Warwick Furnace:
Lost & Found Using UAS-Magnetometer and APEX 3D Electromagnetics

Greg Schultz

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Washington's Retreat: Brandywine to Valley Forge
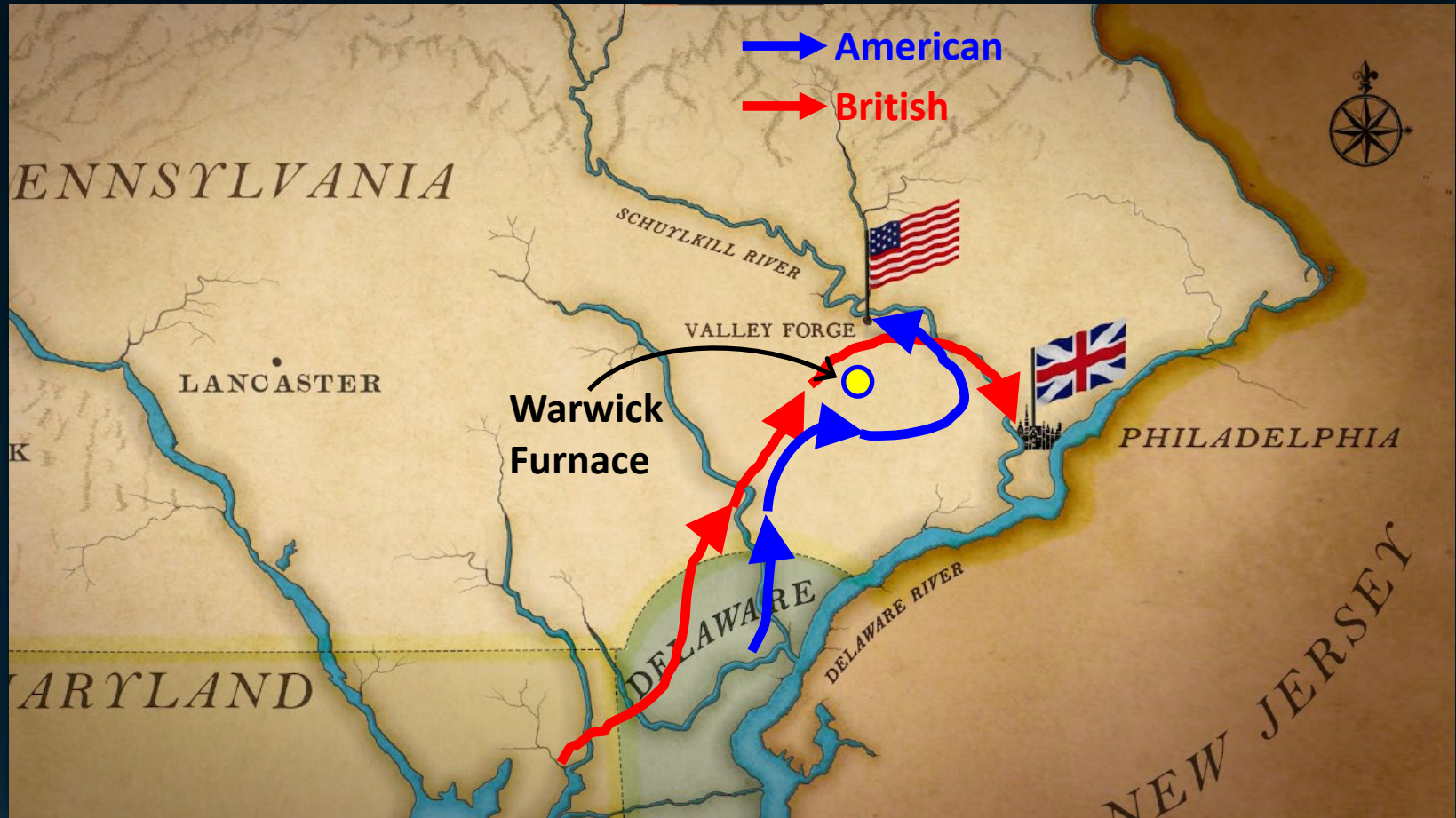
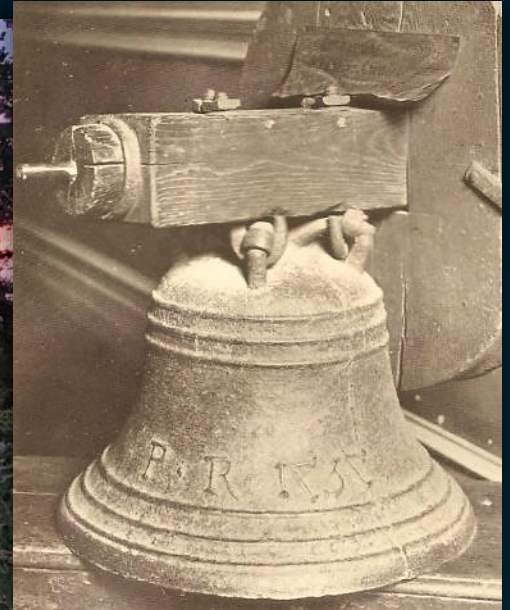# Warwick Furnace: Forging & Proving Cannon
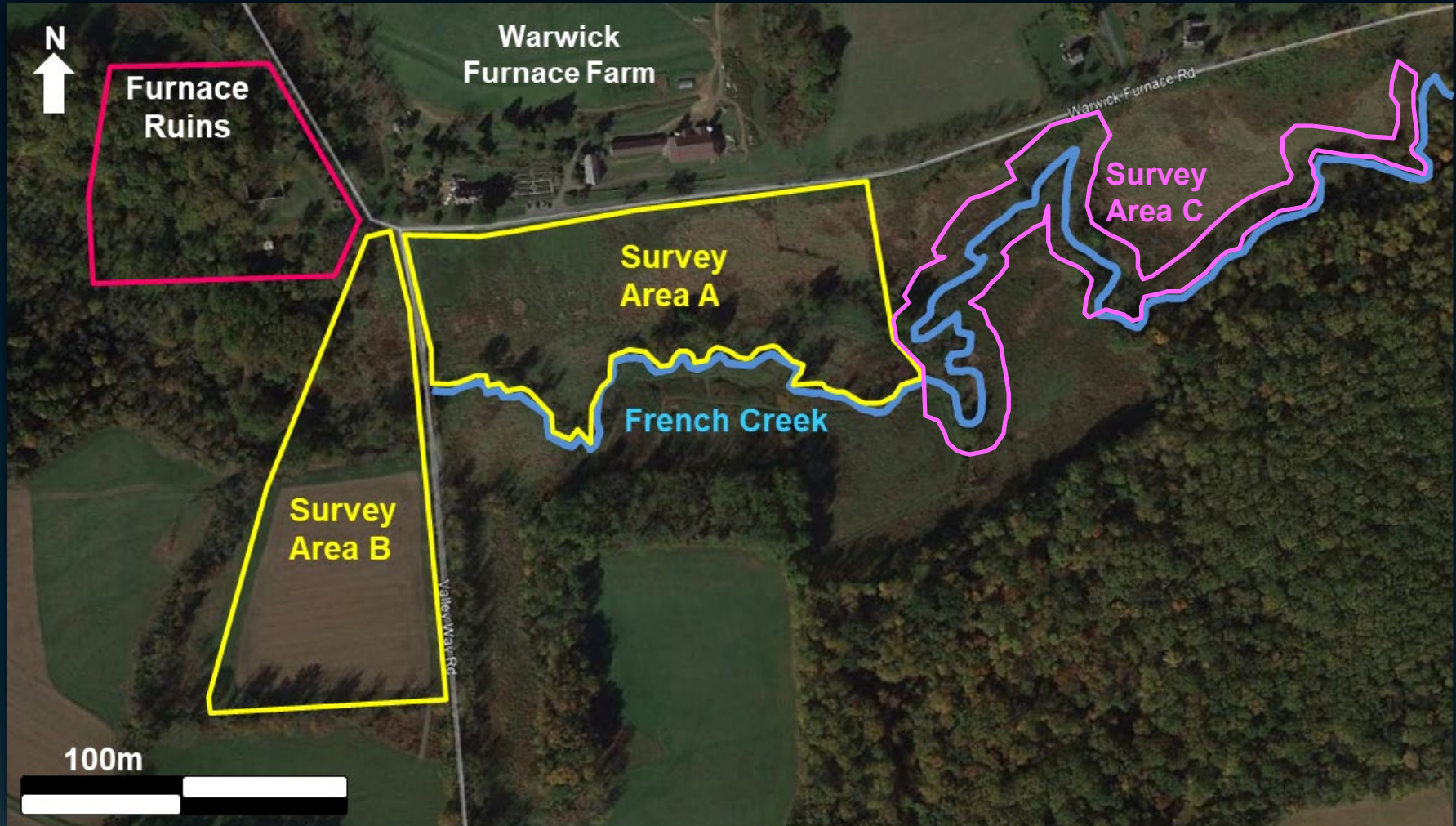
Bury All Cannons at Warwick Furnace:

