National Nuclear Security Administration



# Build Geometry Monitoring & Control for Wire Arc Additive Manufacturing Process

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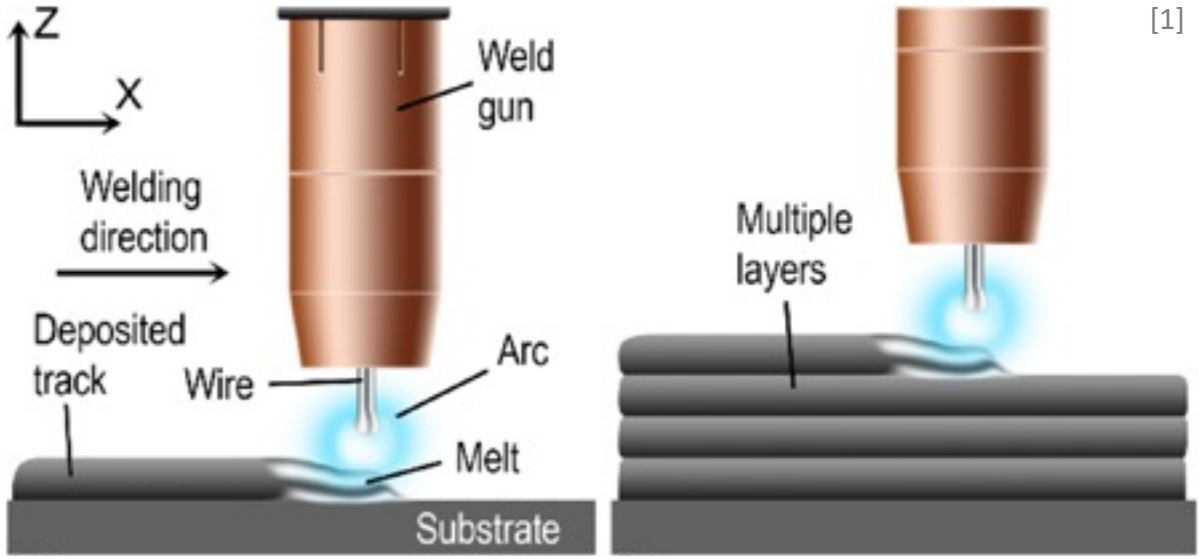
Consortium for Enabling Technologies & Innovation

[1] Nasstrom et al. Laser enhancement of wire arc additive manufacturing, 2019. https://doi.org/10.2351/1.5096111

# Problem

WAAM bead height varies considerably during a build

- Makes path planning difficult & trial & error approach necessary
  - Increases manufacturing time
  - Increases costs due to additional material, operator hours, & electricity used
  - Risks damage to machine if welder hits overbuilt part



[1]

