# Data-driven Local Porosity Prediction in Laser Powder Bed Fusion via In-situ Monitoring

Berkay Bostan (beb171@pitt.edu), Shawn Hinnebusch, David Anderson, and Albert C. To (albertto@pitt.edu)

LinkedIn

UPISC UNIVERSITY OF PITTSBURGH INFRASTRUCTURE SENSING

COLLABORATION WORKSHOP

NATIONAL ENERGY TECHNOLOGY LABORATORY

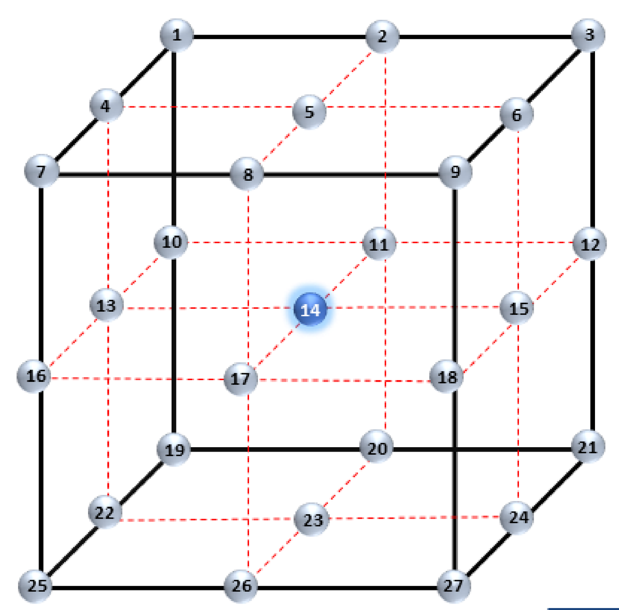
## Overview

**Objective:** Develop a deep learning scheme for detecting defects in the LPBF process.

**Target:** Prediction of defects using thermal signatures and spatter counts obtained through cost-effective equipment.

**Purpose:** Enable in-situ defect prediction during manufacturing and repair of defects via rescanning. Additionally, investigate defect formation mechanisms through feature importance analysis.

## In-Situ Defect Detection Using IR Imaging and Machine Learning



$$\left\{ \begin{array}{c} T_1, T_2, \dots, T_{o^3} \\ \nabla T_1, \nabla T_2, \dots, \nabla T_{o^3} \\ IT_1, IT_1, \dots, IT_{o^3} \\ S_1, S_2, \dots, S_{o^3} \end{array} \right\}$$

