SnT2023

CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

HOFBURG PALACE - Vienna and Online

19 TO 23 JUNE

Explosion Anomaly Detection from Thermal Infrared Photogrammetry

Brandon Crawford, Damien Milazzo, Dane Coats, Emily Schultz-Fellenz, Eric Guiltinan, Adam Collins, Erika Swanson, Juan-Antonio Vigil

Los Alamos National Laboratory

O3.3-689

Presentation Date: 20 June 2023

LA-UR-23-25249

Outline

- Our Team
- Photogrammetry
- Thermal imagery
- Study area
- Methods
- Results
- ML/AI methods in ArcGIS Pro
- Conclusions

Our Team

Seeks to develop and employ tools that can:

- Work towards automating relevant signature detection and discrimination in:
  - Complex natural environments
  - Engineered environments

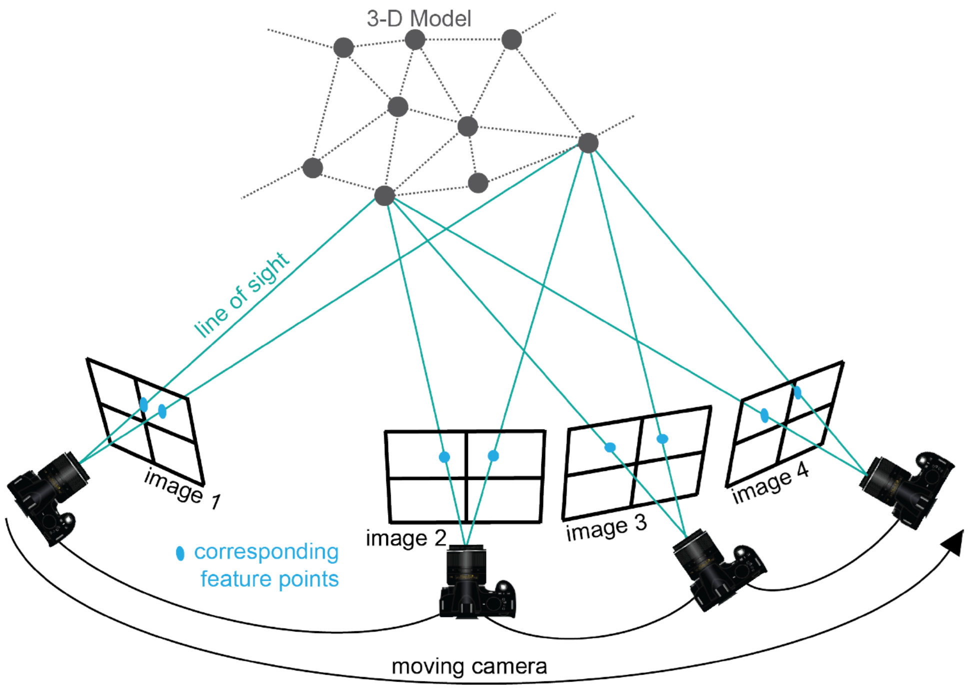
- Drive towards real-time signature detection

…and **develop/refine/test these tools in operational environments**

Structure from Motion (SfM) Photogrammetry

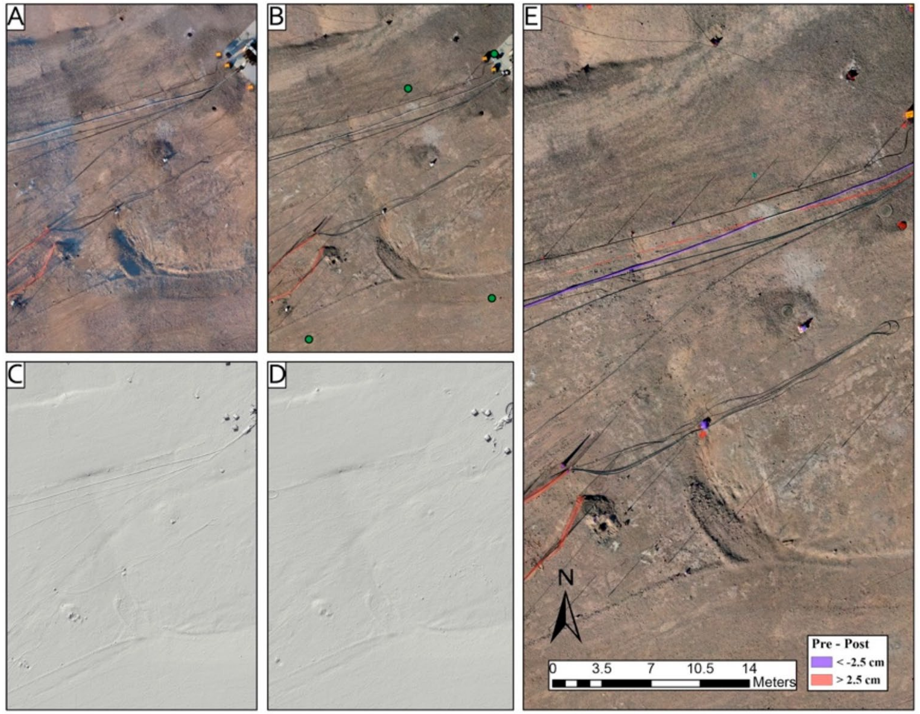
- Structure-from-motion photogrammetry (SfM) is a technique for estimating 3d structures and surfaces from a sequence of images

