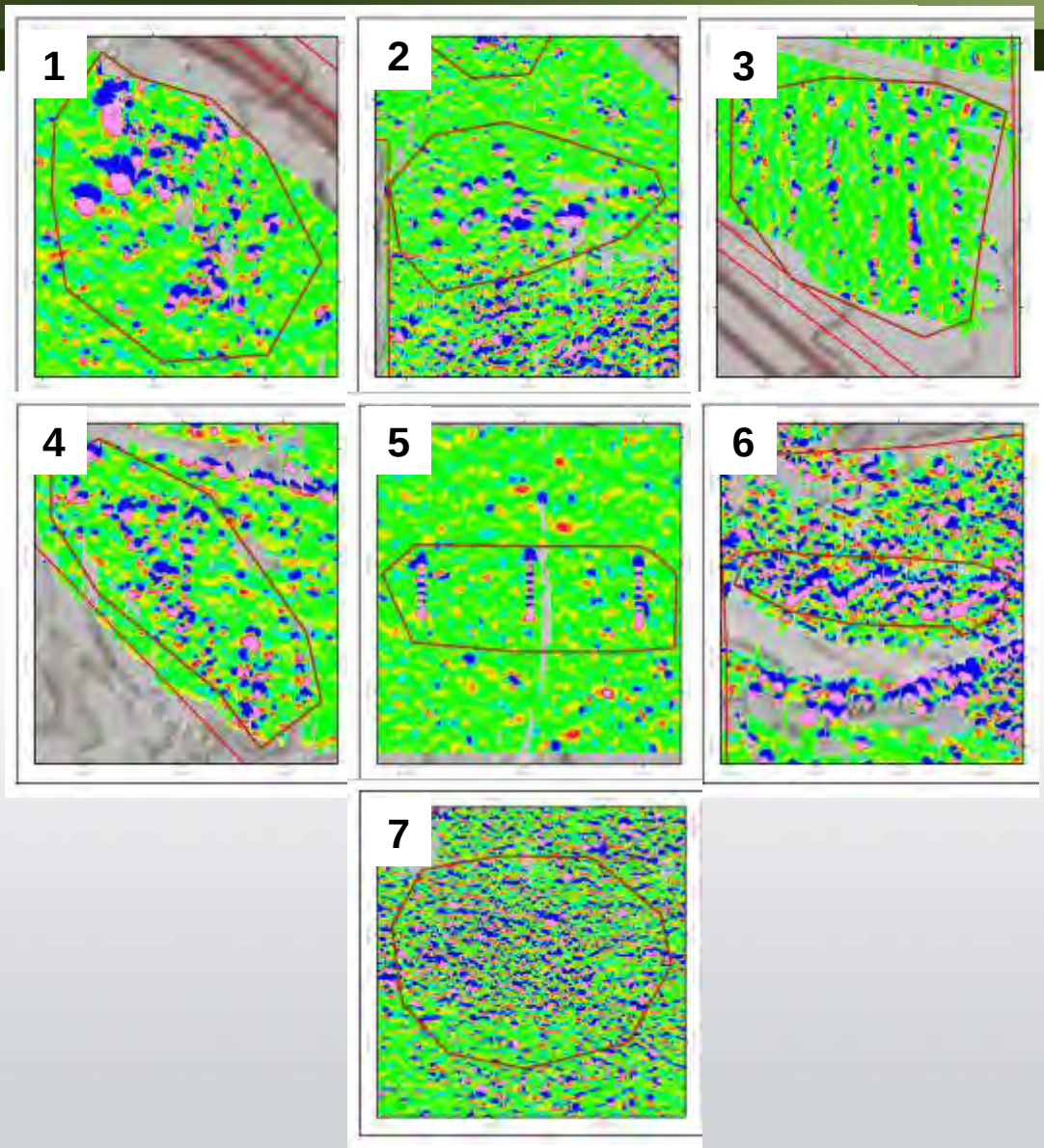


# Areas of Interest



# Helicopter-Borne Mag Study Questions

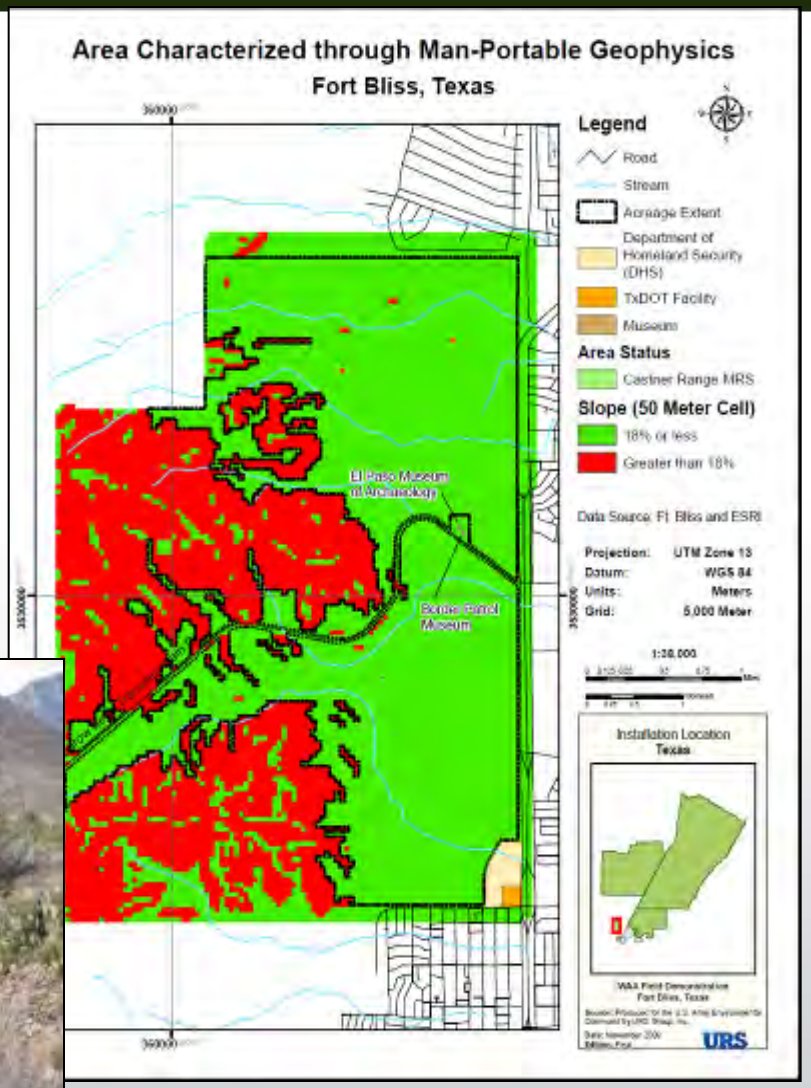
- Can helicopter-borne magnetometry reliably detect each of the munitions types expected on the MRS (i.e., 37mm projectile, 2.36in rockets, 60mm mortar, 75mm projectile)?
- Can helicopter-borne magnetometry:
  - Reliably identify areas of concentrated munitions use?
  - Reliably identify areas with no indication of munitions use?
  - Improve the understanding of relative densities and distributions of MEC across the MRS?
- How confident are stakeholders in these conclusions?
- Does helicopter-borne magnetometry data make subsequent characterization steps (i.e., ground-based geophysics) more cost effective?
- Over what percentage of the MRS can we collect helicopter-borne magnetometry data?
- For what percentage of the MRS are we able to draw statistically valid conclusions based on helicopter-borne magnetometry data?
- What are the total cost, cost per characterized acre, and cost per surveyed acre associated with helicopter-borne magnetometry?

**Recommend greater efforts on site recon and selective application.**

# Ground-based Geophysics

# Ground-Based Geophysics

- Man-portable (litter) EMI array with transect-based coverage
- Estimated characterized acreage is 4,020
- Approximately 1 million linear feet of transects
- Performers: NAEVA Geophysics and Sky Research
- 27 Jan – 18 Feb 2010

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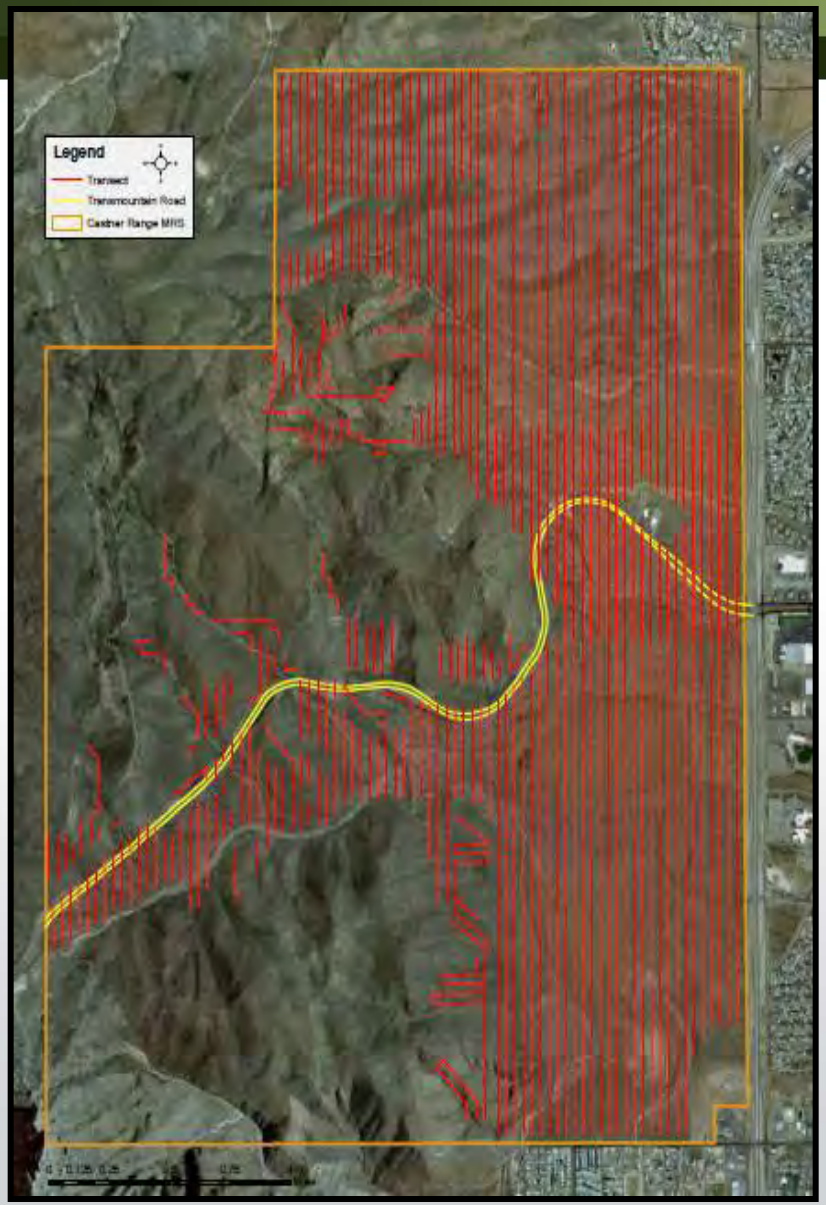
# Ground-Based Geophysics: Preliminary Results

- Able to characterize nearly all terrain up to 18% slope
- Production rates higher than anticipated
- Litter mode increases levels of uncertainty/error in DGM data
- Reproducibility of transect data is surprisingly good

Video

# Summary Statistics

- Collected data over >1 million linear feet (>200 miles) of transects
- Transect spacing approximately 57m apart
- Identified and georeferenced approximately 21,000 anomalies

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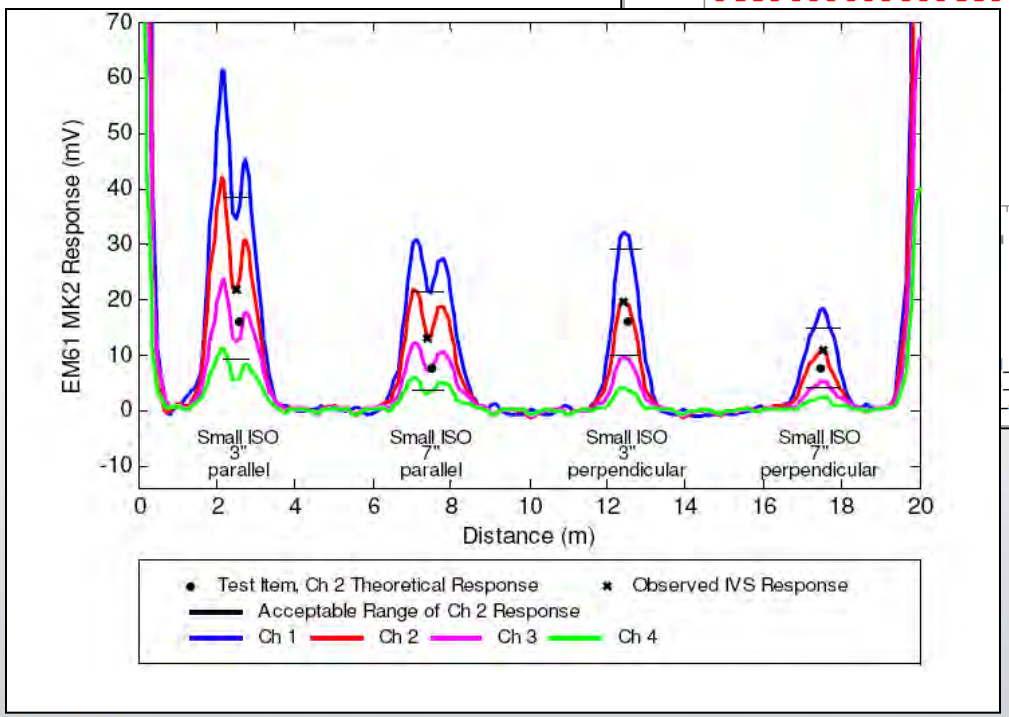
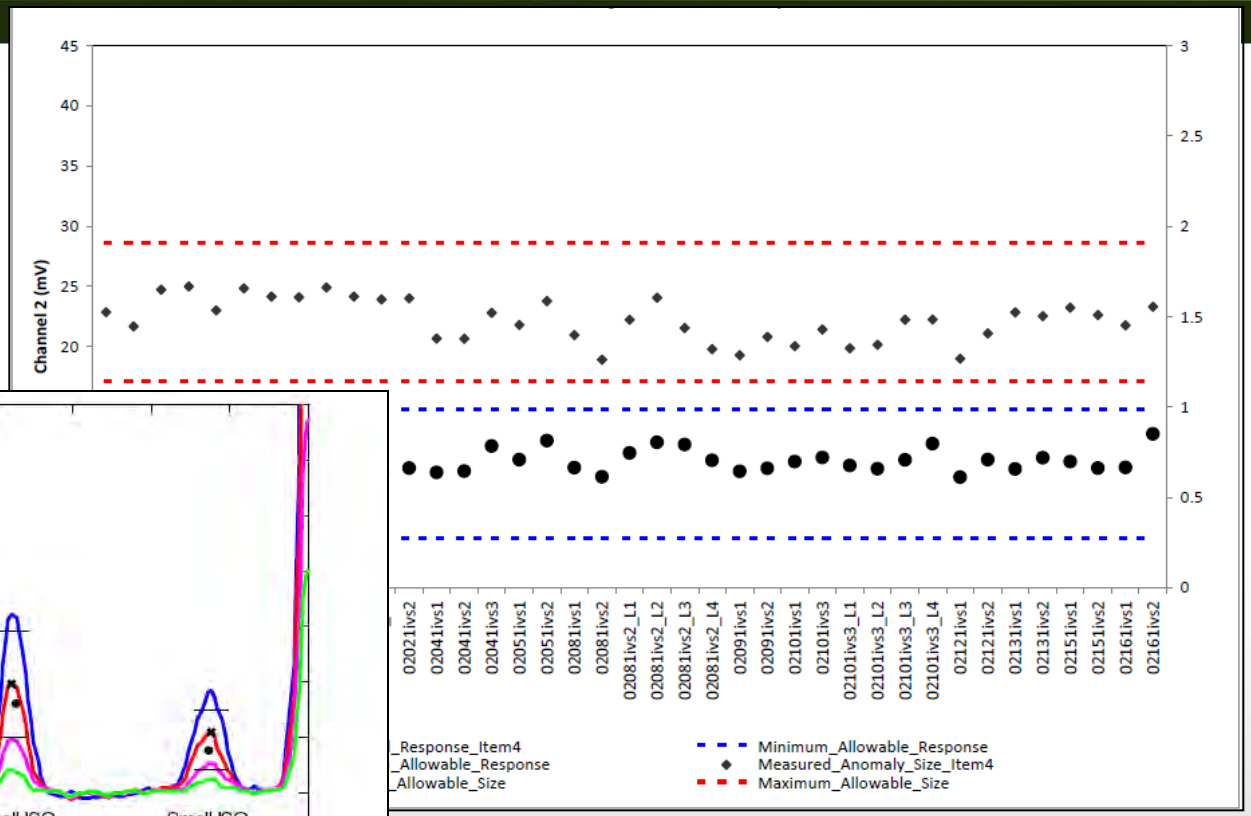
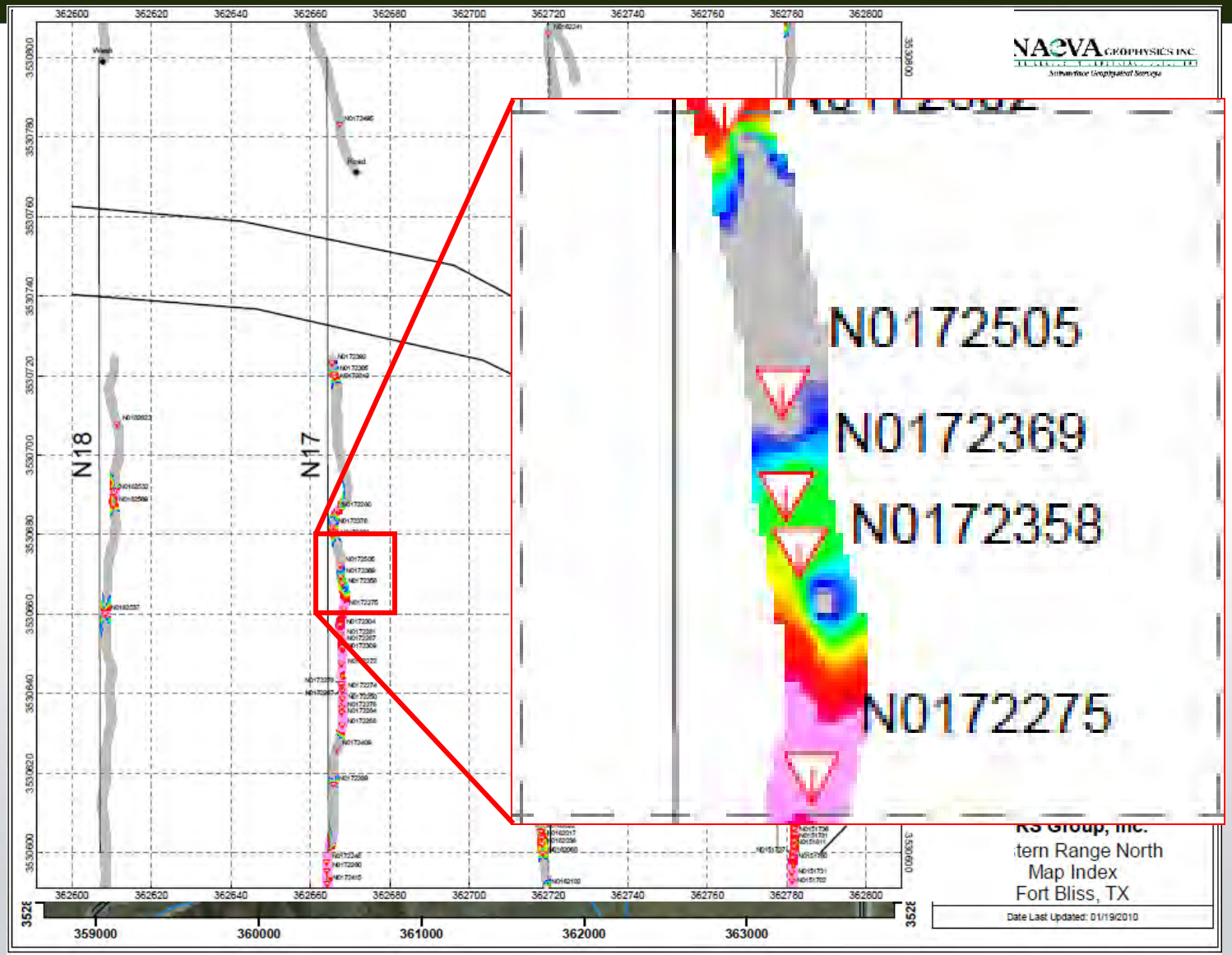
# Sample Instrument Verification Strip (IVS) Results