when the Hessians were passing through the town, <u>the bell was rung to summon the citizens to bury the cannons</u> cast at the furnace that were awaiting delivery to the Continental Army.

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Objective: Find The Cannon

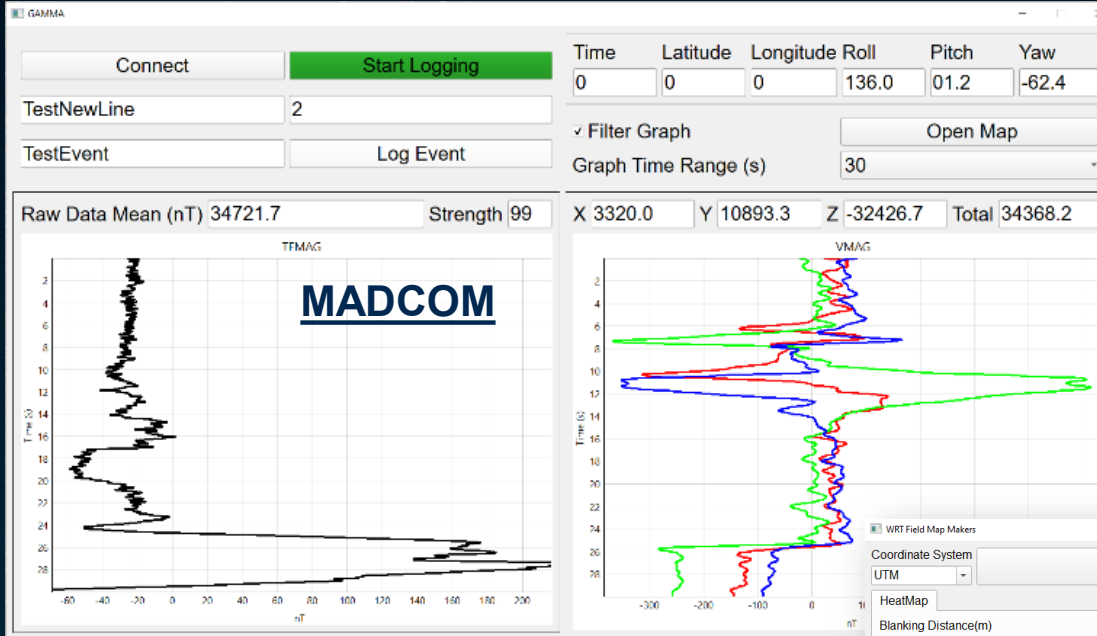## 250 Years After Hasty Burial, Rediscover Warwick Cannon