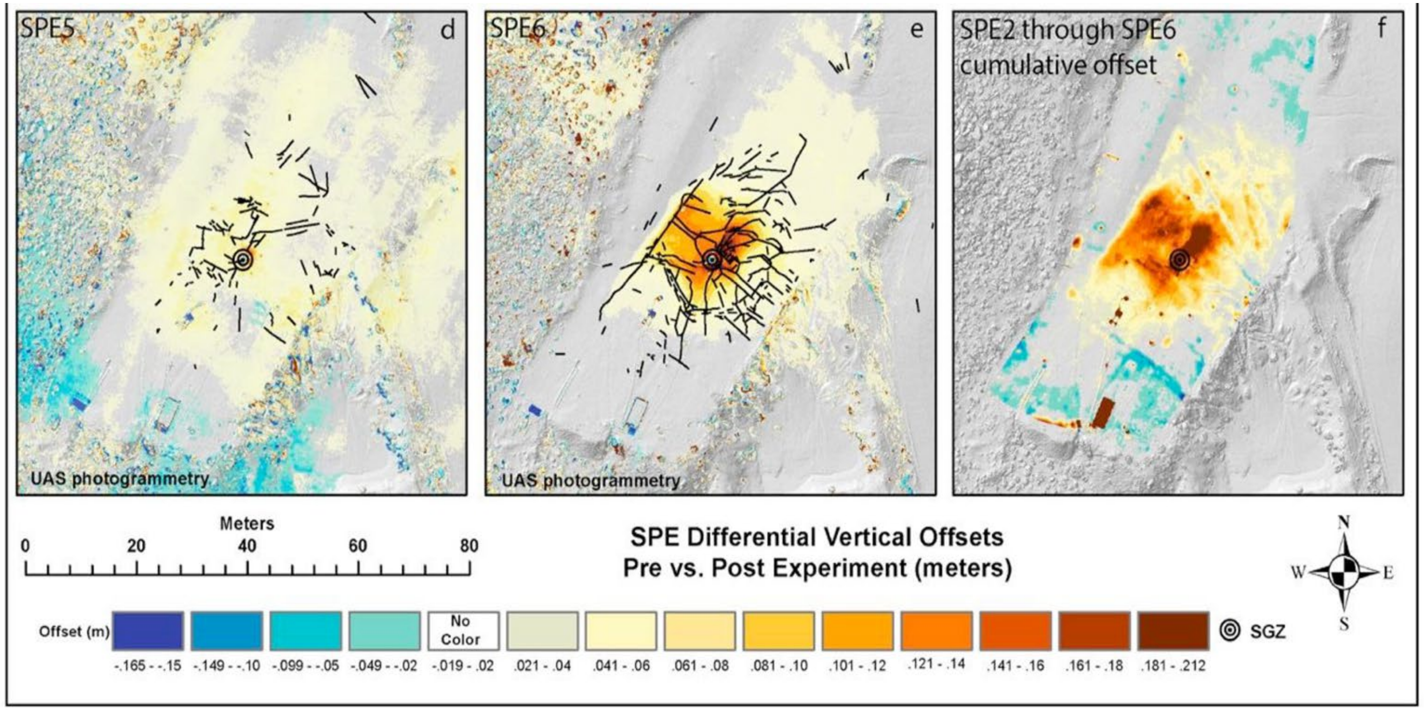
- Locations shared between images are identified on the pixel scale to generate a surface model