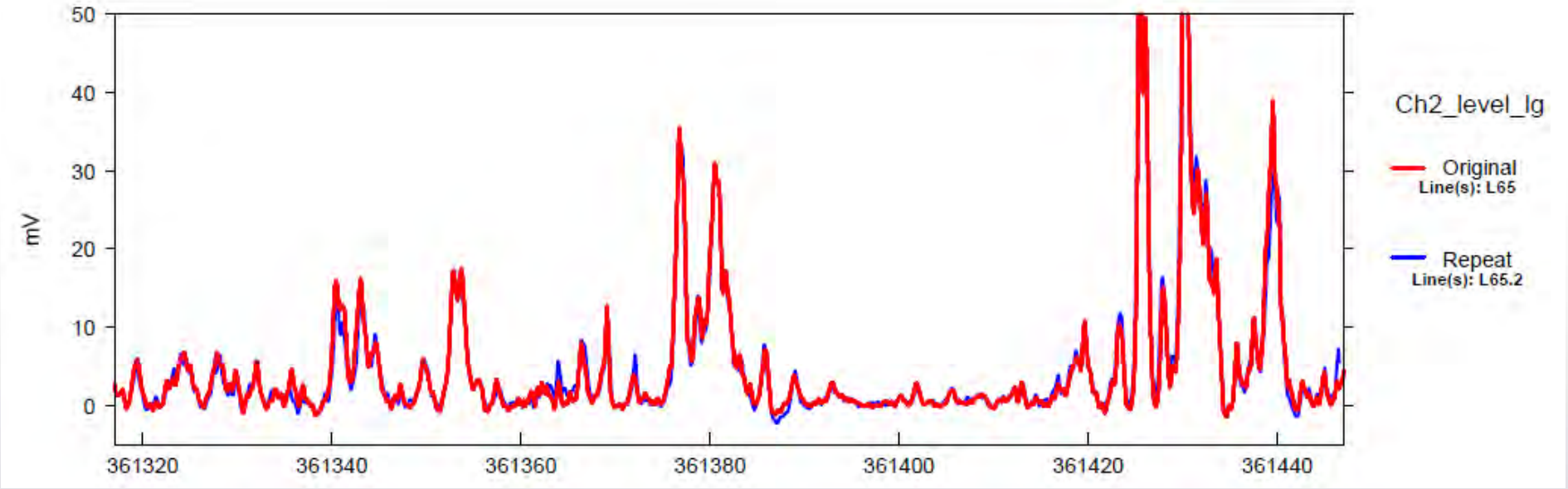


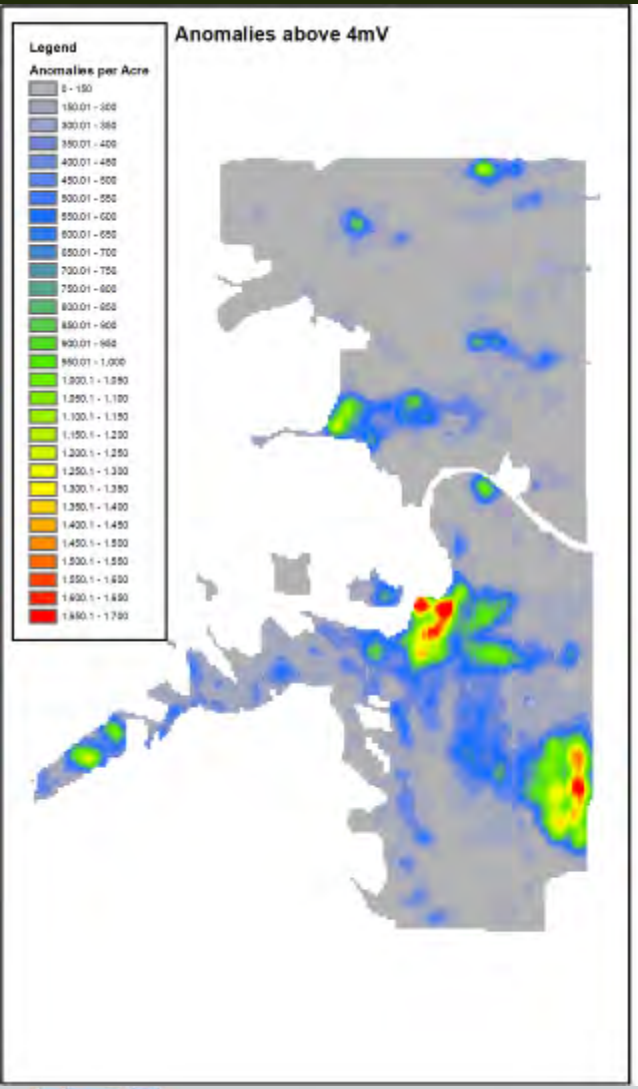
# Instrument Response and Anomalies

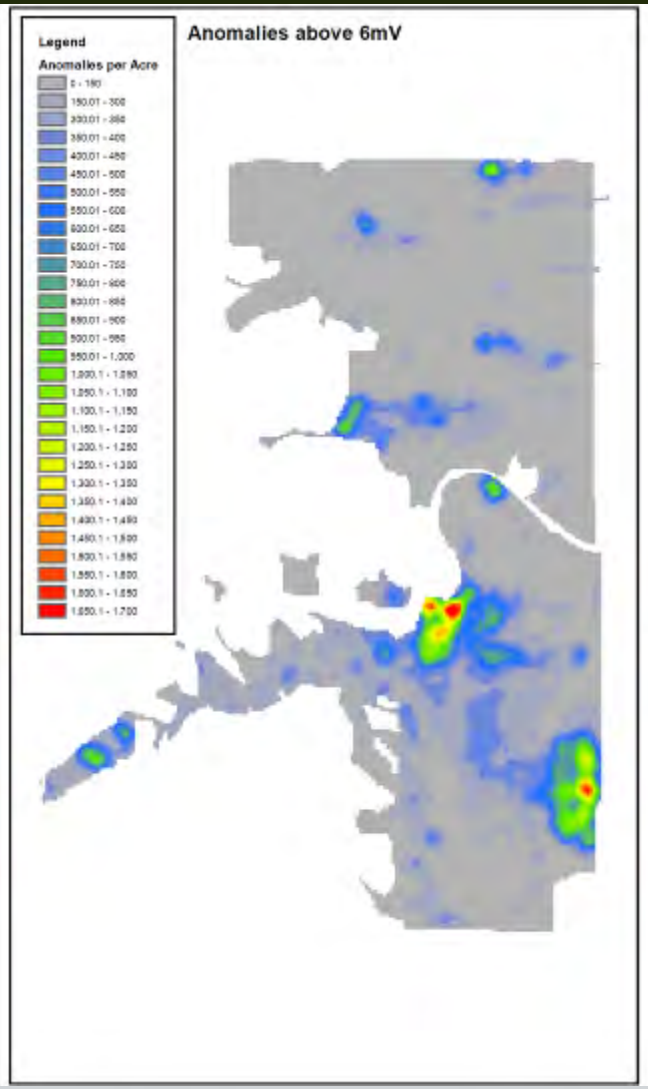


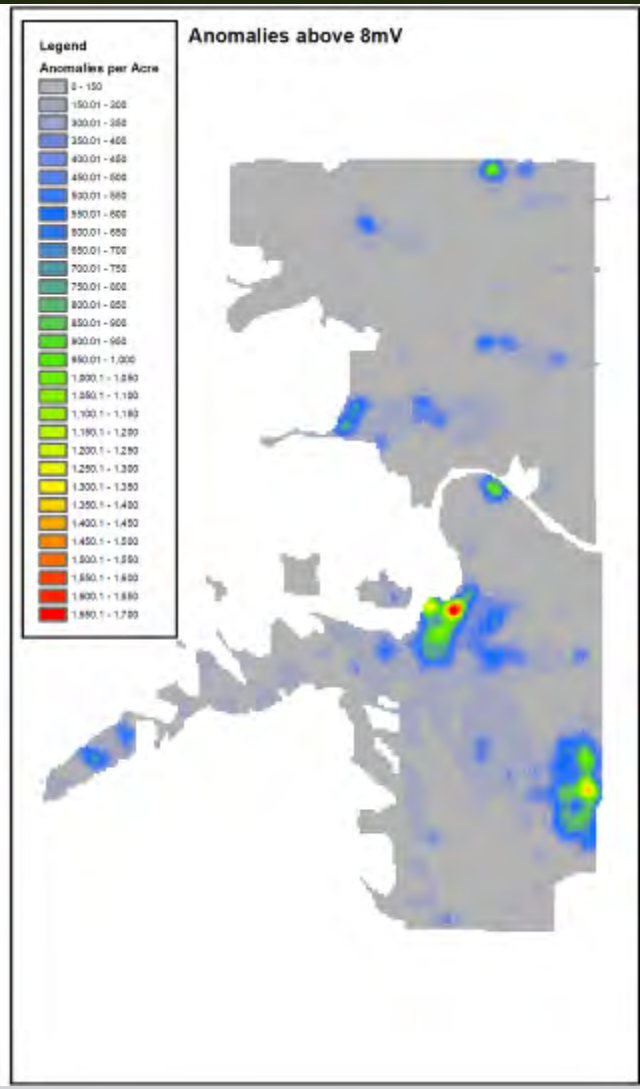
# Sample Transect Repeatability Data



# Anomaly Densities: Variable mV Threshold



# Man-Portable EMI Study Questions

- Can man-portable EMI arrays reliably detect each of the munitions types expected on the MRS (i.e., 37mm projectile, 2.36in rockets, 60mm mortar, 75mm projectile)?
- Can man-portable EMI arrays:
  - Reliably identify areas of concentrated munitions use?
  - Reliably identify areas with no indication of munitions use?
  - Improve the understanding of relative densities and distributions of MEC across the MRS?
- How confident are stakeholders in these conclusions, particularly based on the transect survey approach?
- Over what percentage of the MRS can we collect man-portable EMI array data?
- For what percentage of the MRS are we able to draw statistically valid conclusions based on man-portable EMI array data?
- What are the total cost, cost per characterized acre, and cost per surveyed acre associated with man-portable EMI array?

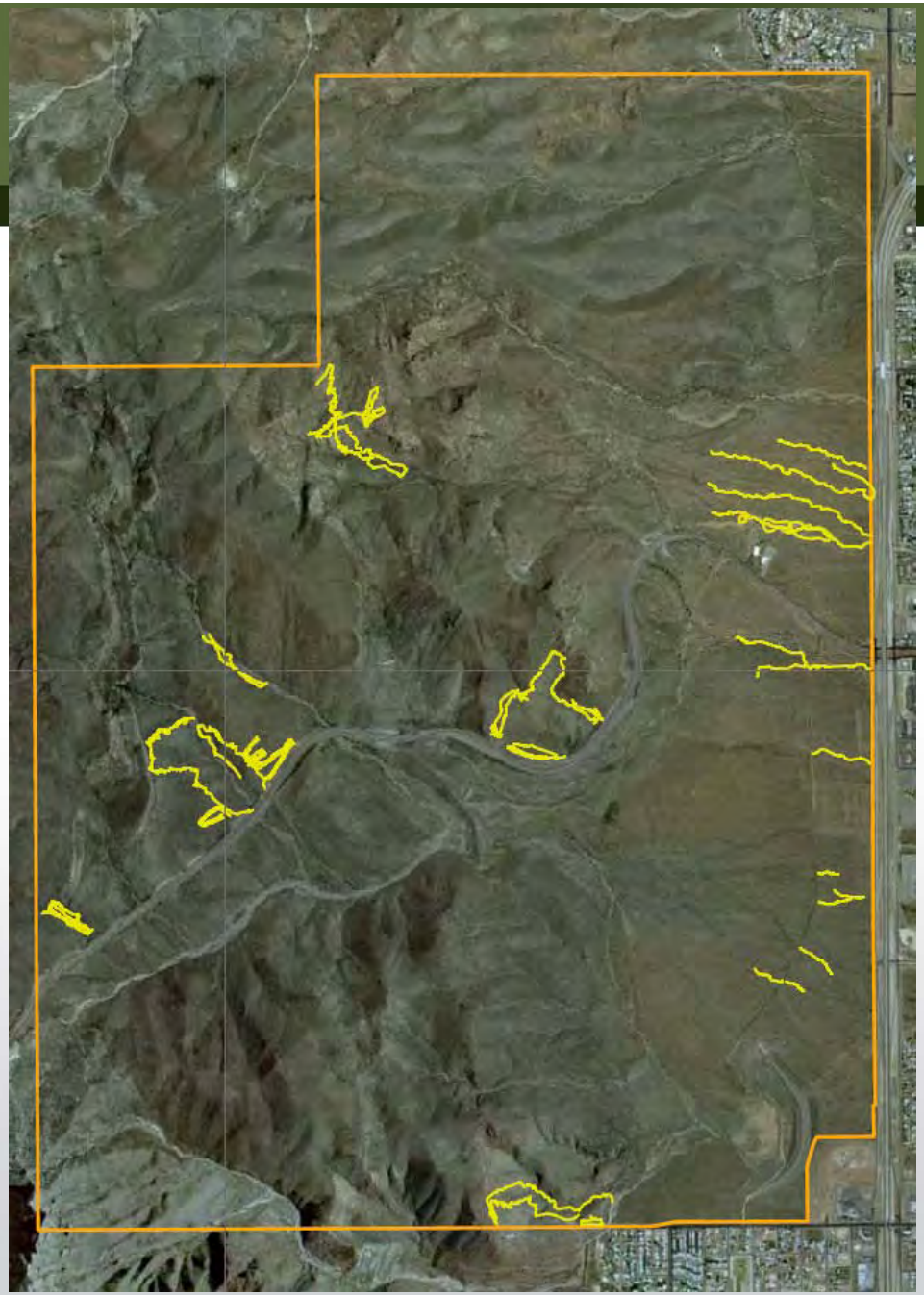
# Analog MEC Reconnaissance

# Analog MEC Reconnaissance

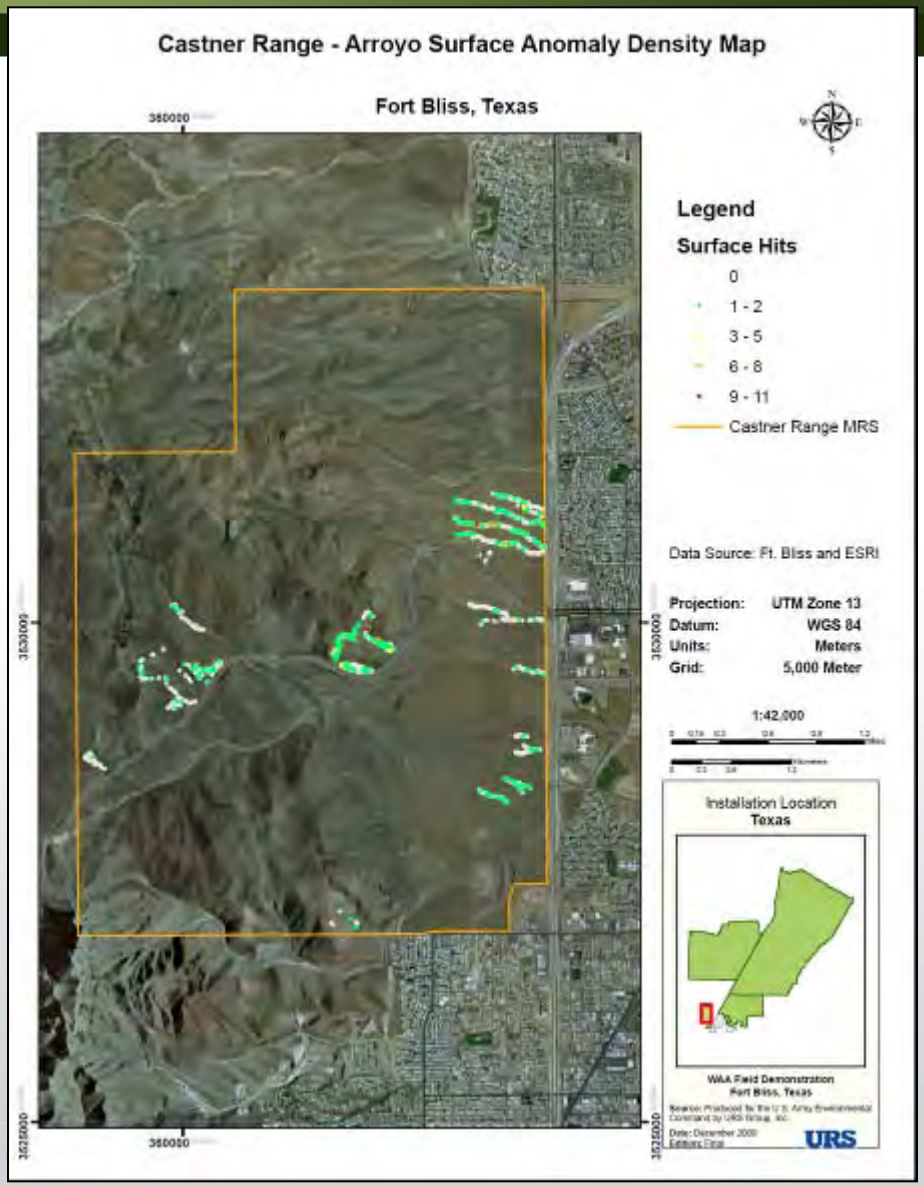
- Based on USACE, Huntsville Center, Programmatic Work Plan for MEC Reconnaissance Surveys
- Use hand-held EMI sensors (MineLab 2) and GPS/PDAs to map anomalies
- Acquire data in areas inaccessible by DGM teams due to terrain:
  - In the arroyos, to test hypothesis that relative anomaly densities are higher inside the arroyos than across the remainder of the site
  - Along the unofficial hiking trails within the mountainous terrain of the site
  - Collected data along approx 22 miles of terrain