Drone Magnetometer Surveys

UAS-based Magnetic Sensor Payload

- **Combines Mini-Atomic MAGs, RTK-GPS, IMU, Radar Altimeter, Telemetry, Processing**
- **Heavy-lift UAS (1-10 kg payloads)**
- **Automated airframe & survey control**

Drone Magnetometer Surveys

MADCOM

MAD_MapMaker:

Real-time Data Telemetry
- Data logging
- Data QC
- Data filtering and display
- Rea-time system tracking (map)
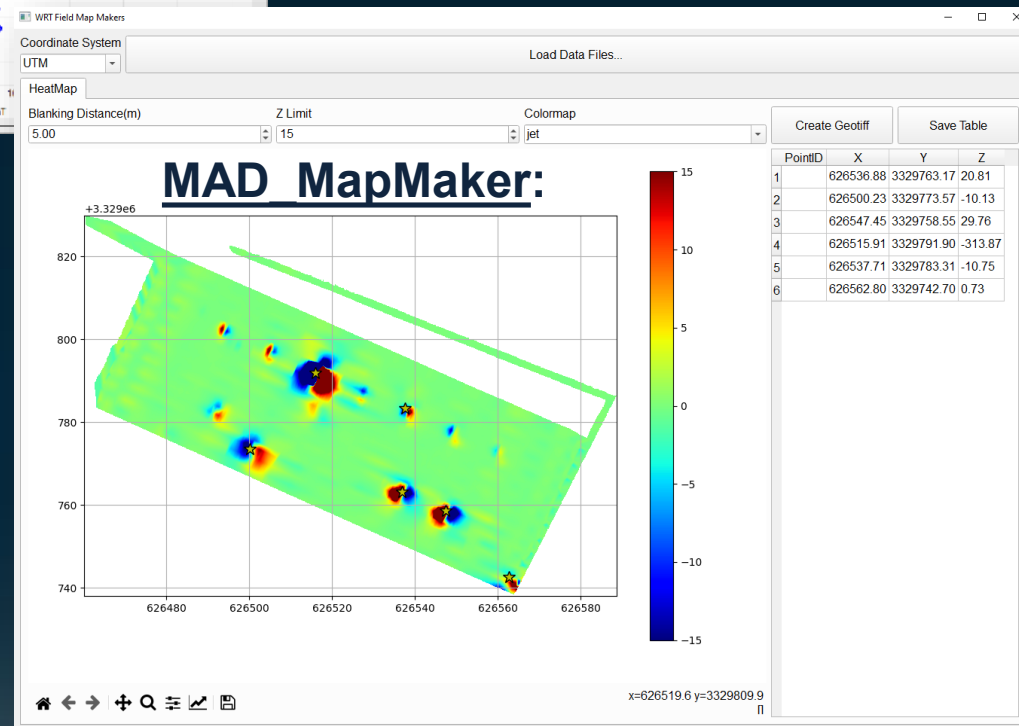- Formatted output (GDB, CSV)