Previous Photogrammetry

Our team has previously used this technology to push the boundaries of resolution and accuracy for surface change detection following sub-surface explosions

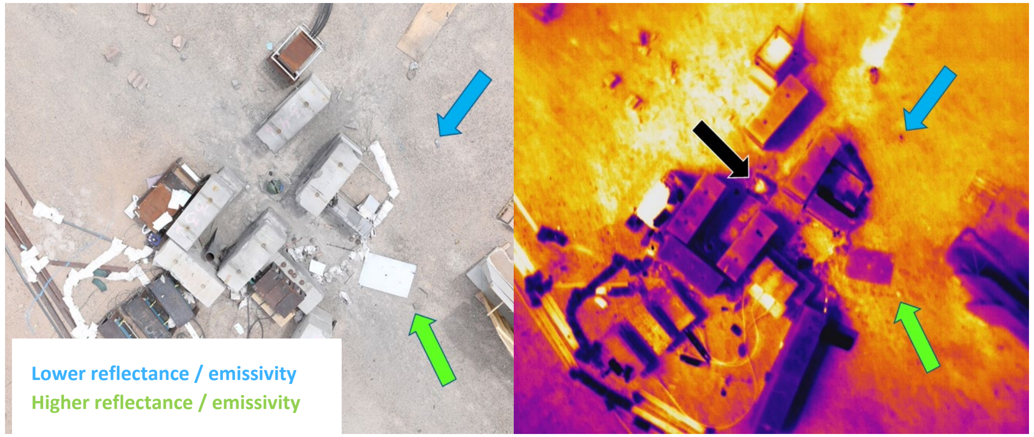


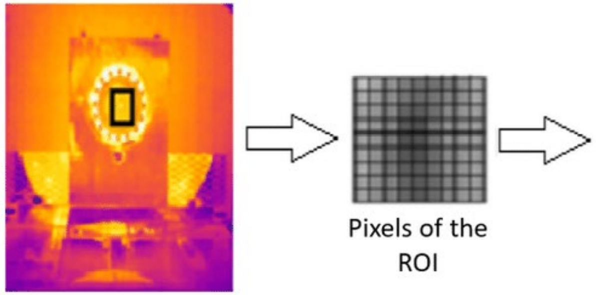


Crawford et al., 2021; Schultz-Fellenz et al., 2020

Thermal Imagery

- Thermal sensors have much lower resolution than traditional (RGB) cameras
- Thermal sensors collects brightness temperature (~reflectance/intensity) values for every pixel
- Imagery is usually converted to a temperature but, without calibration will be inaccurate
- We converted thermal imagery to grayscale imagery since the difference between a pixel with a high reflectance object (metal) will be different than the surrounding landscape





Thermal image

Pixels of the ROI

34,698	34,732	34,827	35,14	35,121
34,613	34,946	34,974	35,003	35,131
34,622	34,955	35,007	35,188	35,306
34,684	34,936	35,036	35,259	35,273
34,722	34,917	34,969	35,192	35,273
35,055	35,192	35,301	35,486	35,628
35,135	35,297	35,467	35,717	35,788

Temperature profile matrix

Scope of Study

Study questions

- Following a surficial experiment can we identify metal fragments greater than 10 cm?
- Can we process these data on a single machine?
- Can we collect and process thermal imagery without GPS tags?
- Can we identify other objects or activity beyond metal fragments?