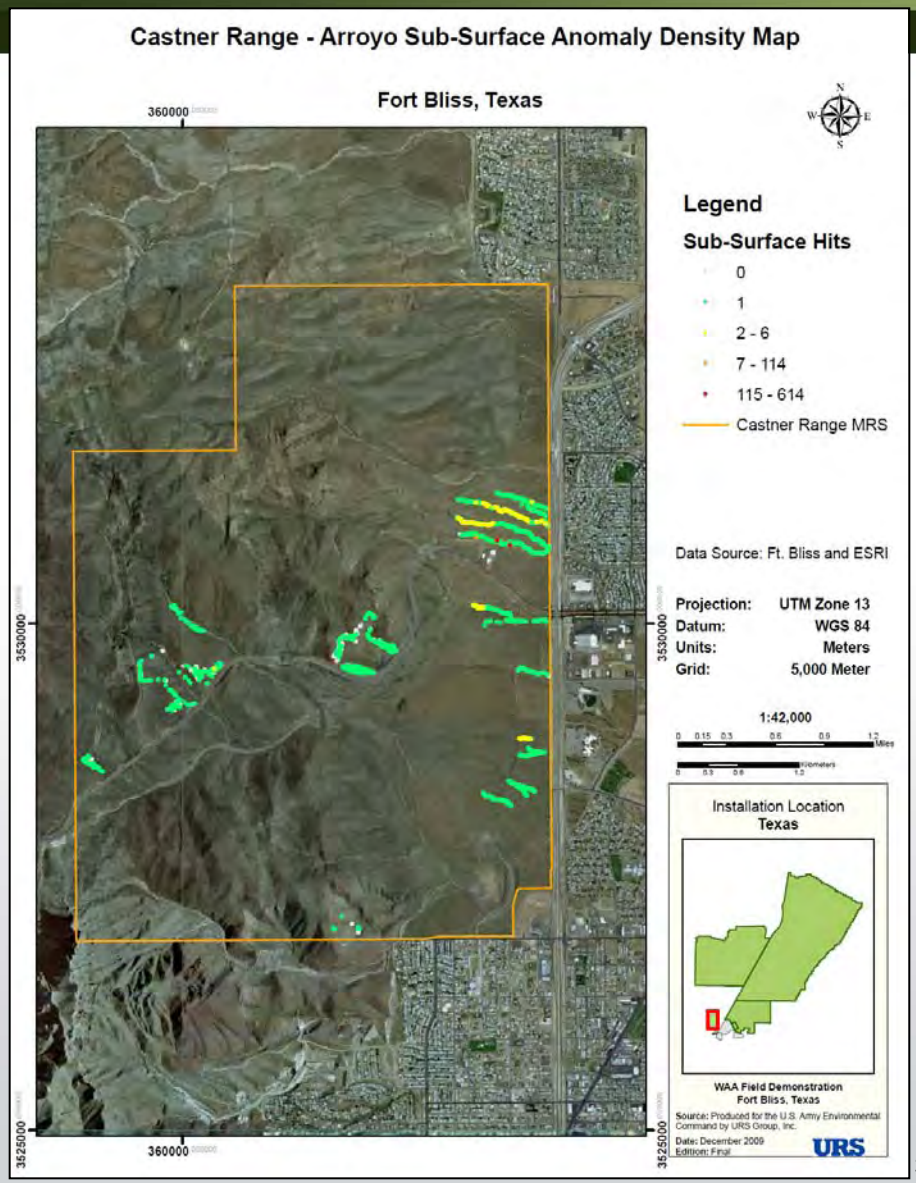
Video

# Course of Analog Data Collection



# Surface and Subsurface Anomaly Densities



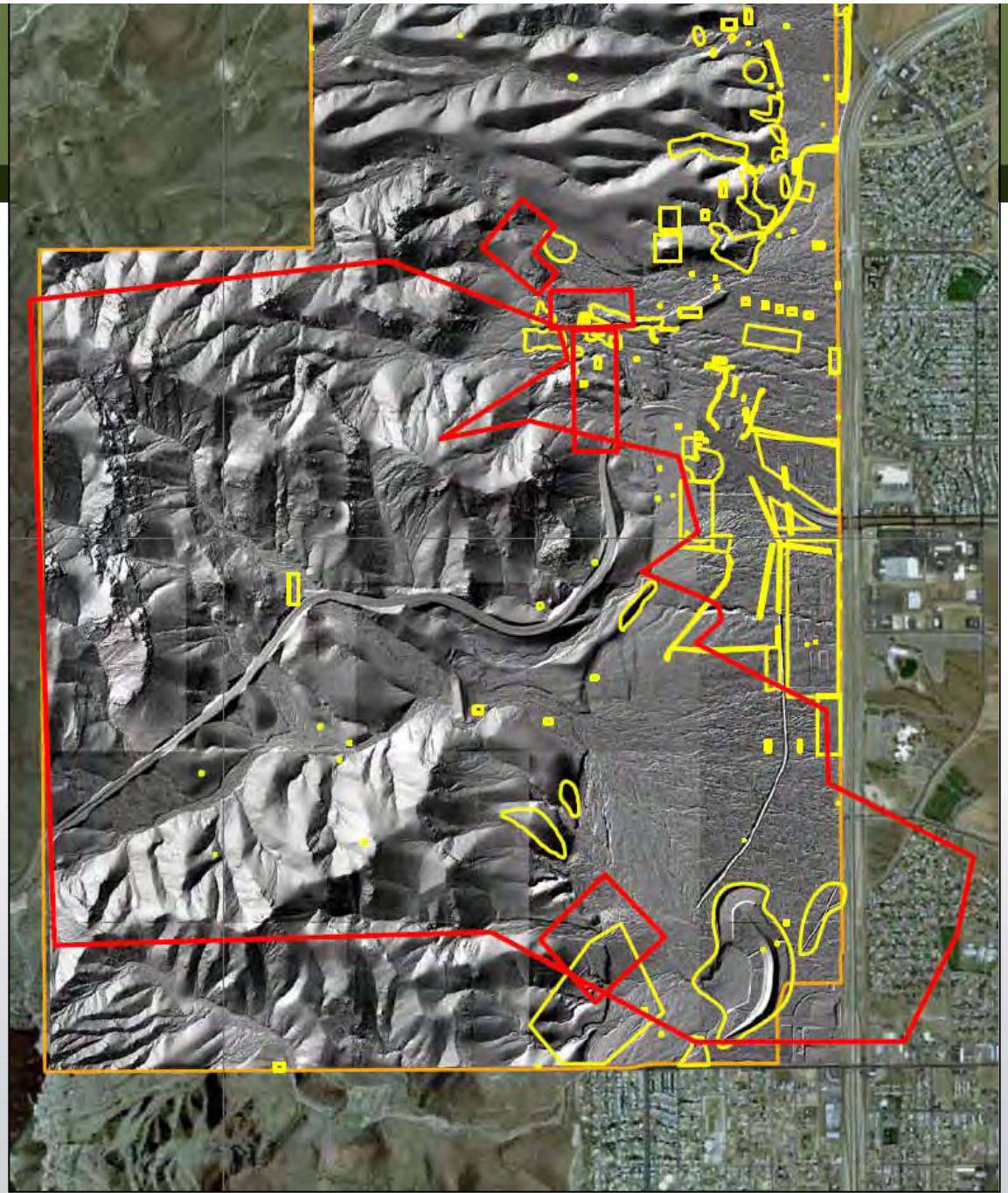



# Data Overlays

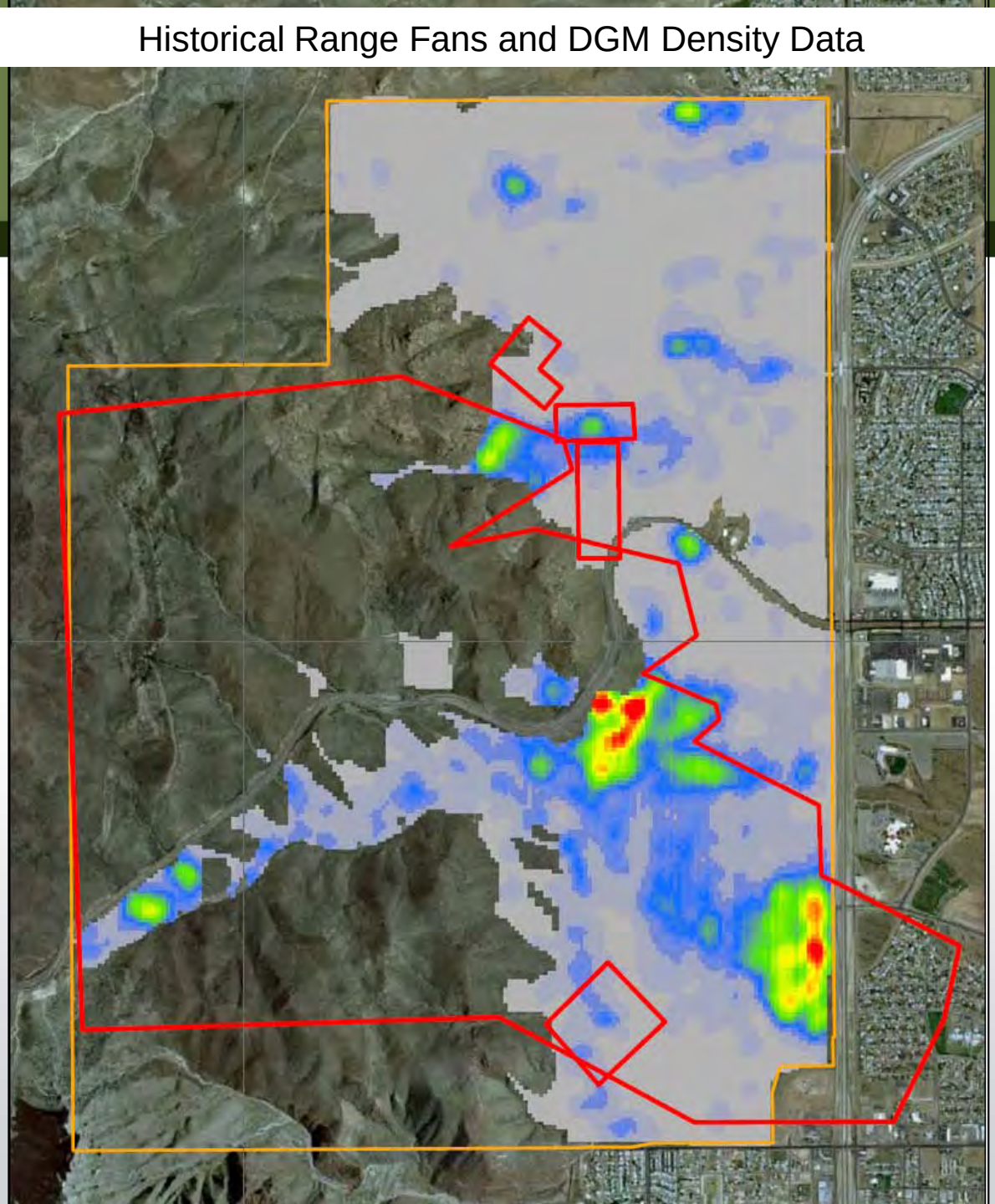
# Weight of Evidence

- Individually, data layers can be compelling
- Used together, multiple data layers corroborate, refute, expand on conclusions and increase level of confidence.
- Overlays:
  - Historical data
  - Recon/observational data
  - Optical sensor (lidar) data
  - Geophysical sensor data

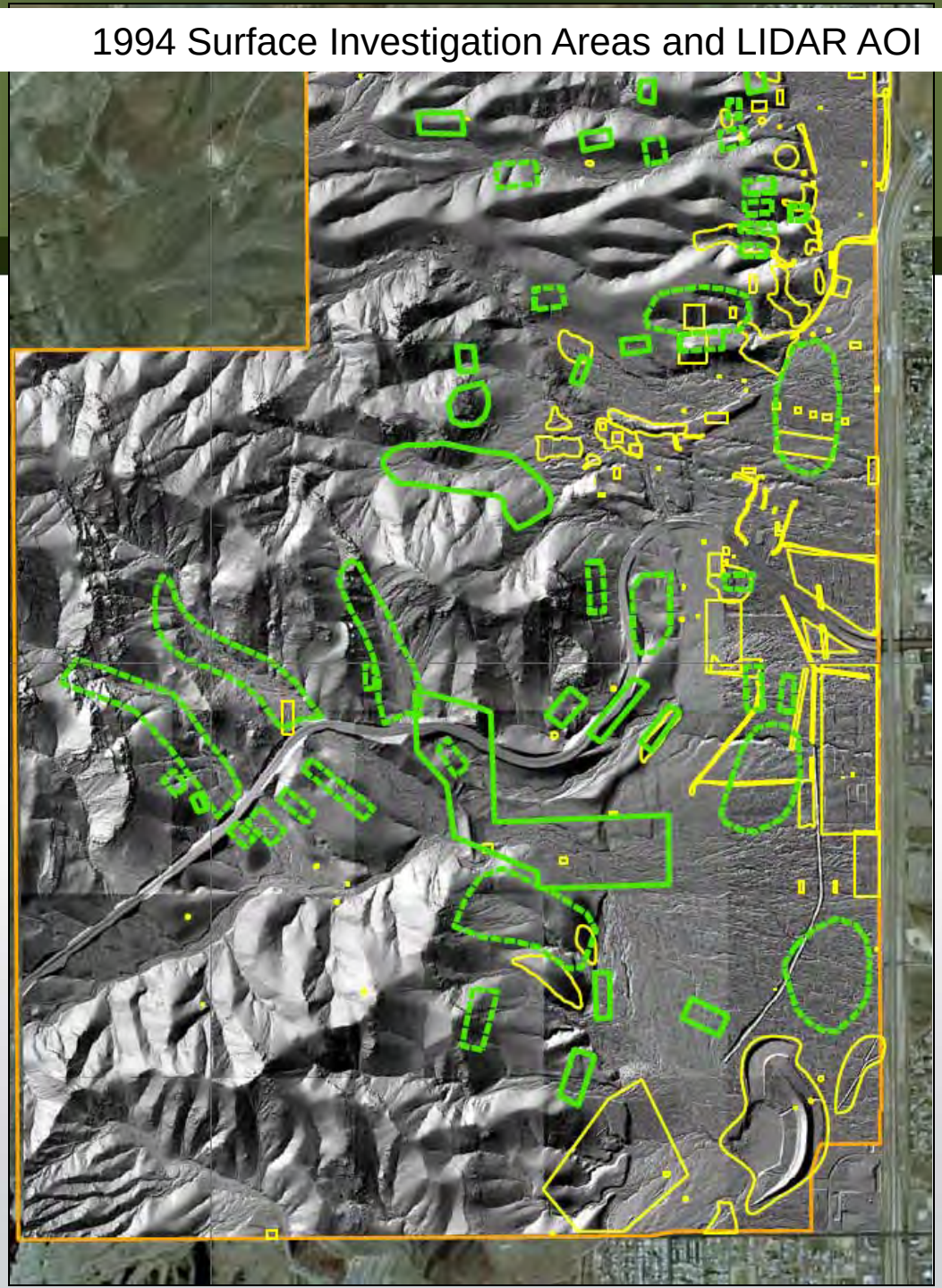
# Historical Range Fans and LIDAR Areas of Interest