Imports:
- Multiple MAG data types
- Geotiff overlays
- Points, PolyLines

Functions:
- Import, crop, filter data
- Gridding, Manual pick (points)
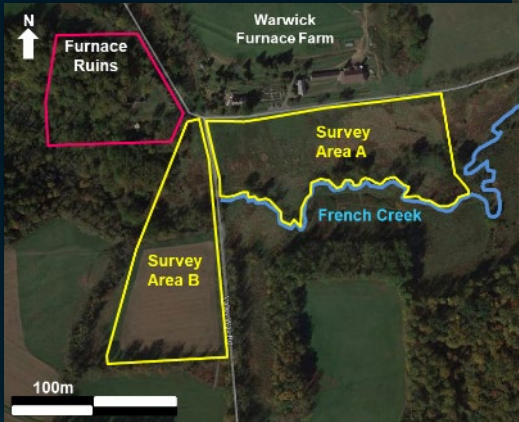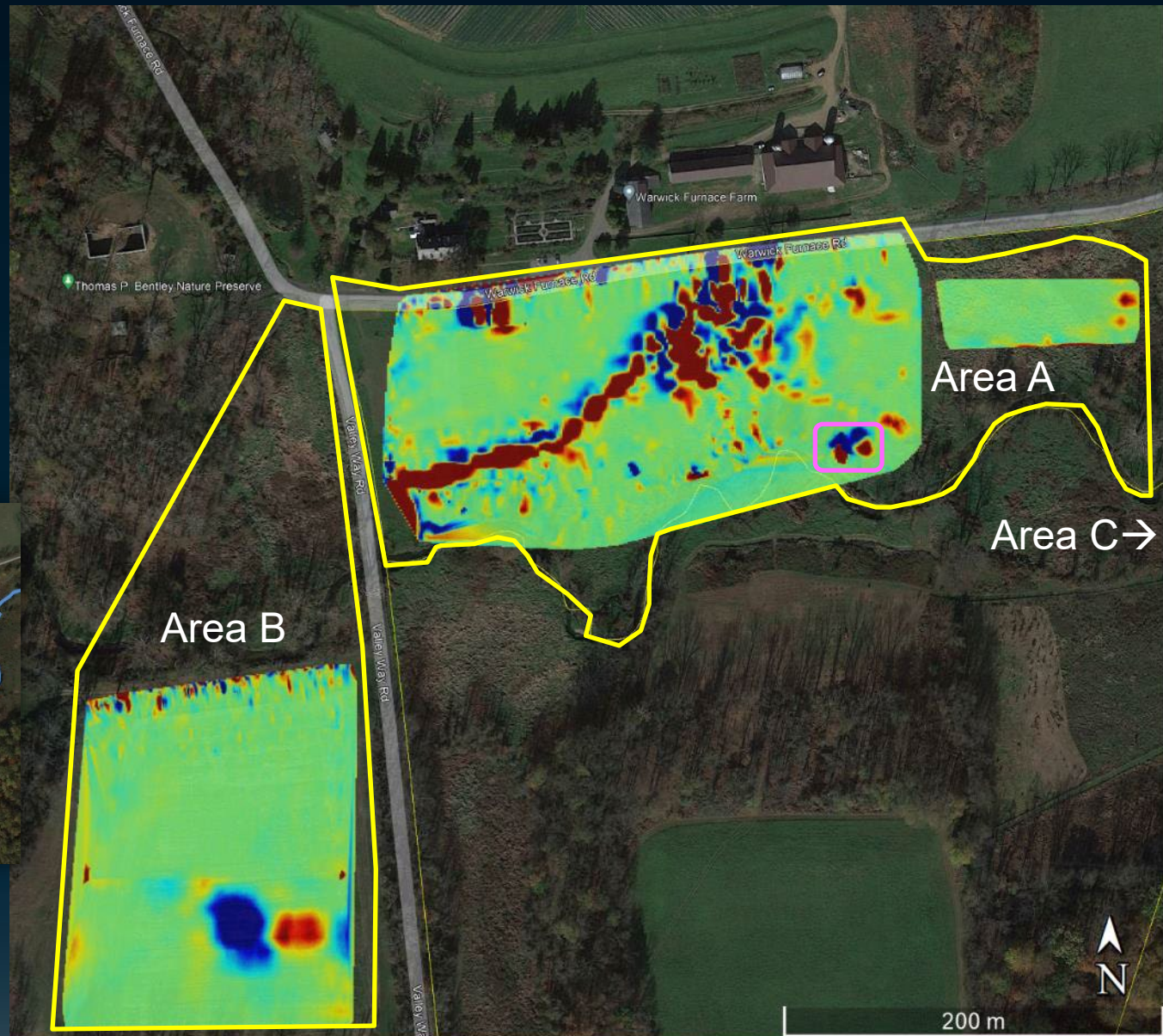
Exports:
- Geotiffs of gridded data
- CSV pick points
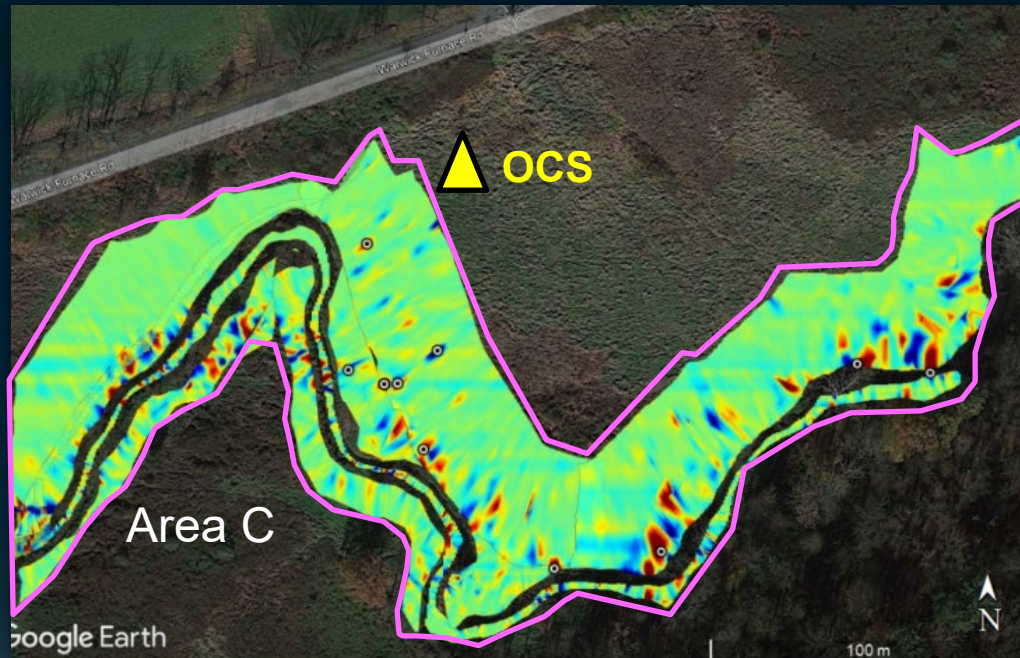
Field Data Collection (video)