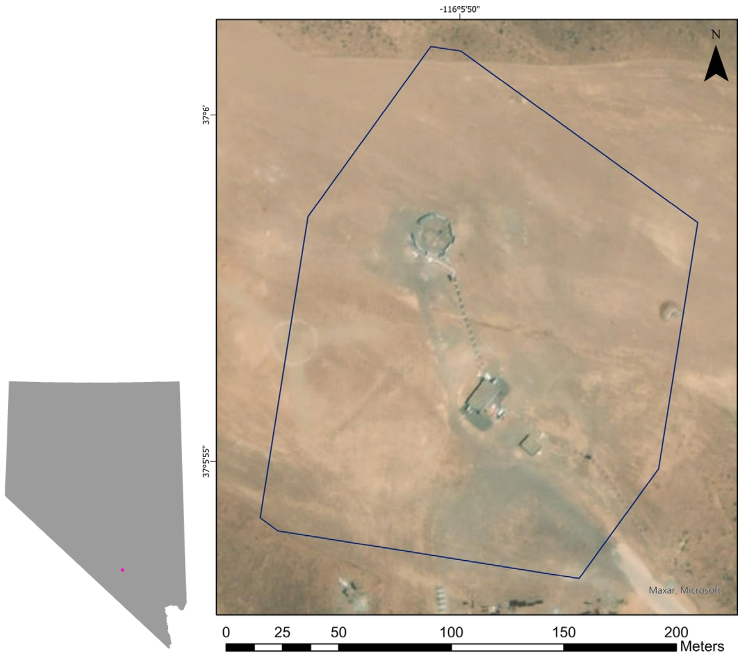
Data Collection Parameters

- An experiment involving a surficial chemical explosion created metal fragments

- Imagery was collected over 3 days

- Temperatures throughout the day ranged from 32C-46C

- Imagery was collected prior to and following the experiment



Equipment

- Platform: Uncrewed Aerial System (UAS)
- Thermal imagery: FLIR DUO Pro R Thermal Sensor
- RGB imagery: Canon EOS 5D Mark IV dSLR Digital Optical Camera