# Historical Range Fans and DGM Density Data



# 1994 Surface Investigation Areas and LIDAR AOI



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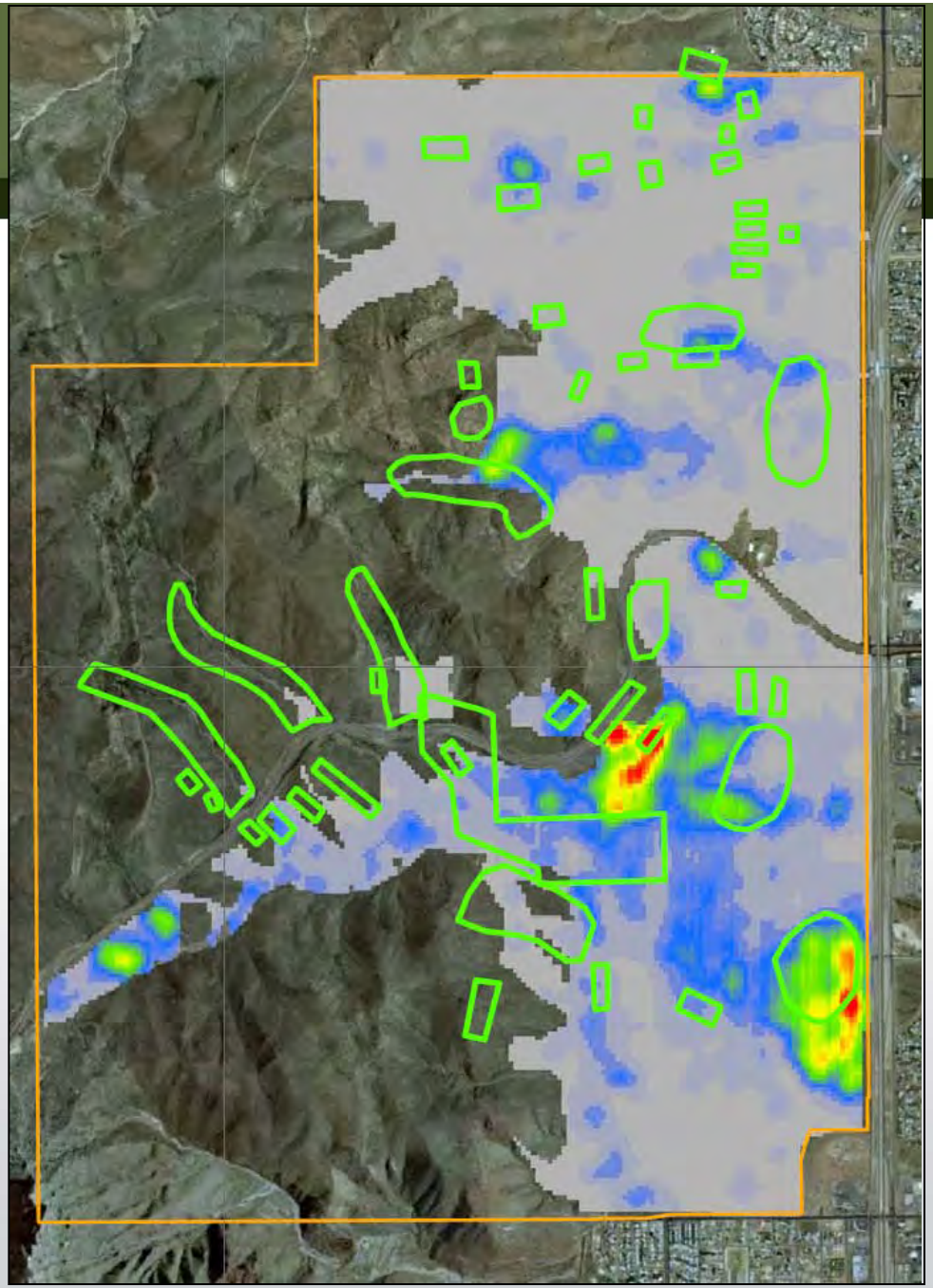
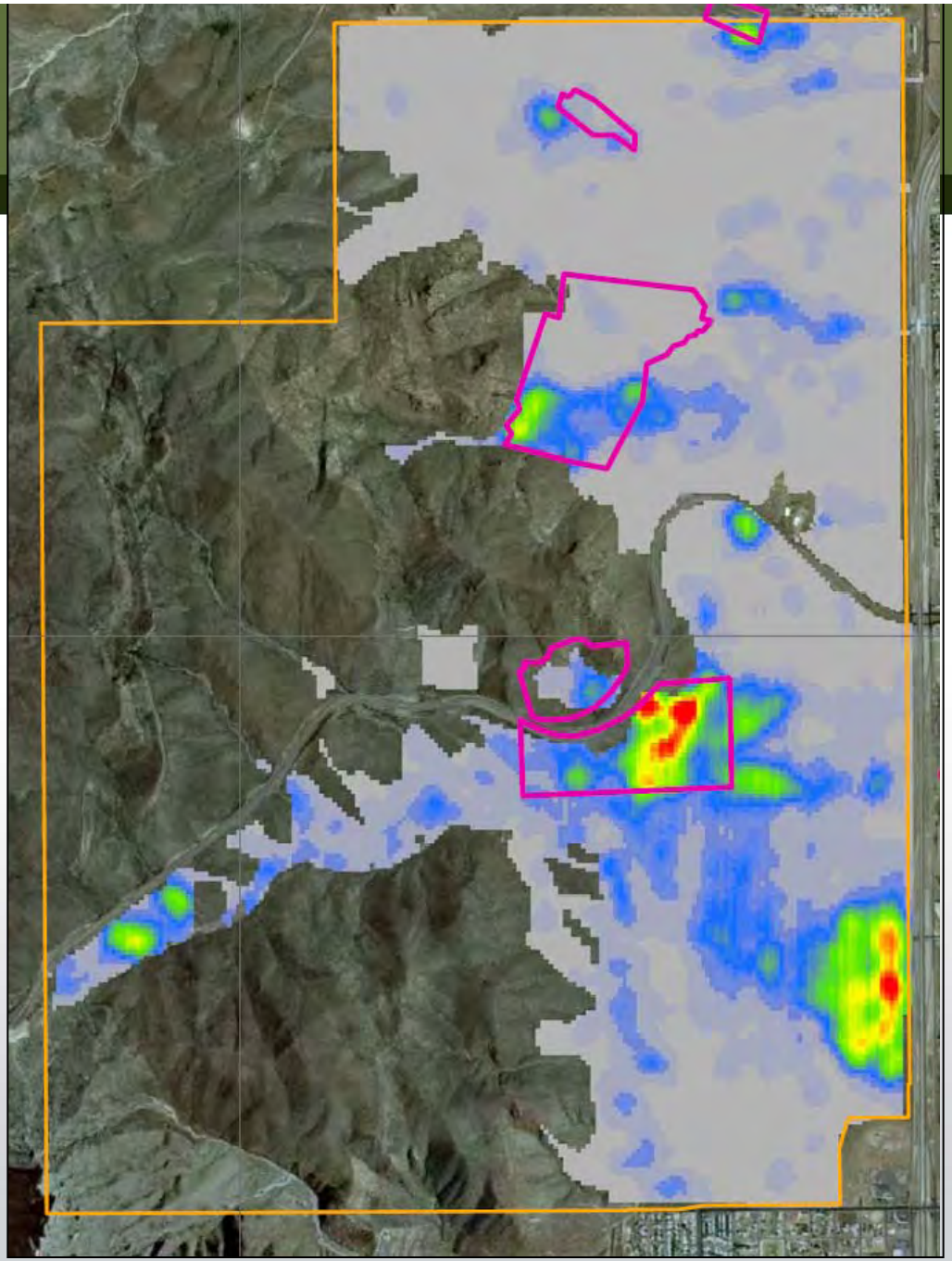
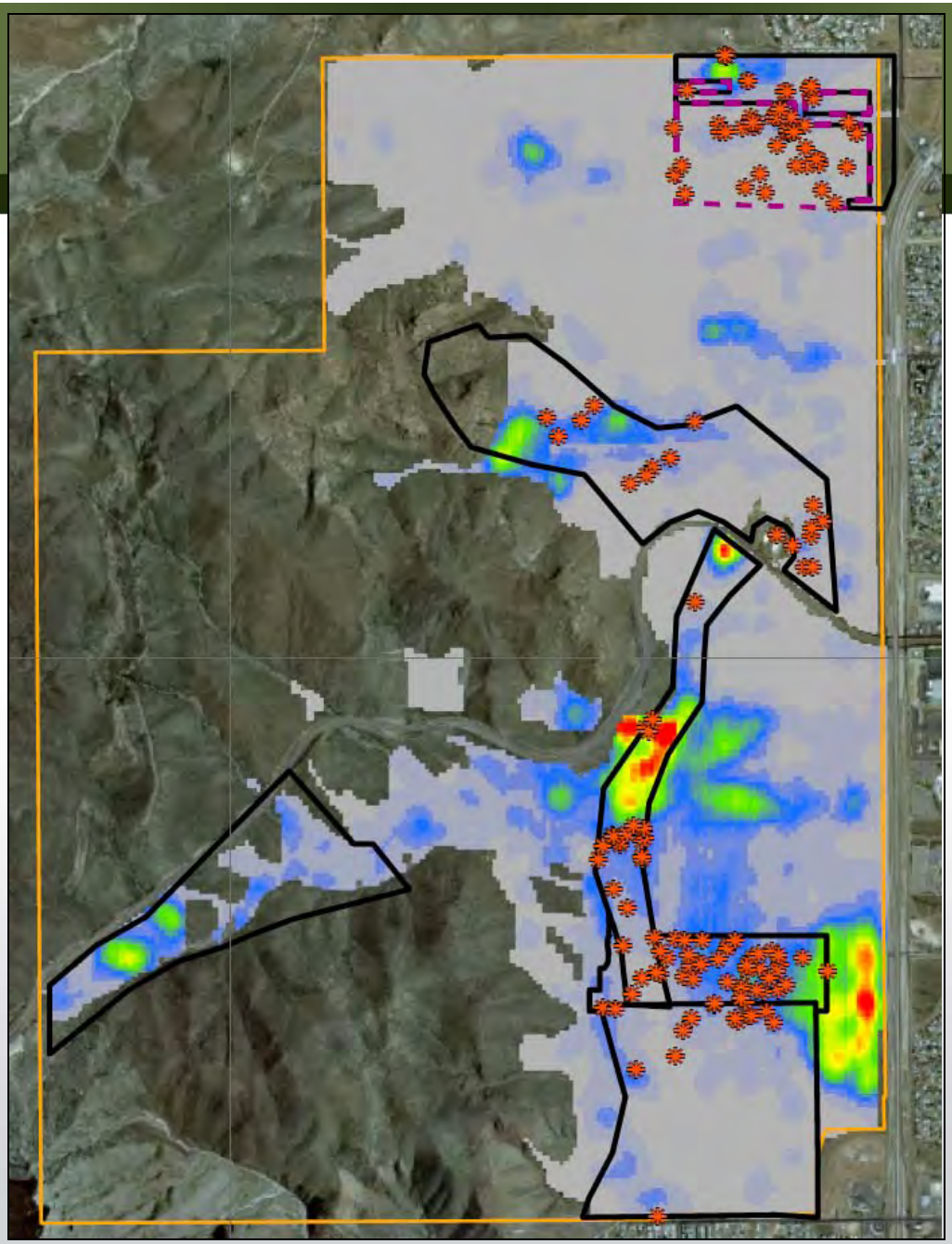