Wire arc additive manufacturing (WAAM) process

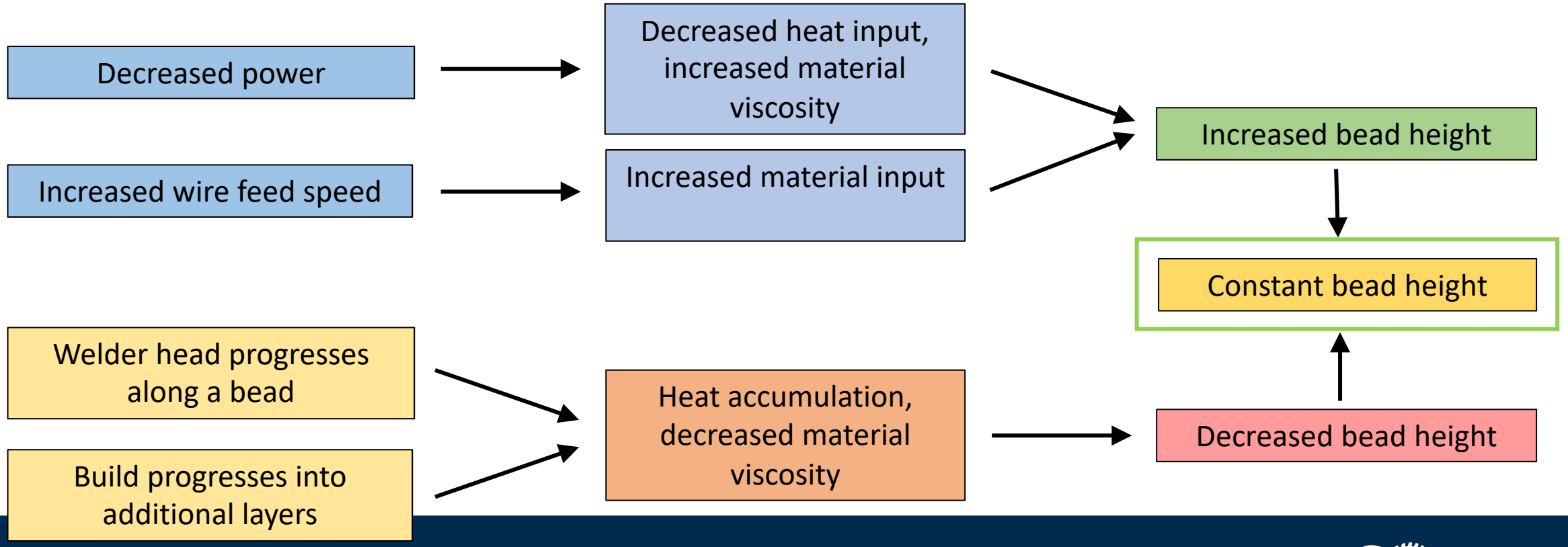
Welder head progresses along a bead

Build progresses into additional layers

→ Heat accumulation, decreased material viscosity → Decreased bead height

# Proposed Solution

- Adjust WAAM parameters in real-time to keep a constant layer height

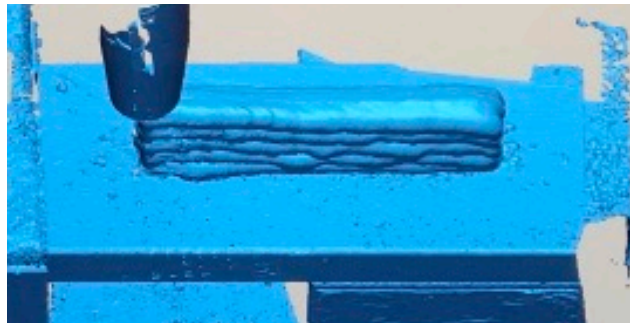


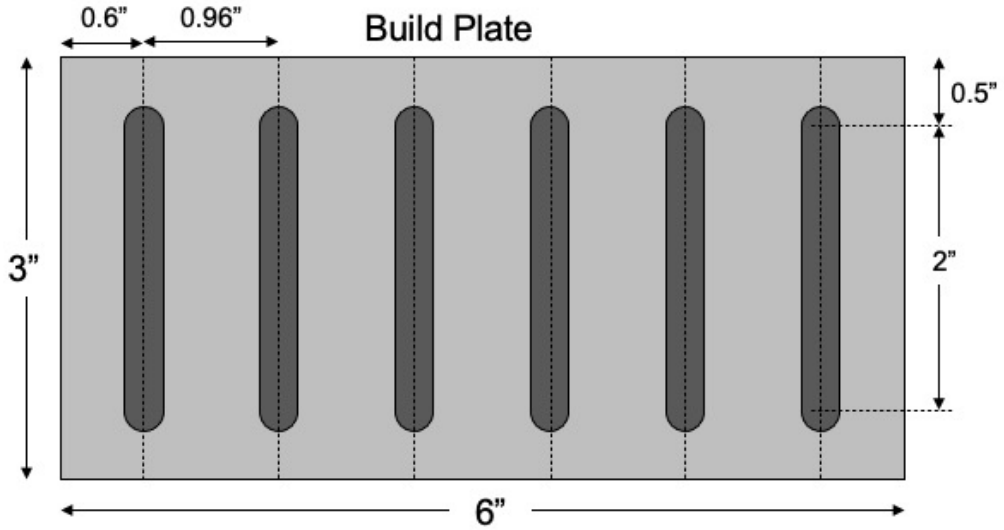
# Proposed Solution

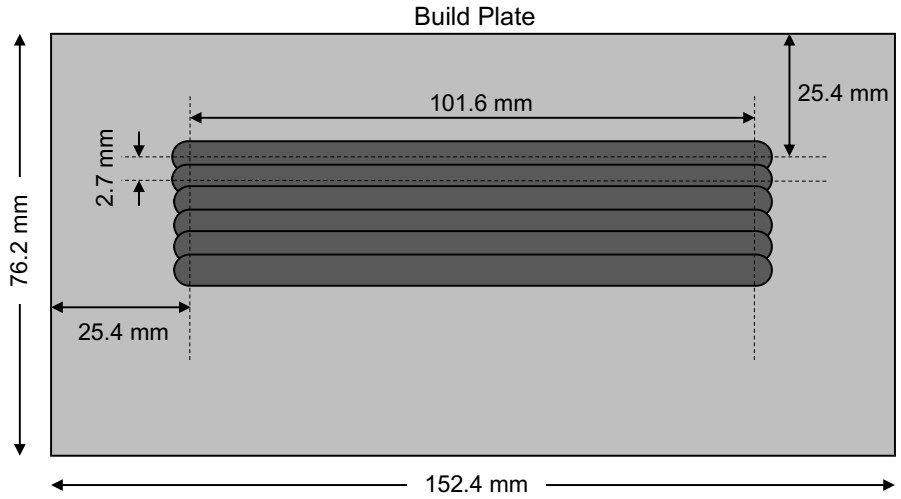
- Application: Adjust WAAM parameters in real-time to keep a constant layer height
- My goal: Design a ML / pattern recognition model which predicts WAAM parameters to be used for each bead section
  - System inputs:
    - Thermal conditions (IR image data)
      - Interpass temperature, temperature at this location shortly before this layer, previous cooling rate at this location, previous weld pool geometry (length, width) at this location, build plate temperature, etc.