Workflow

1 Retrieve imagery from camera
2 hours

2 Convert Thermal images to grayscale
10 Hours

3 Load photos into Agisoft
0.5 Hours

4 Initial alignment
17.5 Hours

5 Remove takeoff / landing / poor quality photos
3 Hours

6 Apply atmospheric corrections to ground control locations
2 Hours

7 Import ground control points
1 Hour

8 Align photos to ground control points
20 Hours

9 Optimize alignment, return to step 8 as needed
2+ Hours

10 Generate dense cloud
40 Hours

11 Clean dense cloud (gradual selection)
5 Hours

12 Generate DEM
1 Hours

13 Generate orthoimage
6 Hours

Total processing time
110 Hours

Manual Processing

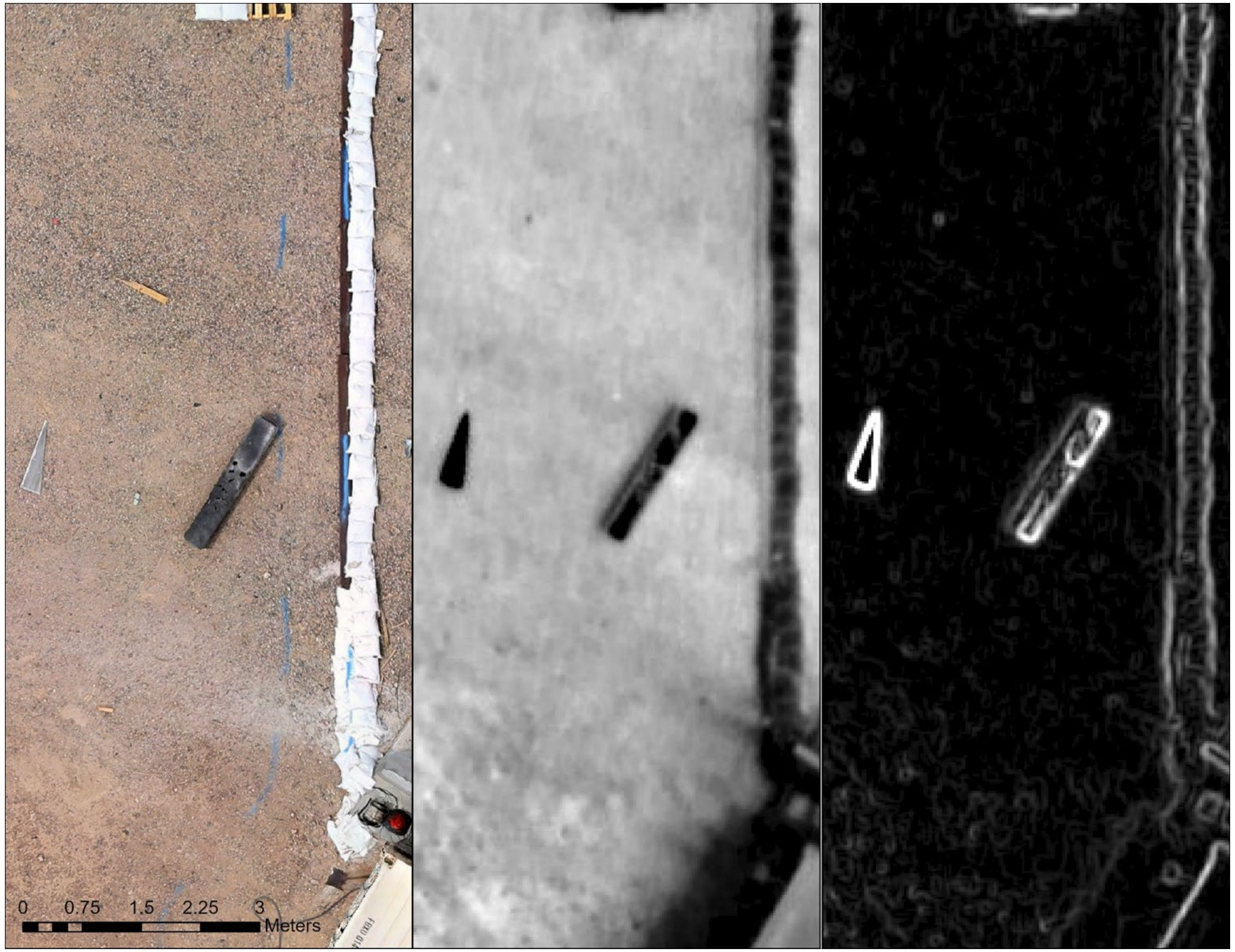
CPU Processing

Results

- Thermal products for the site were generated
- Resolution of imagery:
  - Thermal 10.2 cm
  - RGB 0.57 cm
  - DEM 1.2 cm
- 105 new fragments were found manually ranging in area from 0.88 m^2 - 4.94 cm^2

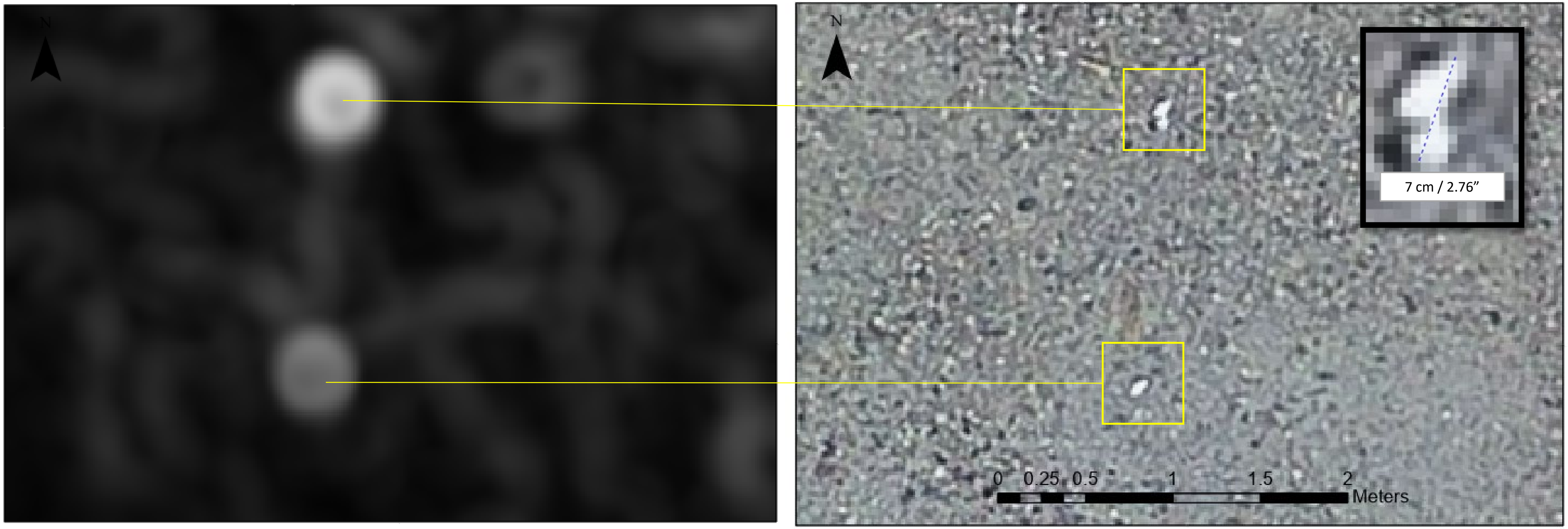
Detection of post-explosion debris from thermal imagery

- RGB imagery shows newly generated metal fragment and debris
- Thermal imagery distinctly shows objects with large variation in reflectance/intensity with the surrounding landscape
- Edge detection can further assist in the distinguishing of objects of interest