MagPi Anomaly Map

UAS-MAG

- 3 Primary Areas
- Full Coverage
- 68,800 m^2
- ~17 acres

Area A

Area B
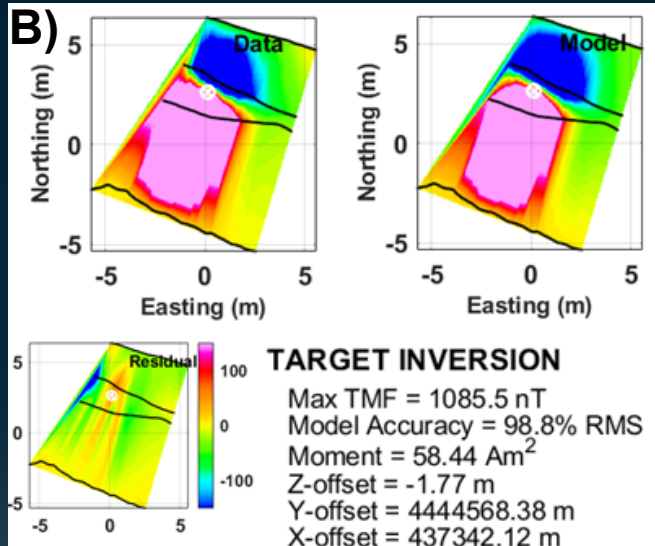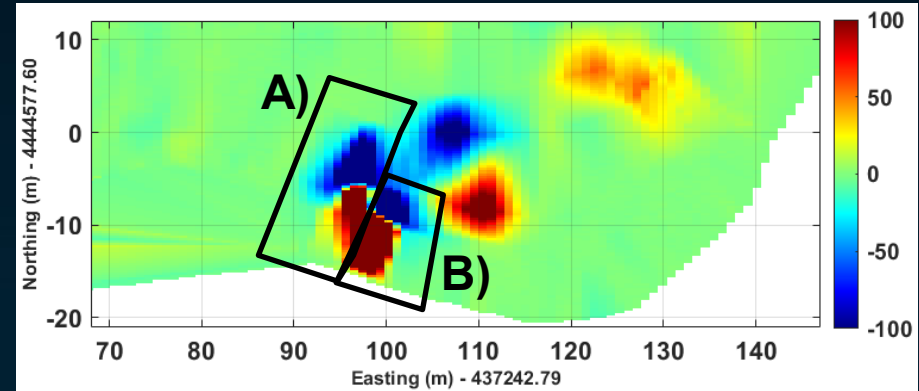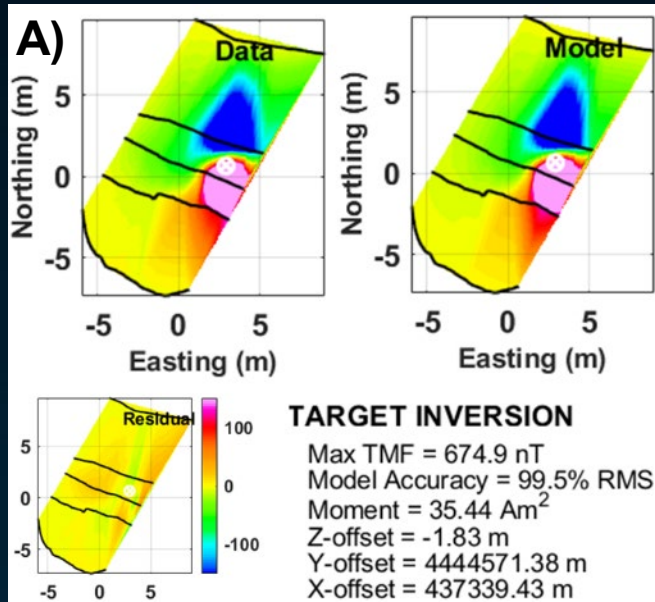
Area C→

MagPi Ground Surveys

Areas Inaccessible to UAS

- **Hand-carried in & along banks of French Creek (Area C)**

- **Simultaneous real-time telemetry from multiple units to OCS**

Area C map showing OCS location and survey area. Google Earth. 100 m scale. N

MagPi Inversions

A)

TARGET INVERSION

Max TMF = 674.9 nT
Model Accuracy = 99.5% RMS
Moment = 35.44 Am^2
Z-offset = -1.83 m
Y-offset = 4444571.38 m
X-offset = 437339.43 m

B)

TARGET INVERSION

Max TMF = 1085.5 nT
Model Accuracy = 98.8% RMS
Moment = 58.44 Am^2
Z-offset = -1.77 m
Y-offset = 4444568.38 m
X-offset = 437342.12 m

Inverted MAG Anomalies

Map → Detect → Classify

UAS-MagPi
Rapid Area Search
(Map & Detect)

APEX 3DEM
Dynamic AGC
(Classify)