    - Desired layer height
  - Parameters to predict / update:
    - Power
    - Wire feed speed
  - 9-class classification problem (3 power values & 3 wire feed speeds)

# Experiments

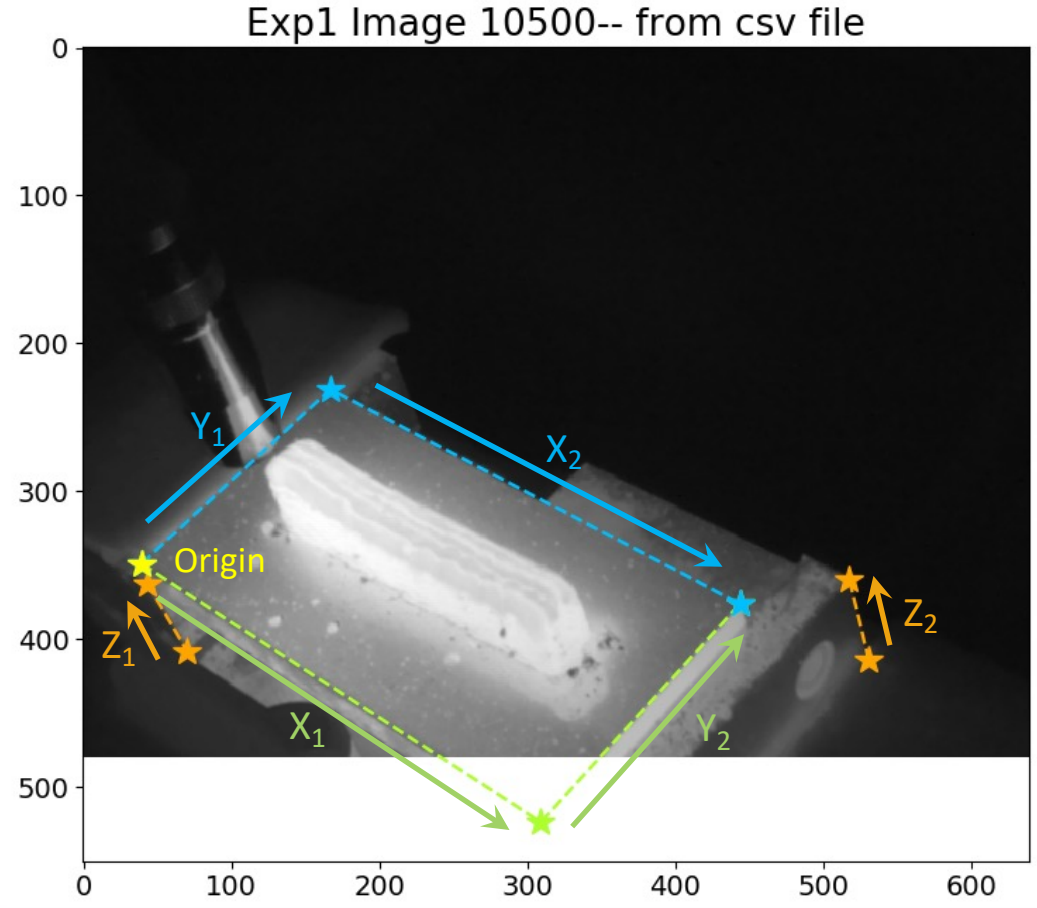
- Machine: Tormach WAAM system at ORNL
- Material: Mild steel
- Initial Experiments:
  - Goal: determine the parameter sets for tallest & shortest layer heights possible, while keeping acceptable build quality
- Main Experiments:
  - Rectangular pads
    - 6 beads wide & 8 layers tall
  - Varied parameters:
    - Traverse speed (3 values)
    - Wire feed rate (3 values)
    - 9 builds total
  - Data collection:
    - Laser light scans after each build layer to capture bead heights
    - IR camera capturing thermal conditions (4 Hz)