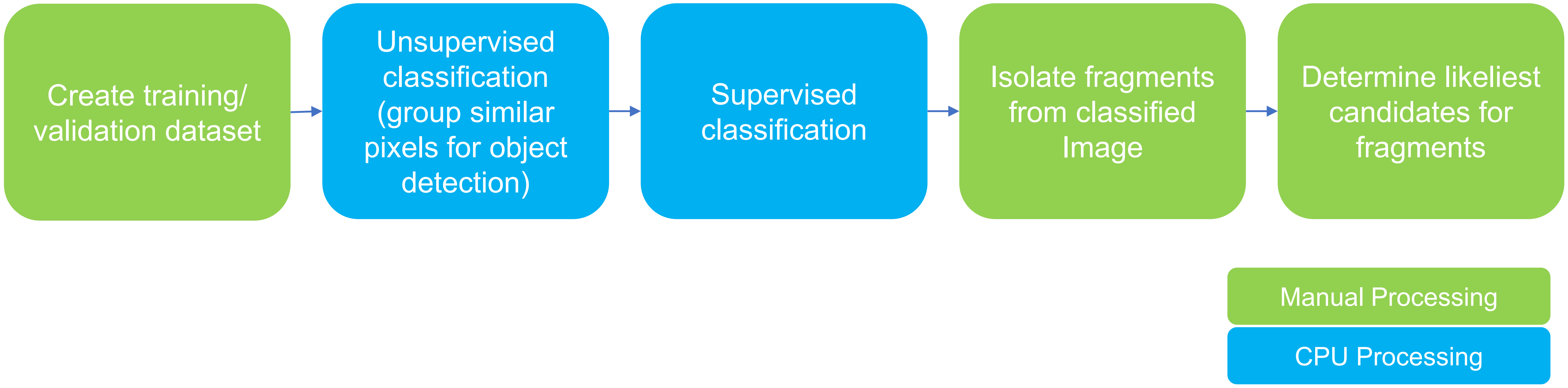
Manual Fragment Identification

Thermal RGB



Thermal Layer helps identify objects smaller than target size (<10 cm)

Workflow for determining probable fragments using machine learning tools in ArcGIS Pro

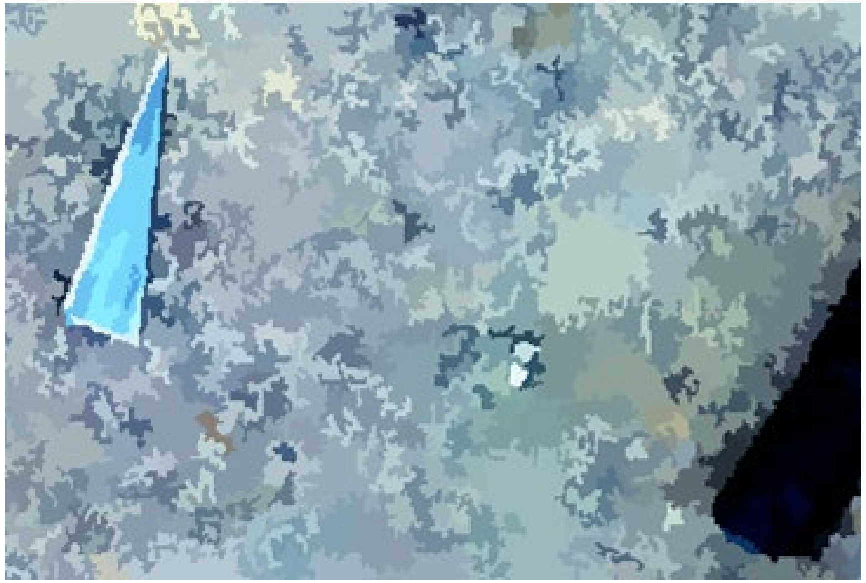


- Detected 461 potential fragments

Machine Learning and AI

- Tested ArcGIS-based ML tools (Random Trees, Support Vector Machine) for thermal signature detection

- Training data generation = initial time investment



Conclusions, Challenges, and Next Steps

- Thermal sensors can be used to generate orthoimages using modified photogrammetric workflows
- Using multiple sensors, we can detect post-explosion fragmentation and surface disturbance following activity
- Method works with thermal sensors, regardless of platform, and without GPS
- Timeline for processing imagery is long, time to completion needs refinement
- Advances in sensors will allow for faster and higher resolution collections
- ML/AI detection methods could greatly reduce the time from collection to actionable data