# 1997 Surface Clearance and LIDAR AOI

# 1997 Surface Clearance and DGM Density Data

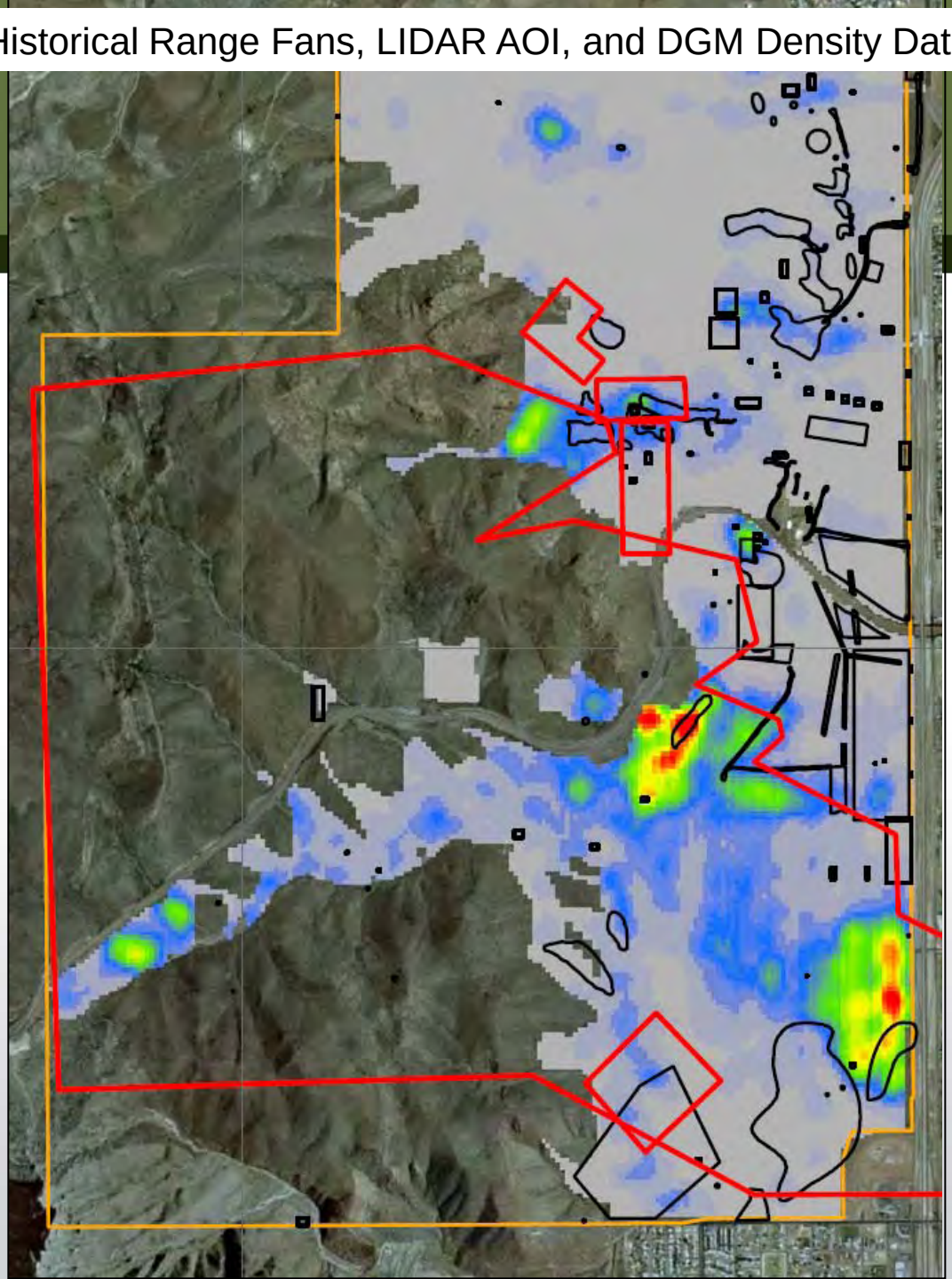


# 2004 Surface and Subsurface Clearance and DGM Density Data

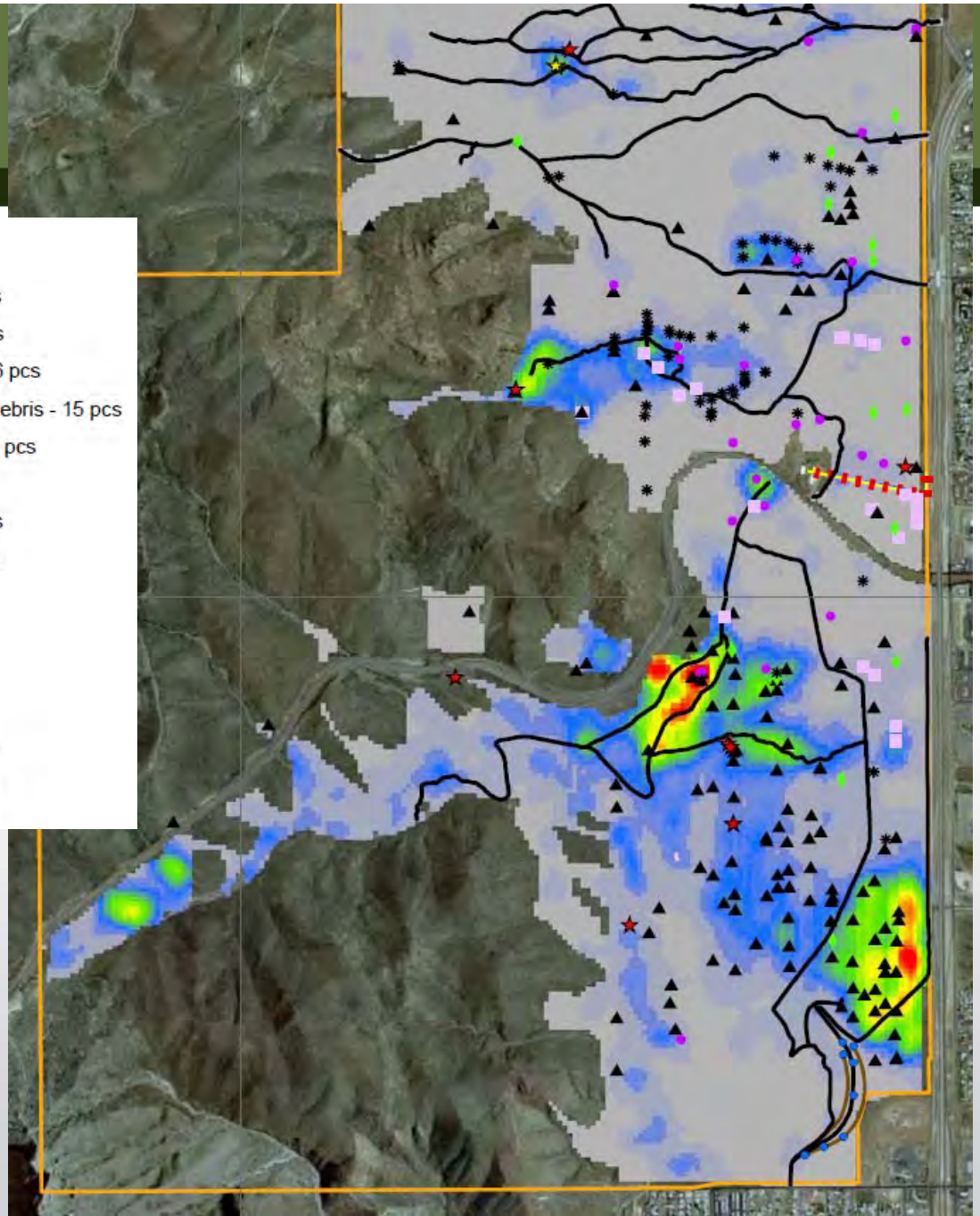


= munitions

# Historical Range Fans, LIDAR AOI, and DGM Density Data



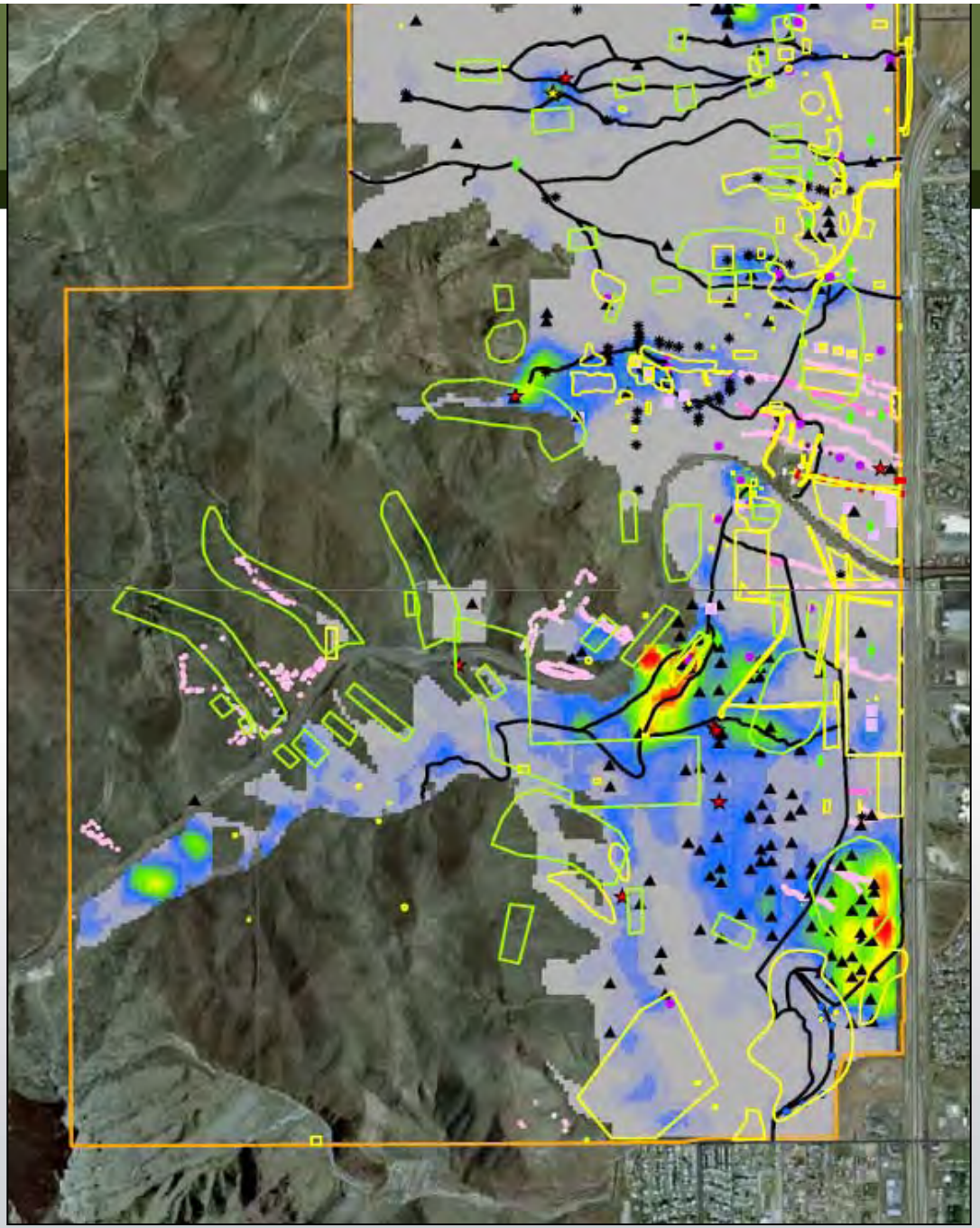
# Analog Range Reconnaissance and DGM Density Data



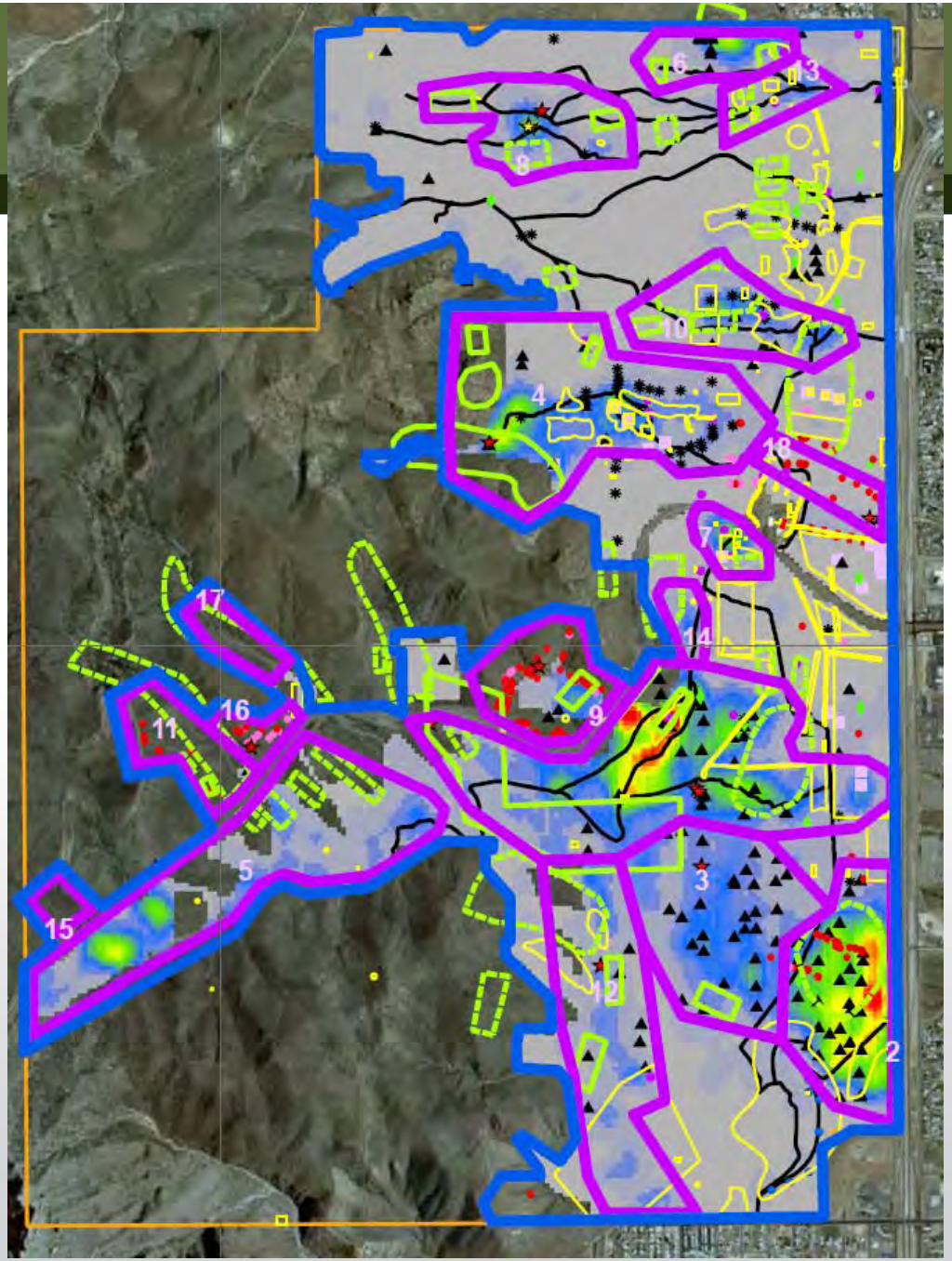
**Legend**

- Demolition Pit - 2 sites
- MEC Location - 11 pcs
- Munitions Debris - 156 pcs
- Range Residue and Debris - 15 pcs
- Concrete Feature - 24 pcs
- Dike - 8 pts
- Surface Metal - 27 pcs
- Wire Fencing - 56 pcs
- Dike
- Water Line
- Building Outline
- Road
- Power/Tel Line (Live)
- Castner Range MRS

# The Big Picture



# Proposed Target Area Delineation



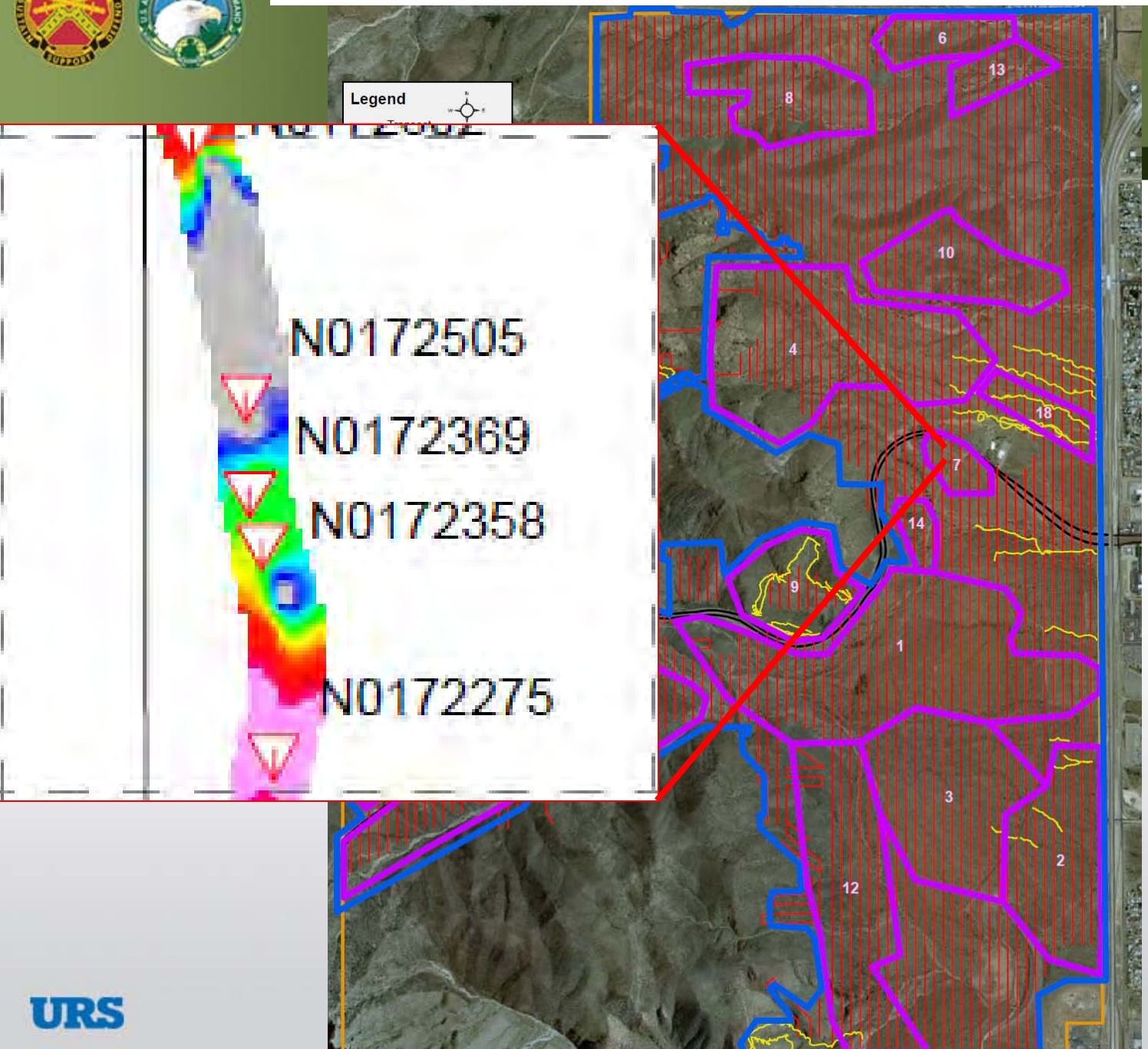
# Intrusive Investigation (Future Work)

# Intrusive Investigation

- Verify target and non-target areas:
  - Target areas:
    - Develop hypotheses about density of HE frag and MEC items per acre (e.g., >/= 50 pieces per acre)
    - Test hypotheses through intrusive investigation of detected anomalies on transects to confirm areas as targets (to 90% confidence level)
  - Non-target areas:
    - Develop hypotheses about MEC densities (e.g., less than or equal to 0.5 MEC items per acre)
    - Test hypotheses through intrusive investigation detected anomalies on transects to confirm non-target areas (90% confidence level)
- Characterize nature and extent of anomalies within target areas
  - Size
  - Nomenclature
  - Condition
  - Depth
  - Orientation
  - Coordinates
  - Photographs

URS

# Notional Sampling Areas for Intrusive Investigation



# Coordination and Consultation

- Coordinate dig locations with Fort Bliss natural and cultural resources staff to minimize disturbance of sensitive areas
- Conduct Section 106 consultation through Fort Bliss programmatic agreement with continued consultation with the Tribes

# Intrusive Procedures

- UXO Tech teams pinpoint anomaly locations using handheld EMI
- Use hand-tools to excavate all anomalies in sampling area
- Classify items
  - MEC
  - Munitions debris
  - Range related debris
  - Cultural debris
- Record data about each item

# Explosives Site Plan (ESP)

# Overview of ESP

- Prepared in accordance with:
  - DoD 6055.9-STD, DoD Ammunition and Explosives Safety Standards
  - EM 385-1-97, Explosives Safety and Health Requirements Manual
- Describes how explosives, including recovered MEC and MPPEH, will be safely managed during the project
  - Management of commercial explosives
  - Methods of MEC disposal/destruction
- Prescribes safety criteria including minimum separation distances and quantity distance arcs

# Commercial Explosives

- Jet perforators. Total NEW = 4.4 lbs
- 50-grains/foot detonation cord. Total NEW = 10 lbs
- Electric blasting caps. (To ensure proper compatibility and separation, stored in integral cap box mounted on side of magazine.)

# Explosives Storage

Options for explosives storage:

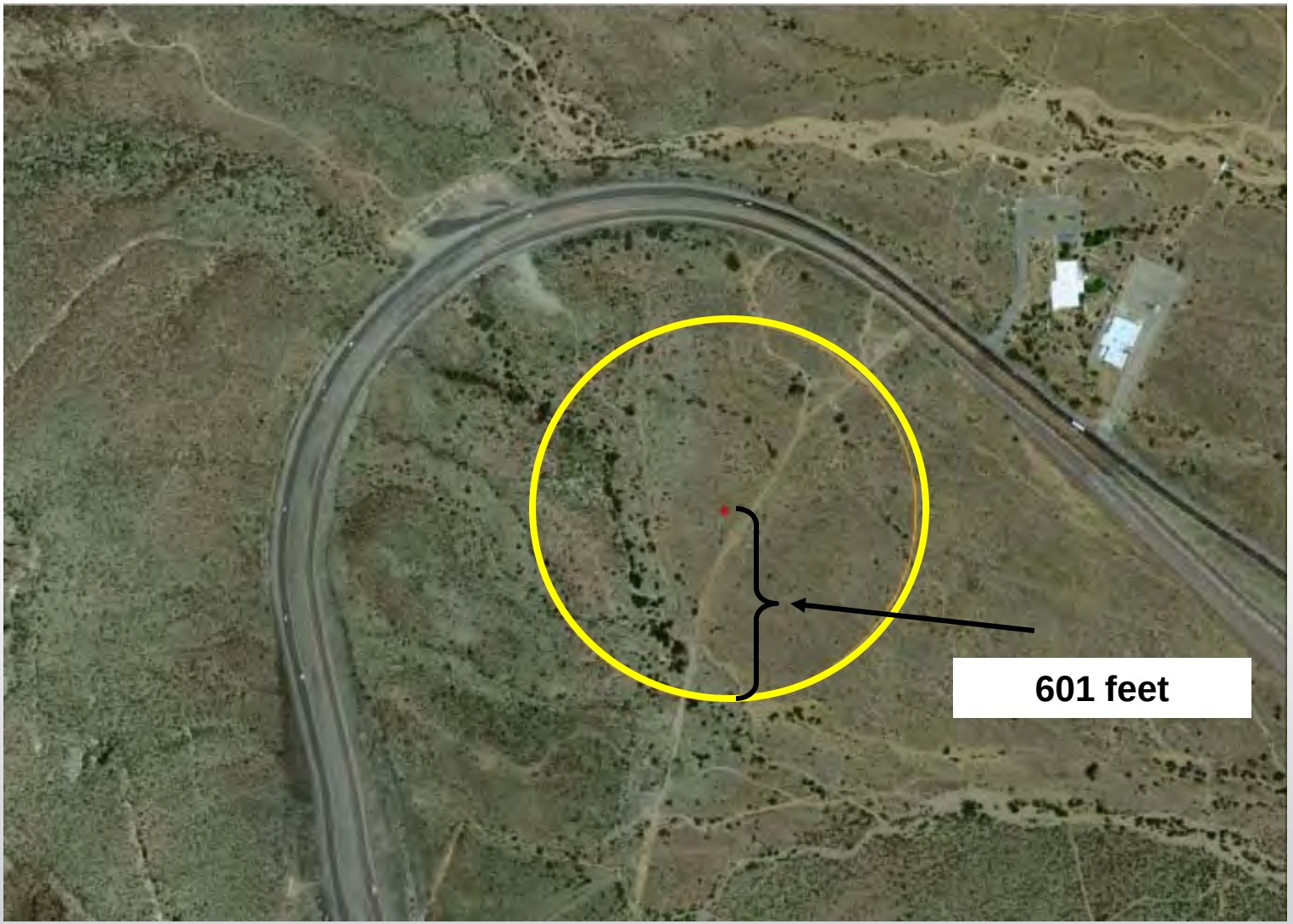
- Fort Bliss ASP
  - Very secure
  - 45 minutes away
  - Transport over public highways
  - Competing with military units for time
- Sited Type 2 BATF Magazine
  - On-site
  - Exclusive use
  - Safe and secure

**Type 2 BATF Explosives Storage Magazine**

# Explosives Siting Requirements

- Quantity-distance arcs (separation based on NEW and HD) between storage and:
  - Operations
  - Buildings and roads
  - Other “exposed sites”
- Compatibility of storage
- Access control
  - Fencing
  - Locks
- Lightning protection / grounding