APEX 3DEM: Object Classification

Wet APEX

Hand-carried APEX

Portable APEX

Chariot APEX

Cold APEX

Hot APEX

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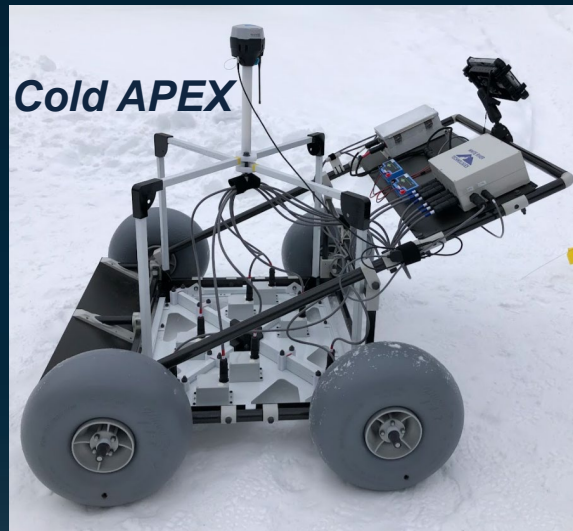
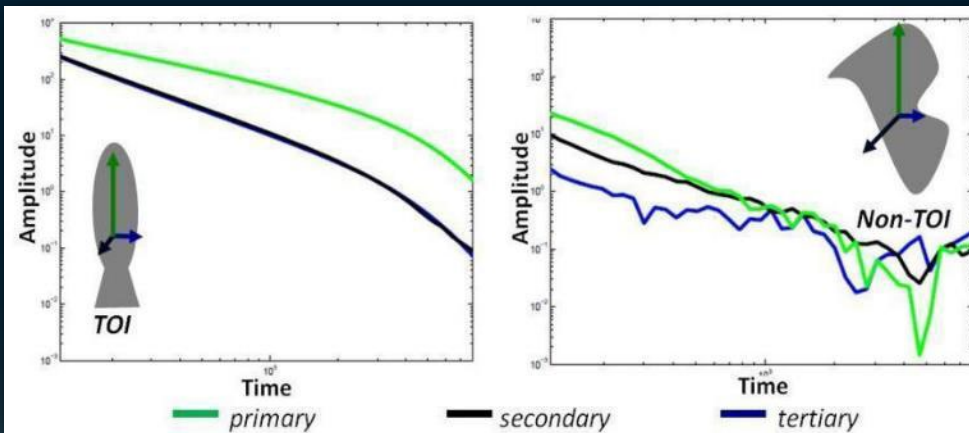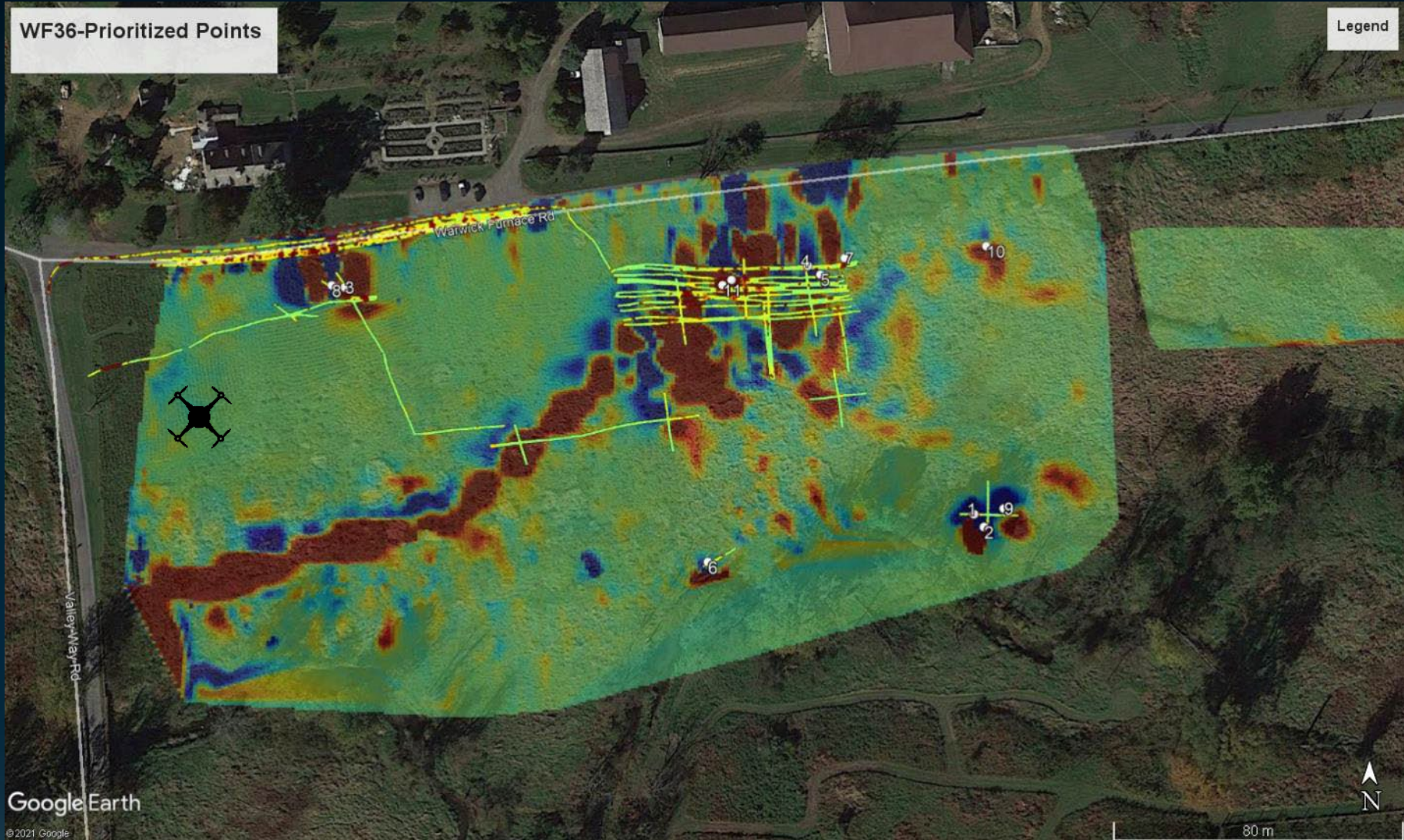# APEX 3DEM: Object Classification