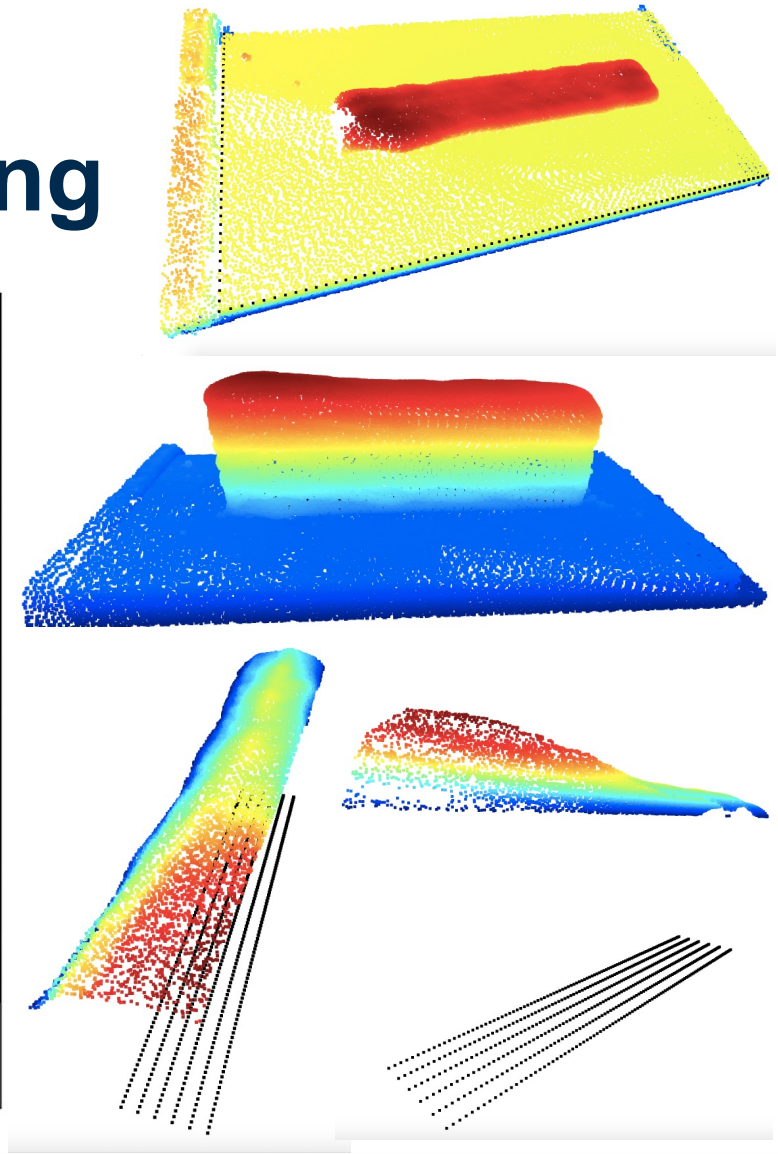


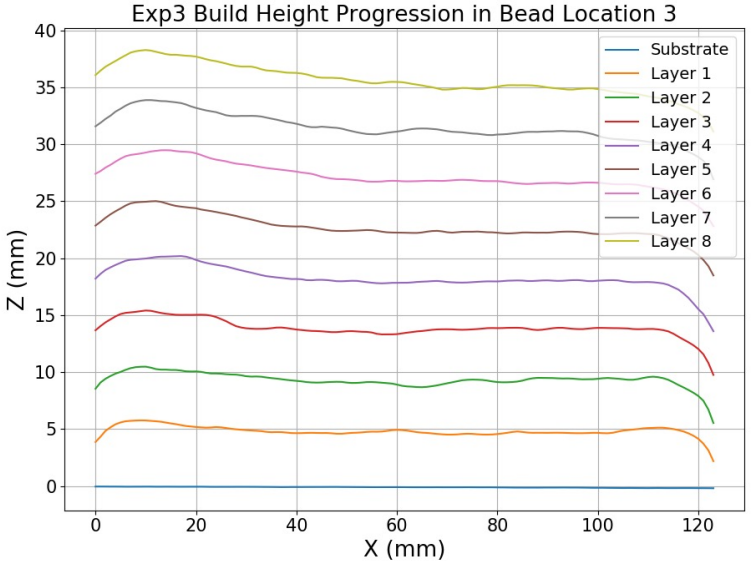


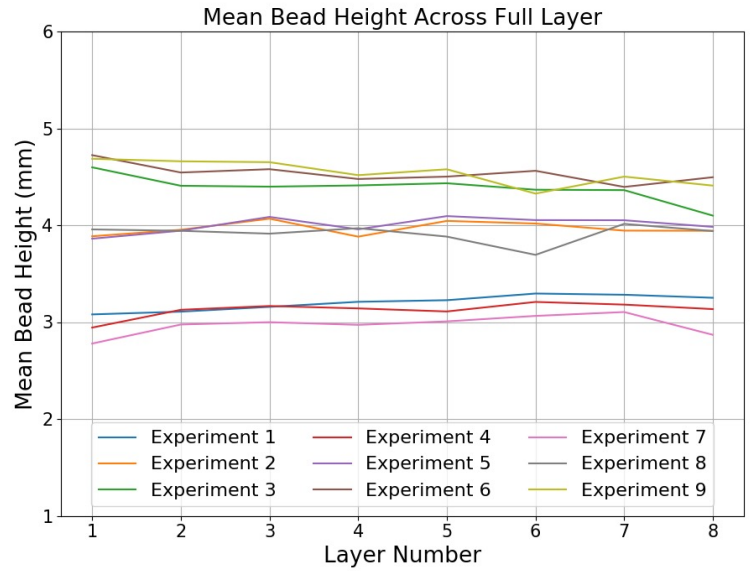



# Data Processing





# Mission Relevance & ETI Impact

Mission Relevance:

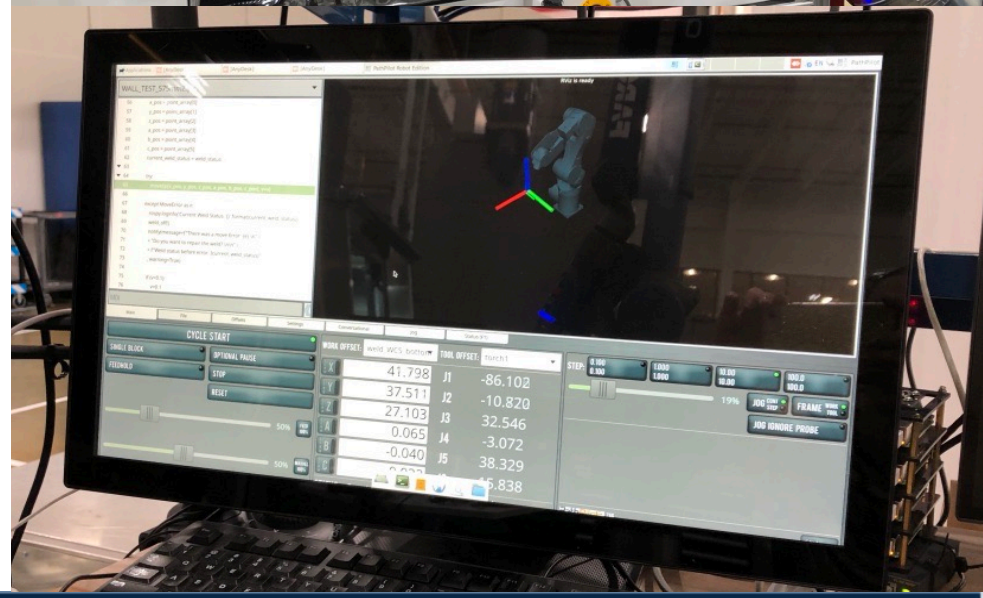
- Metal AM like WAAM can create parts of virtually any shape, from easily-accessible wire or powder
  - Could be used by opposing entities to bypass export controls or produce parts for nuclear weapons without being detected
- Technology like this could discreetly monitor the geometry of parts being constructed, & flag predicted geometries which match restricted part shapes
- This system could also improve American manufacturing efficiency, quality, & sustainability

ETI Impact:

- Experimentation conducted at ORNL during summer internship
- ORNL cutting-edge machines & experienced researchers have been invaluable for project & personal development

# Future Work

- Finish writing IR image processing code & calculating thermal features
- Analyze patterns between thermal features, bead geometry, & process variables
  - Test several pattern recognition techniques, including ML & non-ML strategies
- Evaluate effects of layer #, bead location in layer, process parameters, & thermal conditions on system effectiveness at predicting bead geometry & parameters used
- Potentially return to ORNL to run more experiments
- PhD proposal planned for this summer



# ACKNOWLEDGEMENTS

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