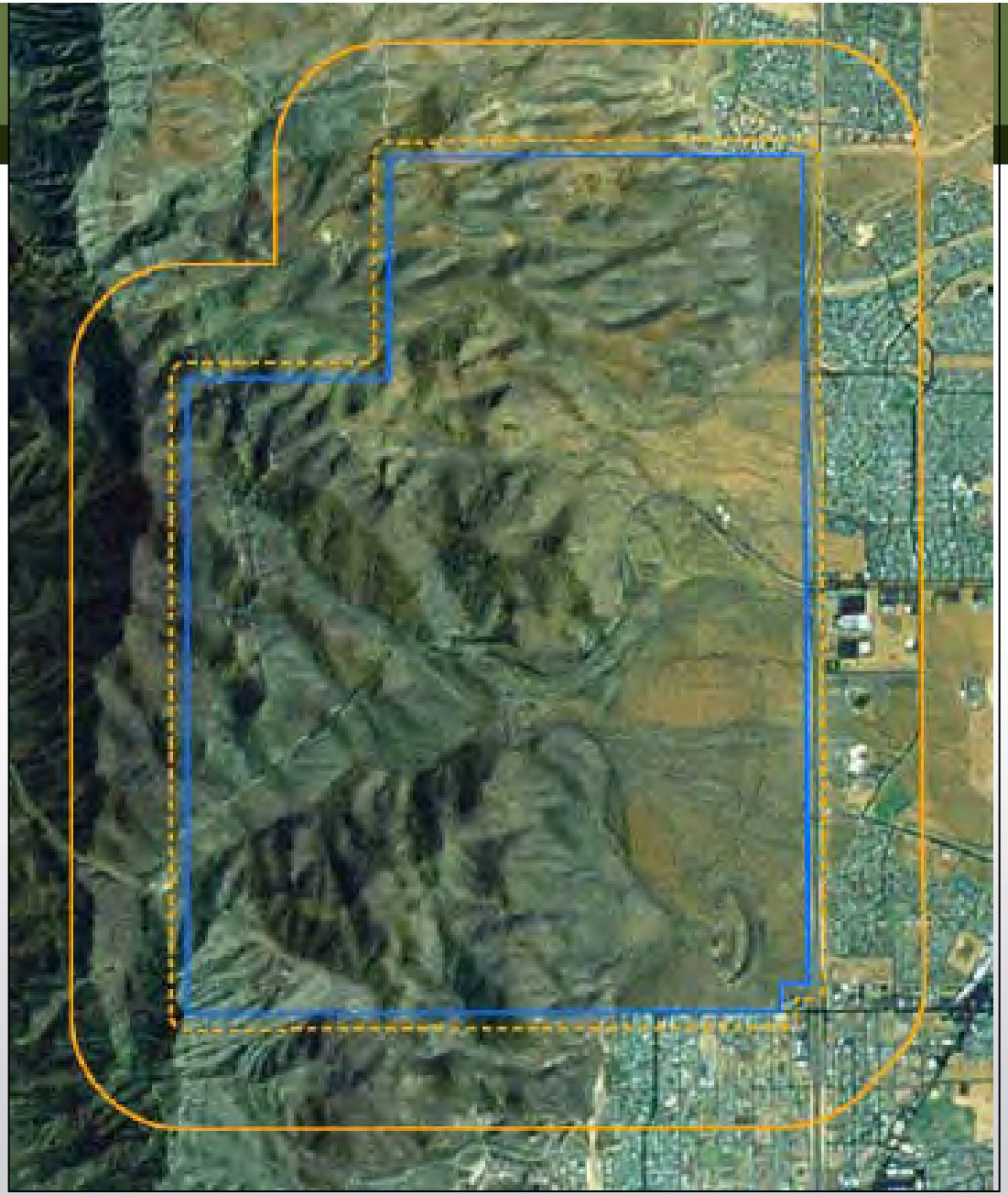
# Quantity Distance Safety Arc Around Explosives Storage



# Minimum Separation Distances

| Area | MEC[2] | MSDs (feet)[1] | | | | |
|---|---|---|---|---|---|---|
| | | For Unintentional Detonations | | For Intentional Detonations | | |
| | | Team Separation Distance (K40) | HFD | Without Engineering Controls (MFD-H) | Using Sandbag Mitigation | Using Water Mitigation Carboys/Pool |
| Closed Castner Firing Range MRS (FTBLS-004-R-01) | 155mm Mk I & Mk III HE projectile | 122 [3] | 447 [4] | 2842 | Not Applicable | Not Applicable |

# Maximum Fragmentation Distance and Hazardous Fragmentation Distance



# Disposal Operations

- MEC will be detonated in place. Exceptions:
  - Movement necessary for the efficiency of operations or the protection of people, property, or critical assets
  - Risk associated with movement is acceptable
  - SUXOS and UXOSO must agree with the risk determination
- If occupied buildings or roadways are within the MFD-H, implement one of the following:
  - Implement engineering controls to reduce the MSD in accordance with HNC-ED-CS-S-98-7, August 1998, Use of Sandbags for Mitigation of Fragmentation and Blast Effects Due to Intentional Detonation of Munitions
  - If acceptable to move, relocate beyond the MFD-H from occupied buildings or roadways
  - Coordinate with Fort Bliss to evacuate any occupied buildings or block public roadways during MEC disposal operations
- Perforate MEC using commercial jet perforator charges in accordance with Explosive Site Plan (ESP)

# Project Schedule

# Project Schedule

- September 2010 – February 2011: Anomaly identification and intrusive investigation
- February – May 2011: WAA Report writing

# Questions?

# Introduction to Incremental Sampling

# What are we doing?

- Field testing the U.S. Army Incremental Sampling Guidance
- Attempting to characterize nature and extent of MC on Castner Range
  - 7,007 acres
  - Variety of uses, terrains, potential for exposure

# Munitions Constituents (MC)

In addition to UXO/MEC

- Energetics (examples):
  - Nitramines (RDX)
  - Nitroaromatics (TNT)
  - Nitrate Esters (NG)
- Metals (examples):
  - Lead
  - Chromium
  - Antimony
  - Zinc
  - Copper

# The Problem: Heterogeneous Chunks (Chips)

- Heterogeneous:
  - Put 10 chips into a cookie recipe
  - Bake 100 cookies
  - Majority of cookies (samples) will have zero chips (underestimating chocolate concentration)
- Homogeneous:
  - Try it again but, this time, grind and blend the dough until the chocolate is evenly distributed throughout
  - Every cookie (sample) will have a representative amount of chocolate (makes really bad cookies though)

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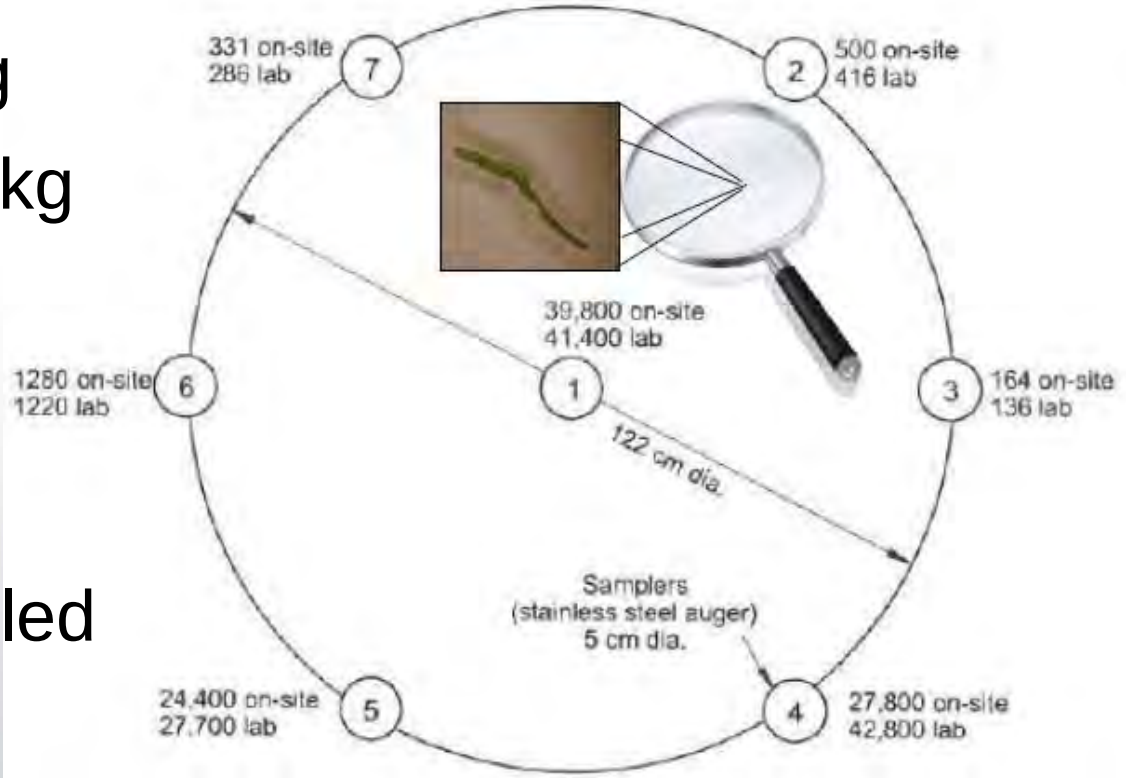
# Heterogeneity of Explosives in Soils

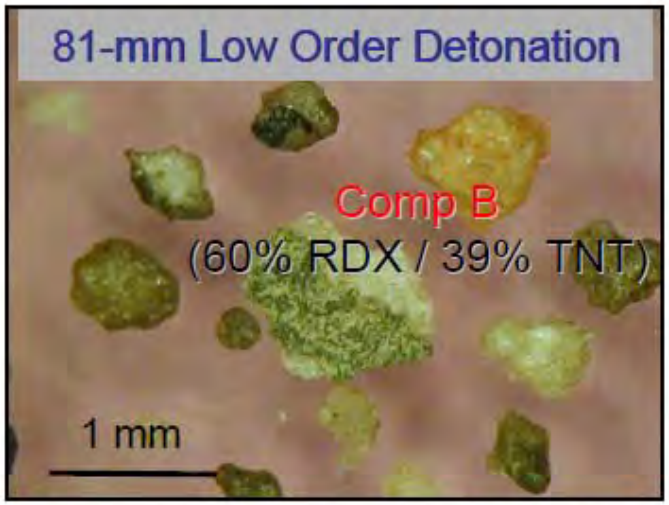
14 Samples from a 4 ft circle:

*per Tom Jenkins, 1996*

- Range from
  136 – 42,800 ug/kg
- Mean = 14,900 ug/kg
- Median = 1,220
- Relative Standard Deviation = 120%
- 1.2% of area sampled



# Explosives/Propellant Residue Particles



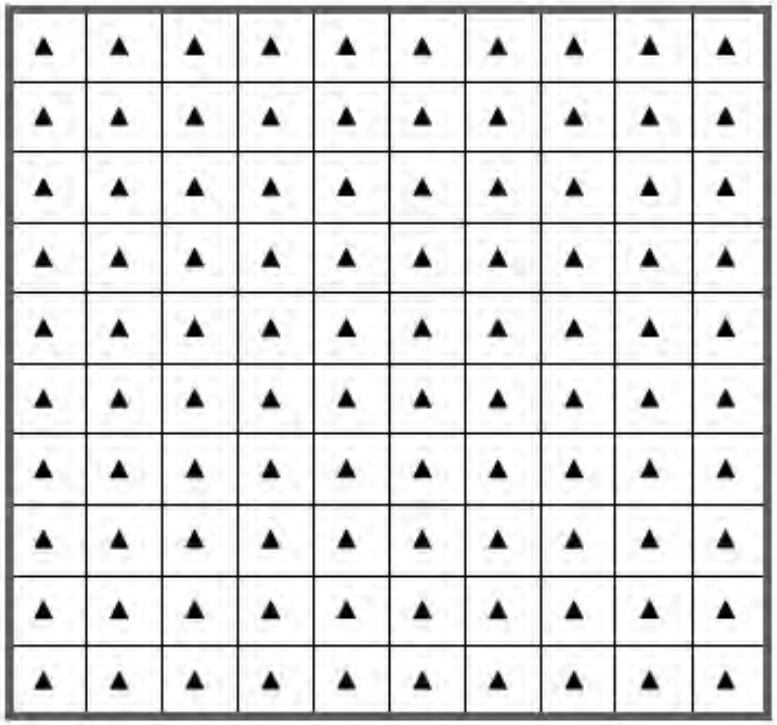
Courtesy of Alan Hewitt, USACE CRREL

# Understanding MC Distribution

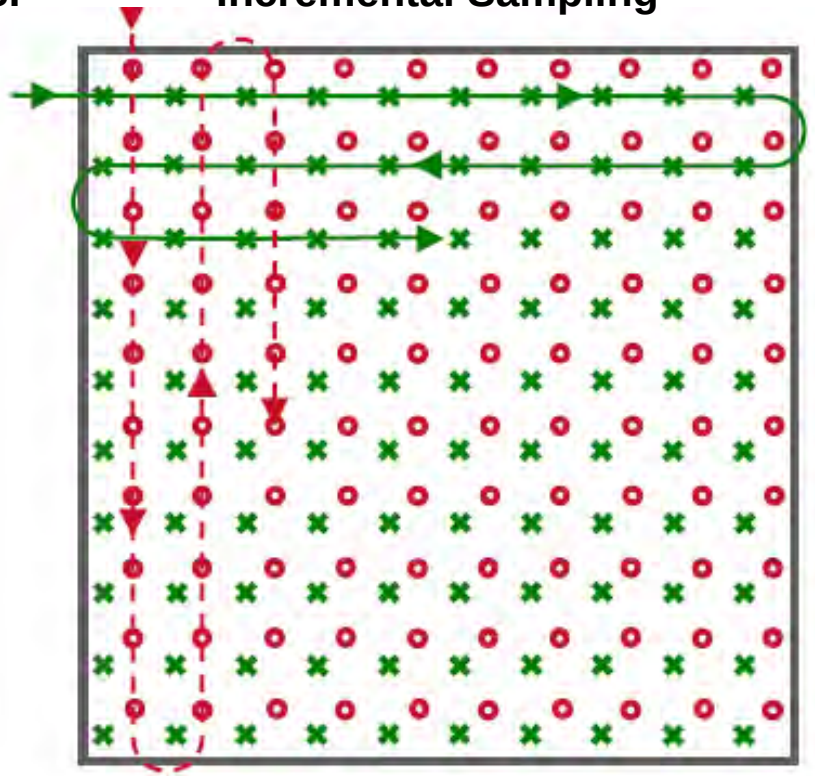
- Most of surface area uncontaminated (>95%)
- Most contamination in chunks localized around “low order” (partial) detonations (distributional heterogeneity)
- Most MC in top inch of soil on training ranges (deeper at demolition ranges)

# Proposed Solution: Incremental Sampling Design

**Discreet Sampling** **VS.** **Incremental Sampling**



▲ Sample collection point for 100 discrete samples



Path of travel

Increment collection point for two separate MI samples

# Soil Sampling Methods

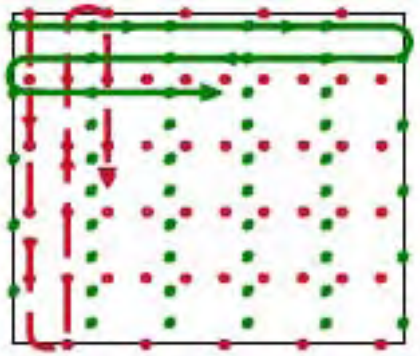
- Shallow surface soils
- Uniform sample depth
- Uniform sample size
- Quick and easy to take a lot of sample increments (remember 100 increments per sample)

# EPA Method 8330

- High performance liquid chromatographic (HPLC)
- Detection of ppb levels of certain explosives residues in water, soil and sediment
- Prior to use, appropriate sample preparation techniques must be used.

# Sample Processing (8330B)

1. Stratify range area
2. Incremental sampling design
3. Whole sample dried
4. Whole sample sieved
5. Whole sample pulverized
6. Subsampling



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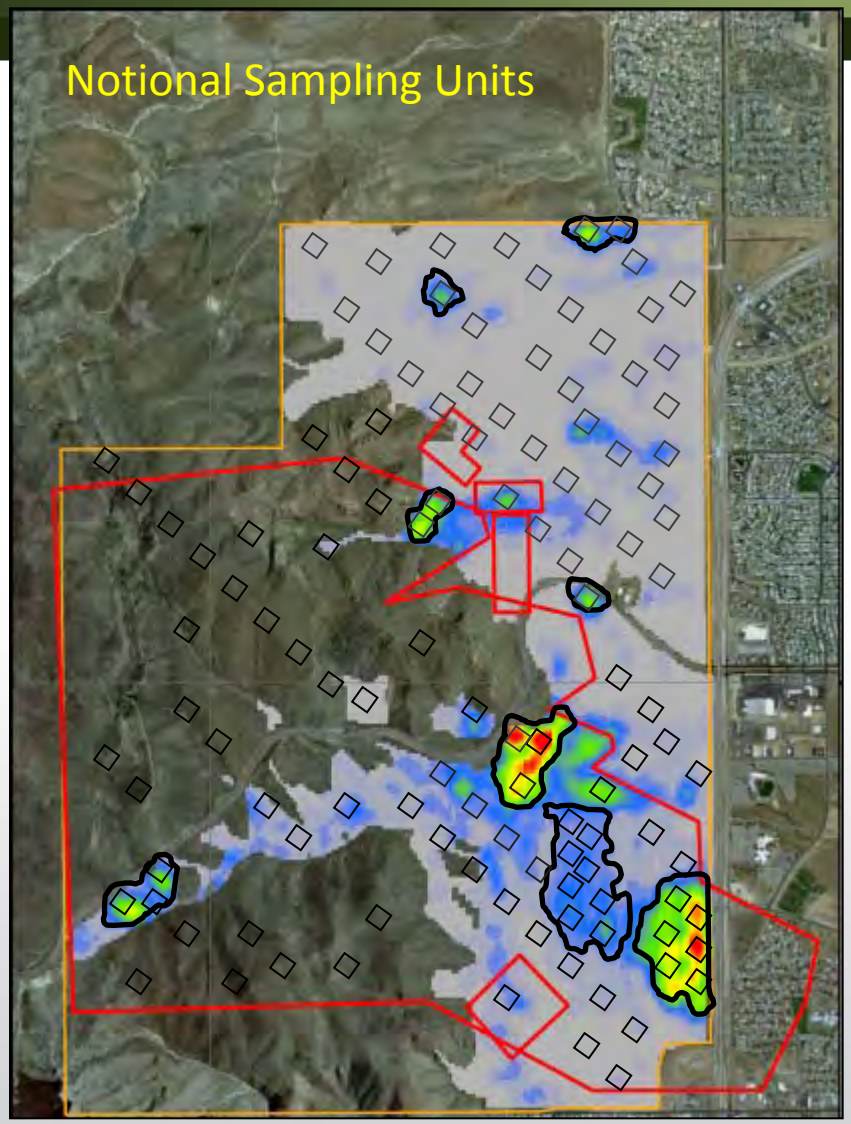
# Demonstrate IS on Castner Range

Proposed study questions:

- What is the effect of sampling unit size on IS concentrations?
- What is the effect of erosion vs. deposition on MC concentrations?
- What is the correlation between MEC and MD density on MC concentrations?