Controlled Source 3D Cart Unit

- Triaxial EM Transmitters

- Array of Multi-axis Receivers

- Dynamic Classification Analyses

- Inverted Parameters Unique

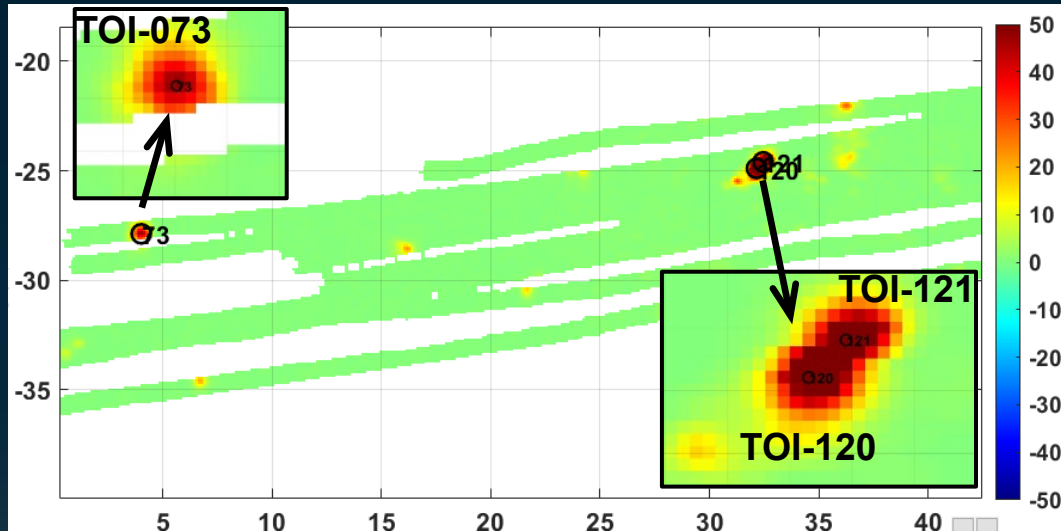- <u>Yield Intrinsic Features</u>: *size, shape, composition, metal thickness*
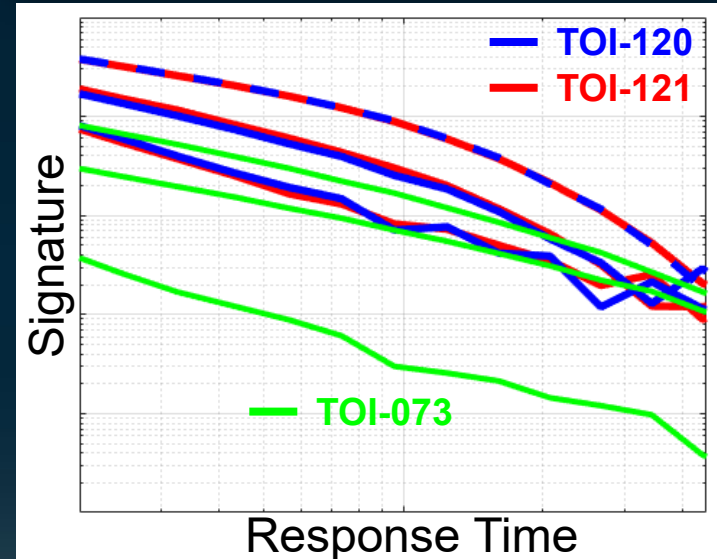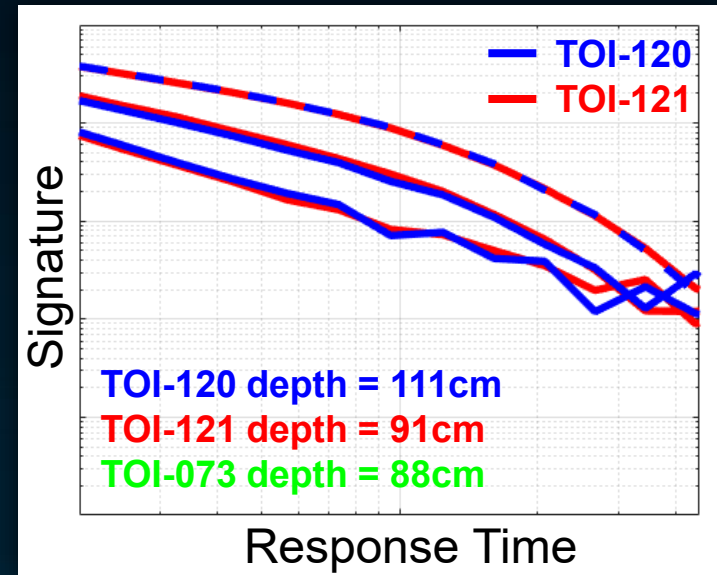
MagPi + APEX Combined

APEX 3DEM Inversions

Inverted Target-of-Interest Signatures

- **Same Signatures for TOIs 120 & 121**
- **Likely large iron-rich cylinders**
- **Smaller Irregular TOI-073**
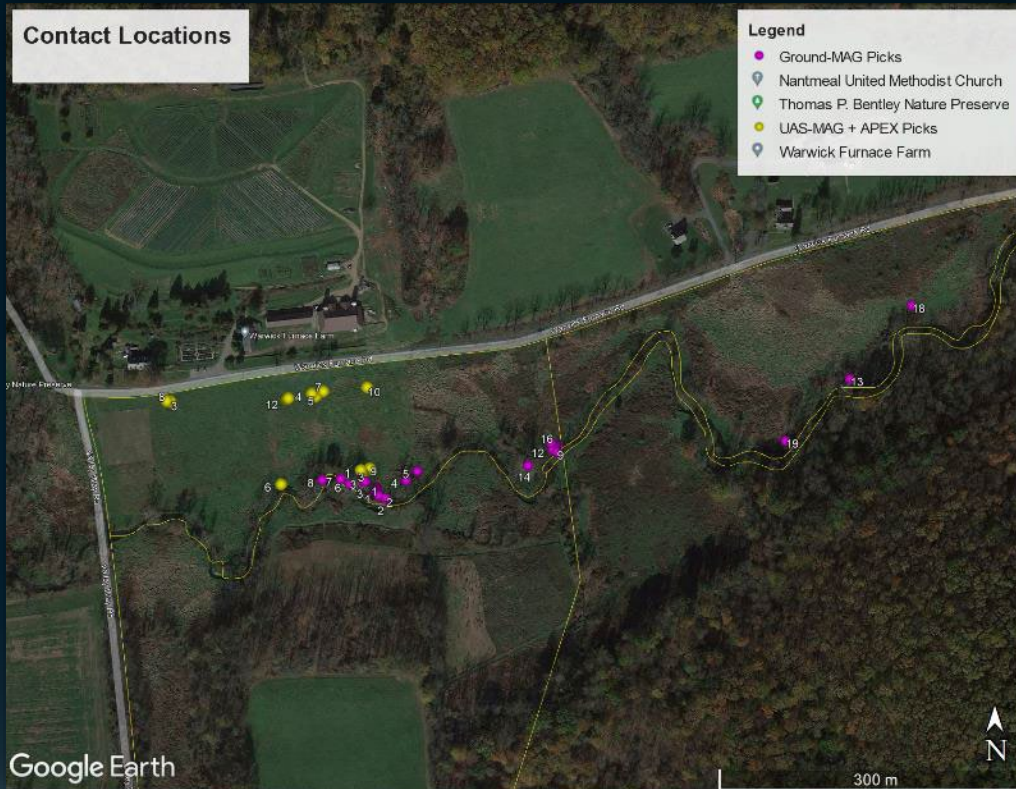- **Listed as highest priority items to dig first**