# Potential Sampling Approach

- Establish multiple Areas of Interest (AOIs) based on WAA
- Characterize nature & extent in each AOI
- Distribute sampling units within each AOI
- Vary sampling unit size
- Bias locations to evaluate potential MC migration
- Assume approximately 200 sampling units dispersed across the site
- Take 60 discreet samples in AOIs and compare results to incremental samples

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# Discussion

- TPP members thoughts on:
  - Incremental sampling
  - Demonstration at Castner Range
  - Study questions
  - Approach
  - Levels and means of participation in process
- Further coordination with TCEQ to evaluate applicability under Texas Risk Reduction Program

# Future TPP Meetings

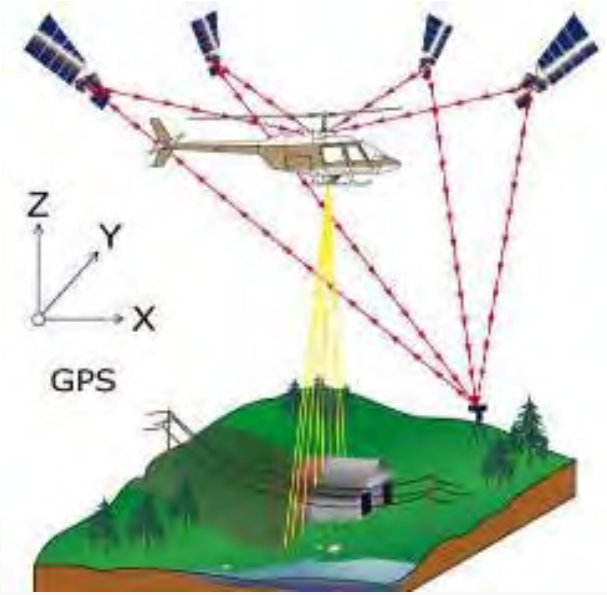
- **October 2010:** Discuss target delineation and approach for intrusive investigation
- **February 2011:** Discuss findings from intrusive investigation
- **June 2011:** Discuss project results, stakeholder confidence in results, and WAA costs/benefits

# Adjourn

# Backup Slides: Lidar

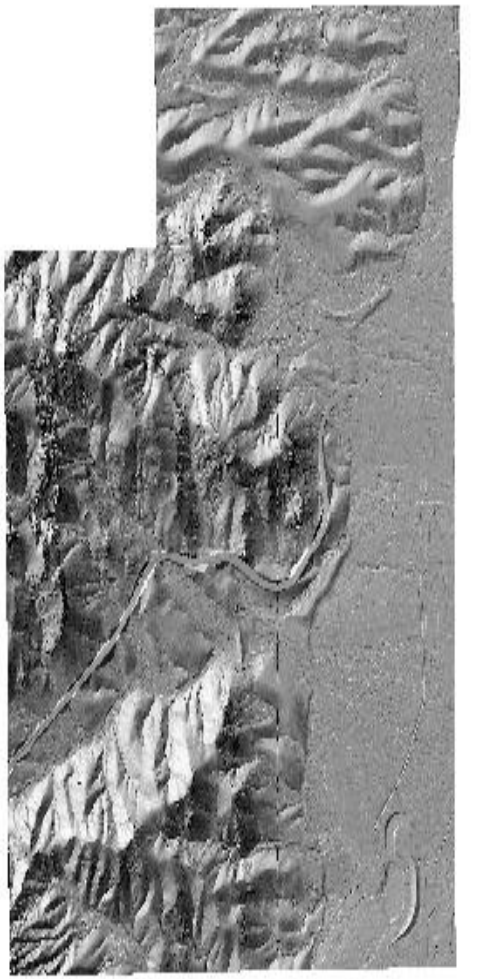
# Lidar & Orthophotography

- Lidar at 20 points/$m^2$
- Analyzing two data sets
  - 20 points/$m^2$
  - 5 points/$m^2$
- Orthophotography at 10cm pixels
- Data acquired October 2009

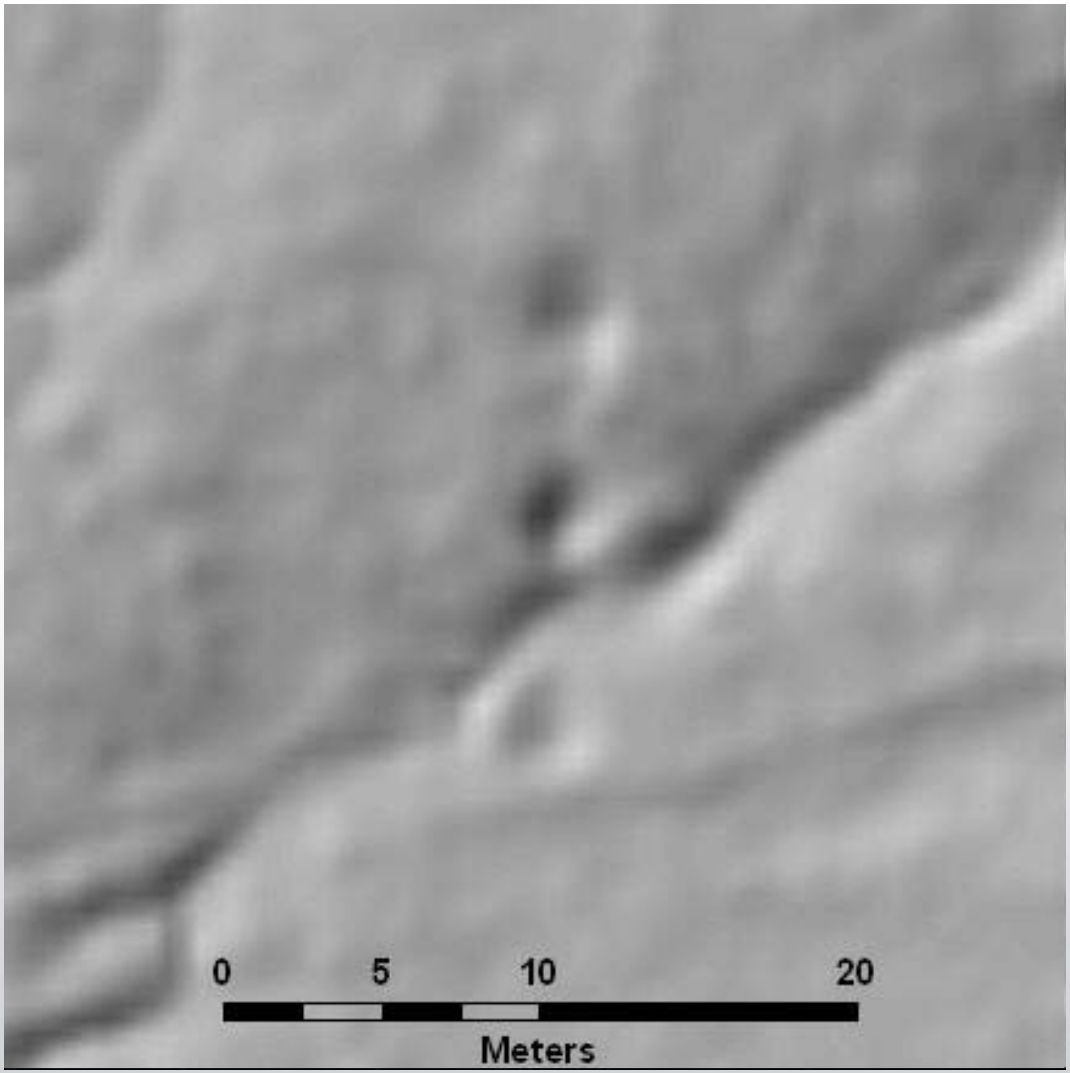


Crater and Fighting Positions

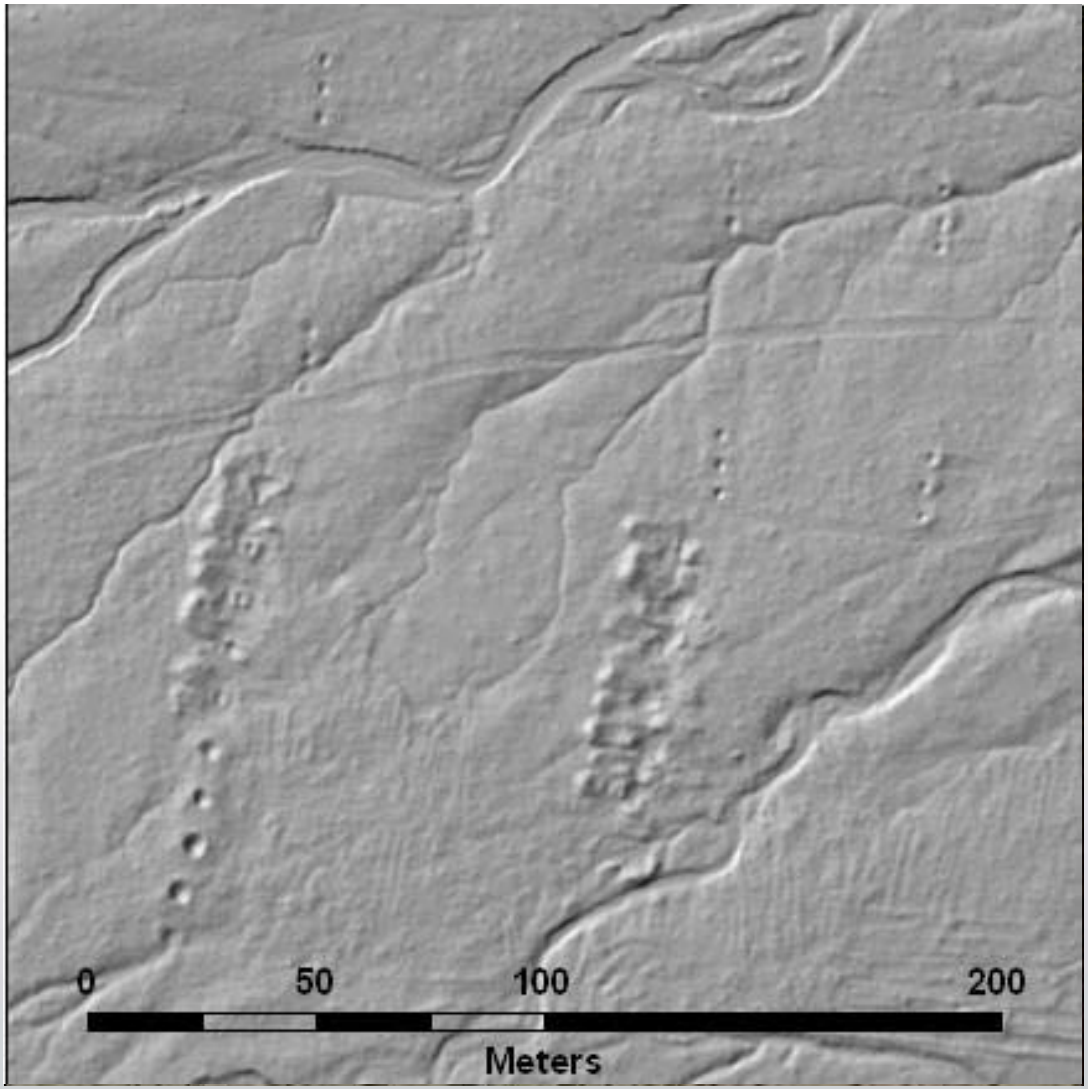
# Lidar Surface Model of the Site



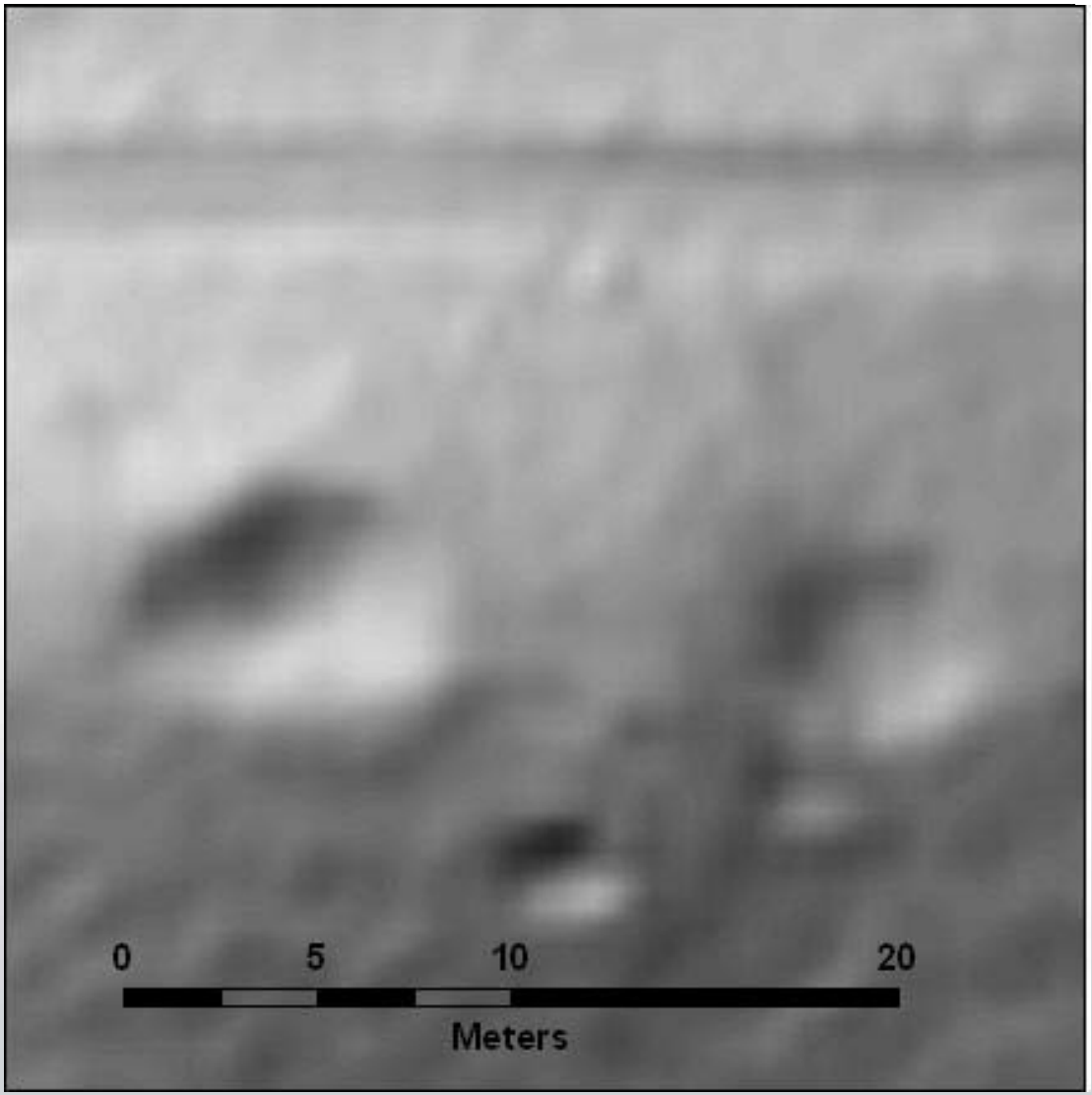
# Hole Groups 2



# Hole Groups 3



# Hole Groups 5



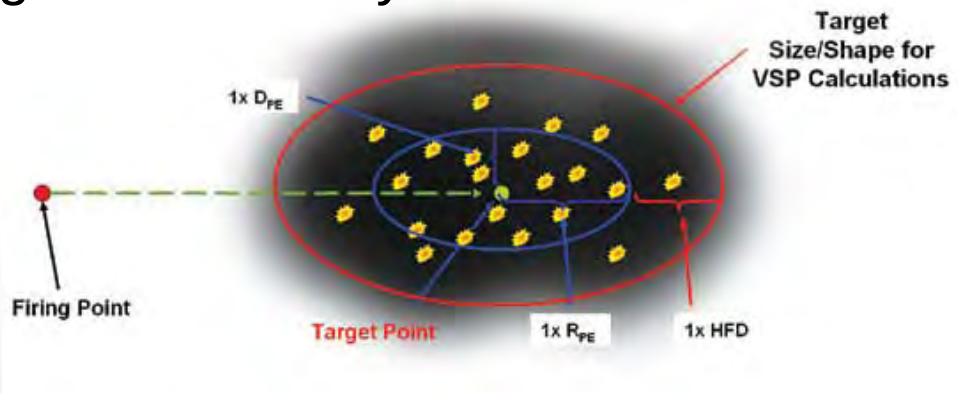
# Lidar & Orthophotography Study Questions

- To what degree do lidar/ortho detect surface features indicative of munitions related activities?
  - Craters/Crater Fields
  - Target Features
  - Berms
  - Demolition Pits
  - Burial Pits
- Do lidar/ortho images provide sufficient evidence to:
  - Reliably identify areas of concentrated munitions use?
  - Reliably identify areas with no indication of munitions use?
  - Improve the understanding of relative densities and distributions of MEC across the MRS?
- How confident are stakeholders in these conclusions?
- To what degree do lidar/ortho data make subsequent characterization steps (e.g., helicopter-borne magnetometry) more cost effective?
- What are the total cost, cost per characterized acre, and cost per surveyed acre associated with lidar/orthophotography?