TOI-120 depth = 111cm
TOI-121 depth = 91cm
TOI-073 depth = 88cm

TOI 120 & 121 Are Same Object Type

Prioritized Dig List

12 Dig Locations Recommended

- **Based on MagPi & APEX Inversions**
- **First 5 Dig Locations Resulted in Discoveries**
- **4 Cannons Were Discovered**
- **Cannonball and Other Artifacts Were Also Found**

Contact Locations

Legend
- Ground-MAG Picks
- Nantmeal United Methodist Church
- Thomas P. Bentley Nature Preserve
- UAS-MAG + APEX Picks
- Warwick Furnace Farm

Google Earth

Eureka!

Dig Site #1

First Dig Site Uncovered a Cannon (and Cannonball)

DISCOVERY: Dig Sites

Warwick Cannon (4500-4800 lbs each)

Synopsis

- Washington's cannon suspected to be hidden at Warwick Furnace in Fall of 1777 (246 years ago)

- Little known of MAG or EM signatures

- Efficient combination of unmanned airborne MAG, limited ground MAG, and high-resolution APEX 3D-EM deployed

- Unique characterizations from "advanced geophysical classification" inversions using APEX 3D-EM

- Prioritized dig-list resulted in discovery of cannon and artifacts at first 5 locations

French & Pickering
CREEKS CONSERVATION TRUST

GES
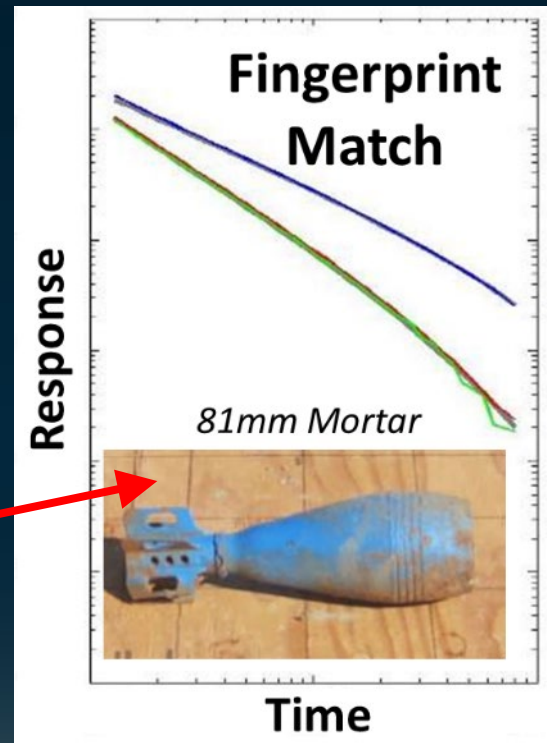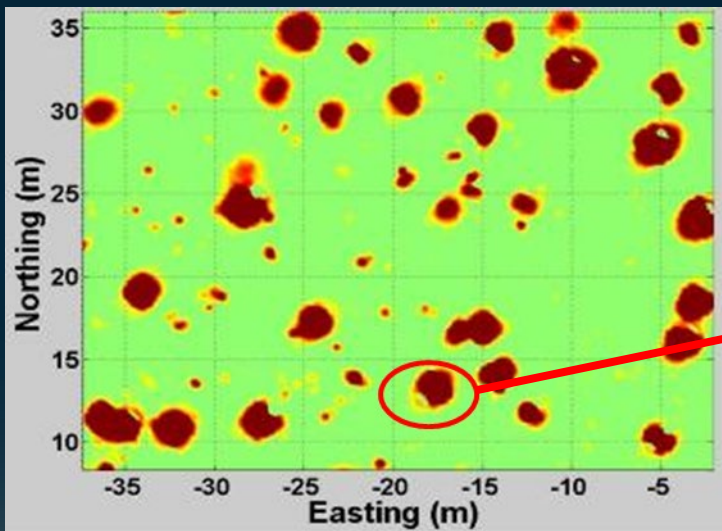Groundwater & Environmental Services, Inc.

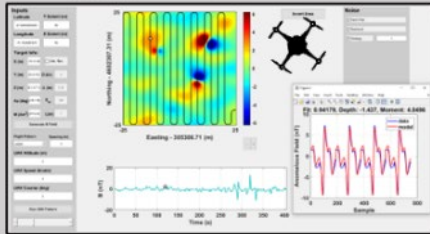white river technologies

APPENDIX

APEX 3DEM

UAS-MAG Workflow

1. Site Assessment — WRT MAD Performance Prediction & Optimization Tool
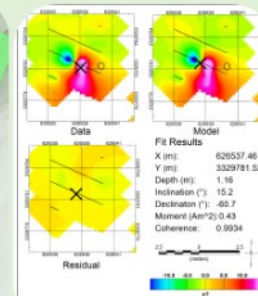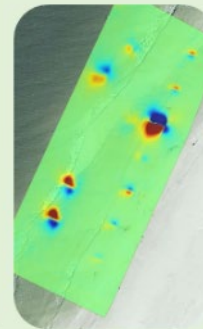2. Mission Planning — Airspace approval; Coverage / waypoints; Altitude control; Exclusion Areas
3. Flight Survey/QC — Geodetics; Quality Control; Take-off / Land; Power Mgt.
4. Analysis & Anomaly ID List

1. PLAN IT
2. FLY IT
3. FIND IT

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