# Backup Slides: Site Prep

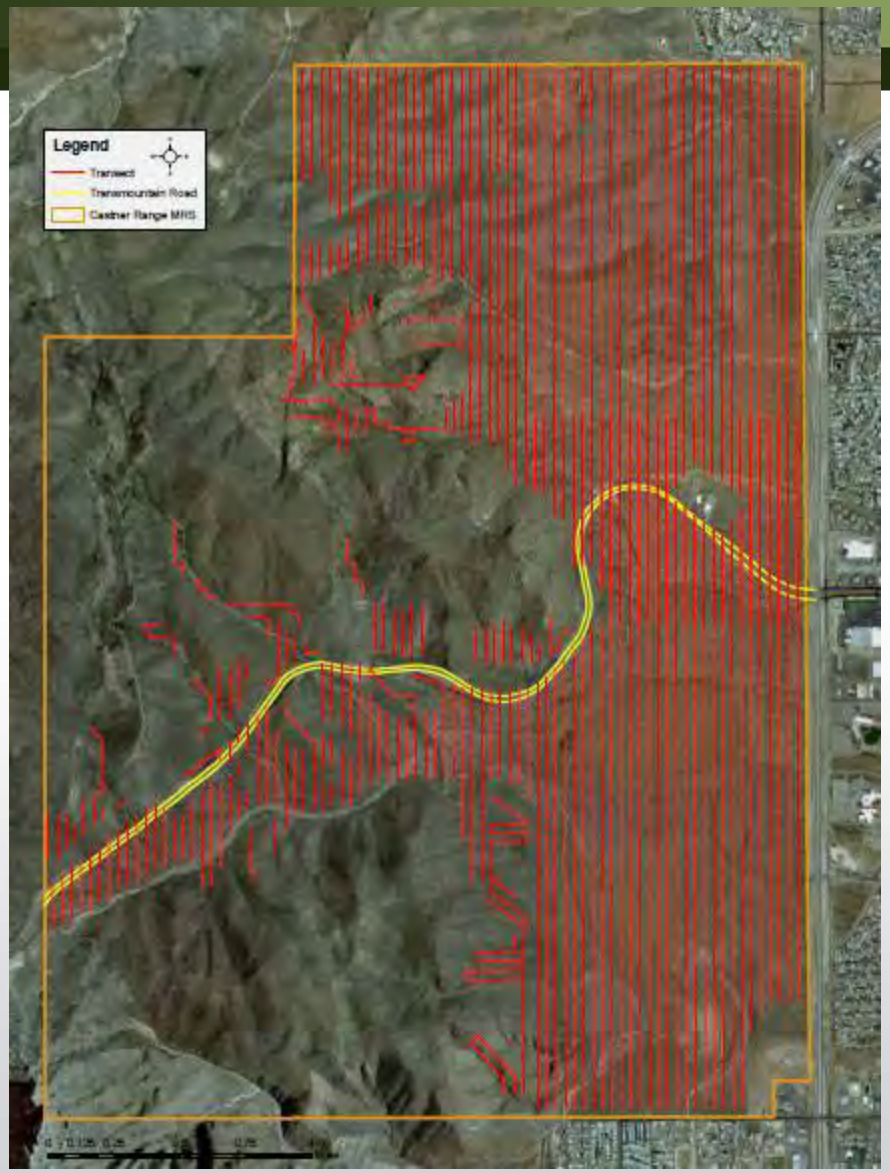
# Visual Sampling Plan (VSP)

- "Transect Spacing to Ensure High Confidence (95%) of Traversal and Detection of Target Areas"
- Evaluated transect spacing for most likely munitions items:
  - 37mm projectiles
  - 60mm mortars
  - 75mm projectiles
  - 2.36-in rockets
- Used combination of:
  - Munitions firing table data (range and deflection probable errors) from Army field manuals
  - Hazardous fragmentation distances from DDESB fragmentation database
- 2.36 inch rocket is the munitions item with the smallest estimated transect spacing at 57m



# Establish Transects

- Used VSP output (57m) transect spacing
- Plotted on areas of <18% slope (safety/accessibility)
- Marking nearly 1 million linear feet of transect for ground-based geophysics

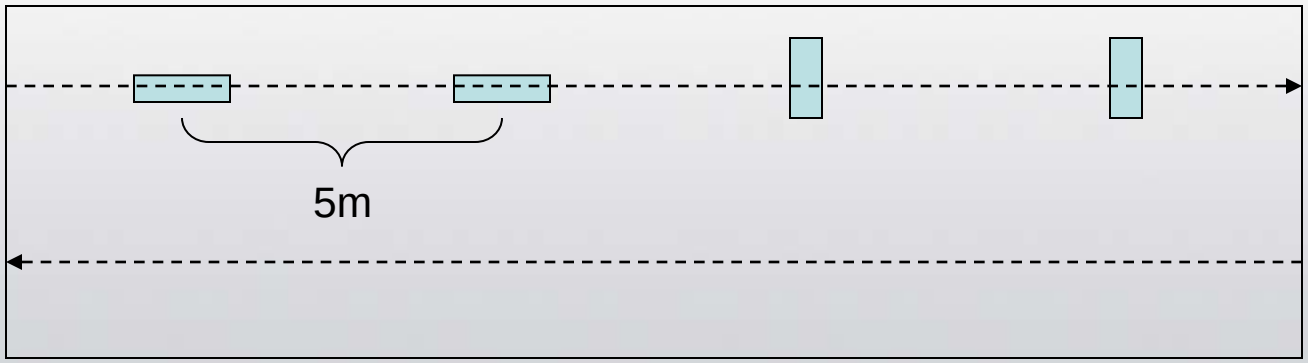


# Geophysical System Verification

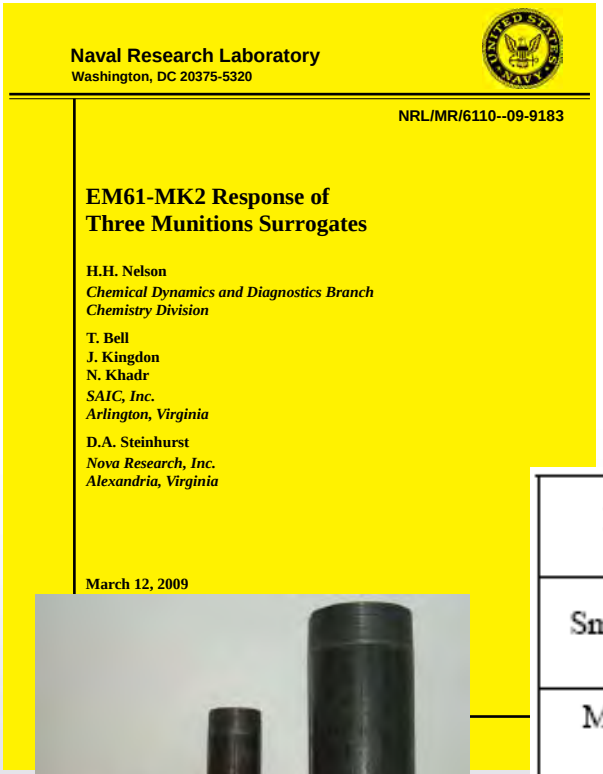
- Purpose
  - Demonstrate the geophysical system is meeting typical and acceptable detection performance
  - Evaluate the project team's data collection and data transfer methods
  - Establish site-specific signal-to-noise ratios for selection criteria
- For ground-based and helicopter-borne systems
- Using specifications contained in *"Geophysical System Verification (GSV): A Physics-Based Alternative to Geophysical Prove Outs"* (ESTCP 2009)
- Includes:
  - Instrument verification strip (IVS)
  - Blind seed items in the production area

# Instrument Verification Strip (IVS)

- A line of seed items of known size, shape, orientation, depth, and location
- Run geophysical equipment over the IVS before and after each data collection day to verify instrument performance
- Use “industry standard objects” (ISOs) with known signal responses for common instruments (e.g., EM61)



# Industry Standard Objects (ISOs)



Naval Research Laboratory
Washington, DC 20375-5320

NRL/MR/6110--09-9183

**EM61-MK2 Response of Three Munitions Surrogates**


H.H. Nelson
*Chemical Dynamics and Diagnostics Branch*
*Chemistry Division*

T. Bell
J. Kingdon
N. Khadr
*SAIC, Inc.*
*Arlington, Virginia*

D.A. Steinhurst
*Nova Research, Inc.*
*Alexandria, Virginia*


March 12, 2009

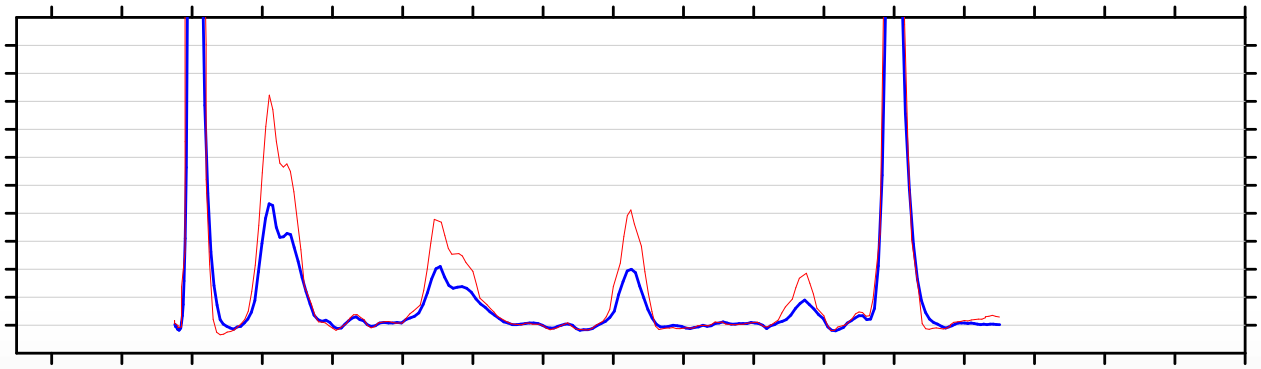
- Readily available, similar in size and shape to common munitions items
- Documented response curves
- Repeatable, consistent EM signals for calibration and performance validation

| Item | Nominal Pipe Size | Outside Diameter | Length | Part Number[1] | ASTM Specification |
|---|---|---|---|---|---|
| Small ISO | 1" | 1.315" (33 mm) | 4" (102 mm) | 44615K466 | A53/A773 |
| Medium ISO | 2" | 2.375" (60 mm) | 8" (204 mm) | 44615K529 | A53/A773 |
| Large ISO | 4" | 4.500" (115 mm) | 12" (306 mm) | 44615K137 | A53/A773 |

1. Part number from the McMaster-Carr catalog.

# Ground-based IVS

EM61 Signal Response for Seed Items in IVS



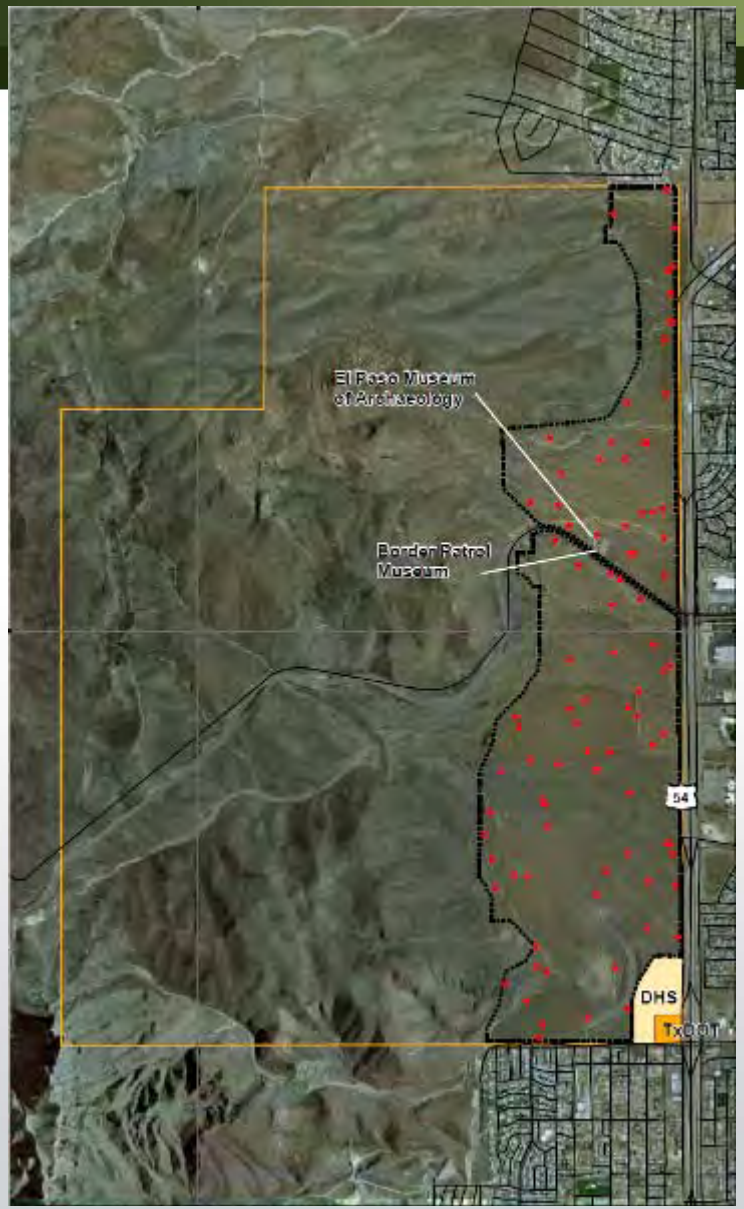
| ISO Size | Position (m) | Depth (in.) | Orientation (relative to instrument path) |
|---|---|---|---|
| Small | 2.5 | 3 | Horizontal along path |
| Small | 7.5 | 7 | Horizontal along path |
| Small | 12.5 | 3 | Horizontal across path |
| Small | 17.5 | 7 | Horizontal across path |

# Airborne IVS

| Item/ Size | Orientation (relative to instrument path) |
|---|---|
| 2.75-in. rocket (inert) | Horizontal along path |
| 155mm projectile (inert) | Horizontal along path |
| 155mm projectile (inert) | Horizontal across path |
| 100-lb. bomb (inert) | Horizontal across path |
| ISO Large | Horizontal along path |
| ISO Medium | Horizontal along path |
| ISO Small | Horizontal along path |

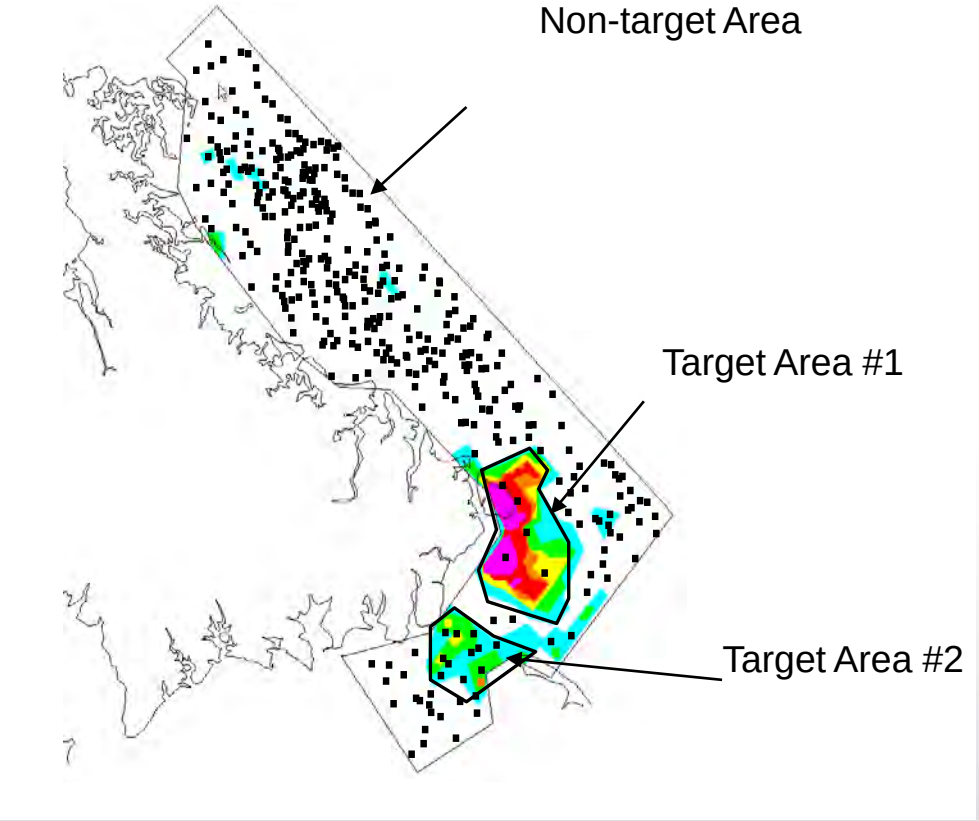
# Blind Seeds

- Blind seeds evaluate adequacy of coverage, signal levels/instrument response, data processing, and positional accuracy
- 90 seed placements using 93 seed items:
  - 31 small ISO
  - 31 medium ISOs
  - 31 large ISOs
- 3 of the placements will contain two ISOs



# Delineate Target Areas and Non-Target Areas

- Delineate boundaries of target areas through analysis of anomaly densities using VSP (90% confidence level)
- Target areas:
  - Develop hypotheses of MD densities (e.g., at least 100 pieces of MD/acre)
  - Test hypotheses through intrusive investigation of 20'x20' grids to confirm munitions target areas (90% confidence level)
- Non-target areas:
  - Develop hypotheses of MEC densities (e.g., less than or equal to 0.25 MEC items per acre)
  - Test hypotheses through intrusive investigation of 20'x20' grids to confirm non-target areas (90% confidence level)



# Investigate the Nature of MEC in Target Areas

- Once the target areas have been confidently identified and delineated, reacquire and dig individual anomalies
- Focus on anomalies of high priority/high likelihood of being MEC
- Record:
  - MEC, munitions debris, range related debris, metal debris types
  - Size and type
  - Depth
  - Orientation
- Excavate anomalies
- Work scheduled September – December 2010

# Intrusive Investigation (General)

- Coordinate dig locations with Fort Bliss natural and cultural resources staff to minimize disturbance of sensitive areas
- Conduct Section 106 consultation through Fort Bliss programmatic agreement with continued consultation with the Tribes

URS

# Data Review & Analysis

- Review the ability of methods (i.e., lidar/ortho, helicopter-borne magnetometry, and ground-based geophysics) to answer study question
  - Did the method improve the understanding of relative densities and distributions of MEC across Castner Range?
  - Did the method reliably identify areas of past munitions use?
  - Did the method identify areas with no indication of munitions use?
  - How confident are stakeholders in the conclusions?
- Review the effectiveness of methods
  - Individually
  - In combinations (layered application)

**Look for efficiencies: methods that give more bang for the buck, methods that make subsequent phases more effective, can we skip steps.**

URS

# MC on Castner

- Extensive use of HE munitions
- Extensive demolition/disposal operations
- Relatively low precipitation rates
- Relatively low solubility of MC