Input vector

$[1 \times (n \times o^3)]$

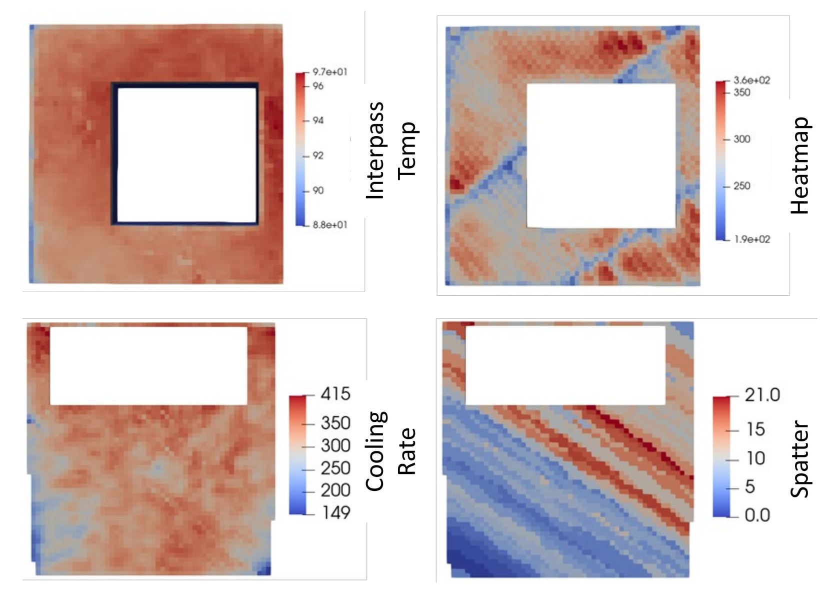
DNNs

$\{Porosity\ \%\}$

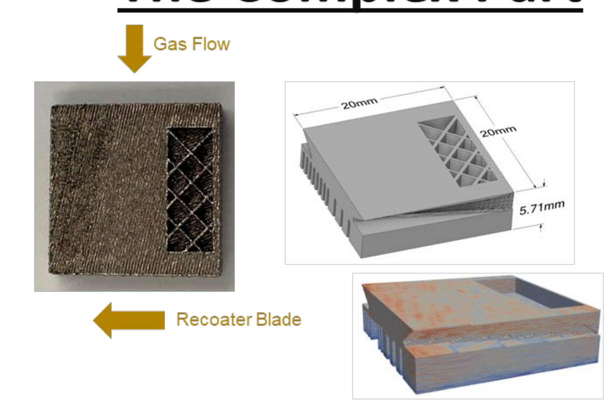
$[1 \times 1]$

- T : Heatmap value
- $\nabla$T : Cooling rate
- IT : Interpass temperature
- S : Spatter count
- o : Neighbor order
- n : Number of main features

### Inputs (12 Images in Total)




### The Complex Part

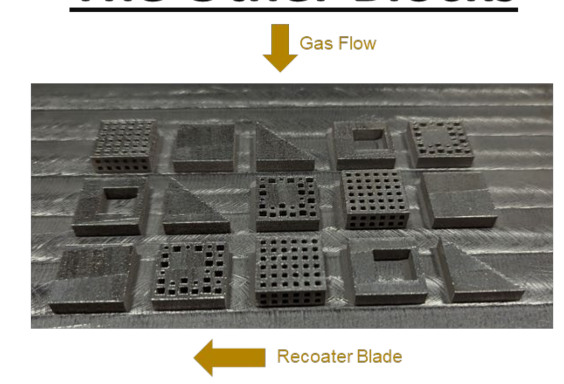



Parameters

- P = 350 W
- V = 1000 mm/s
- Hatch distance = 0.168 mm
- Layer thickness = 0.08 mm
- Rotation = 67°
- No stripes
- Layer thickness = 0.08 mm
- Rotation = 67°
- No stripes

LOF REGIME

### The Other Blocks

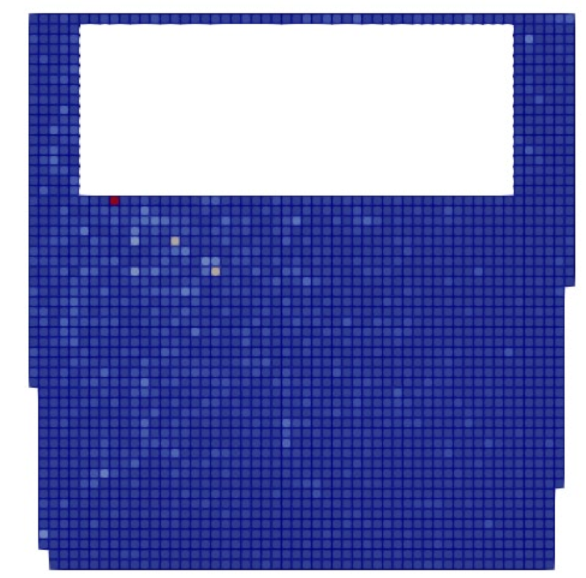



Standard EOS Parameters

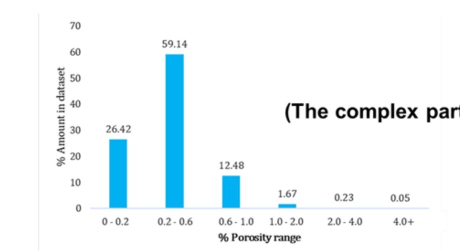
- P = 285 W
- V = 960 mm/s
- Hatch distance = 0.11 mm
- Layer thickness = 0.04 mm
- Rotation = 67°
- 5 mm stripes

STANDARD REGIME

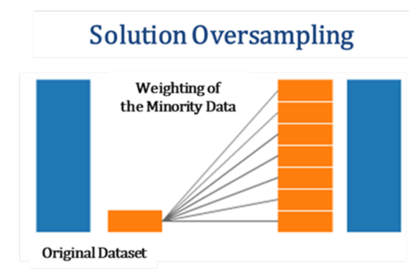
### Output



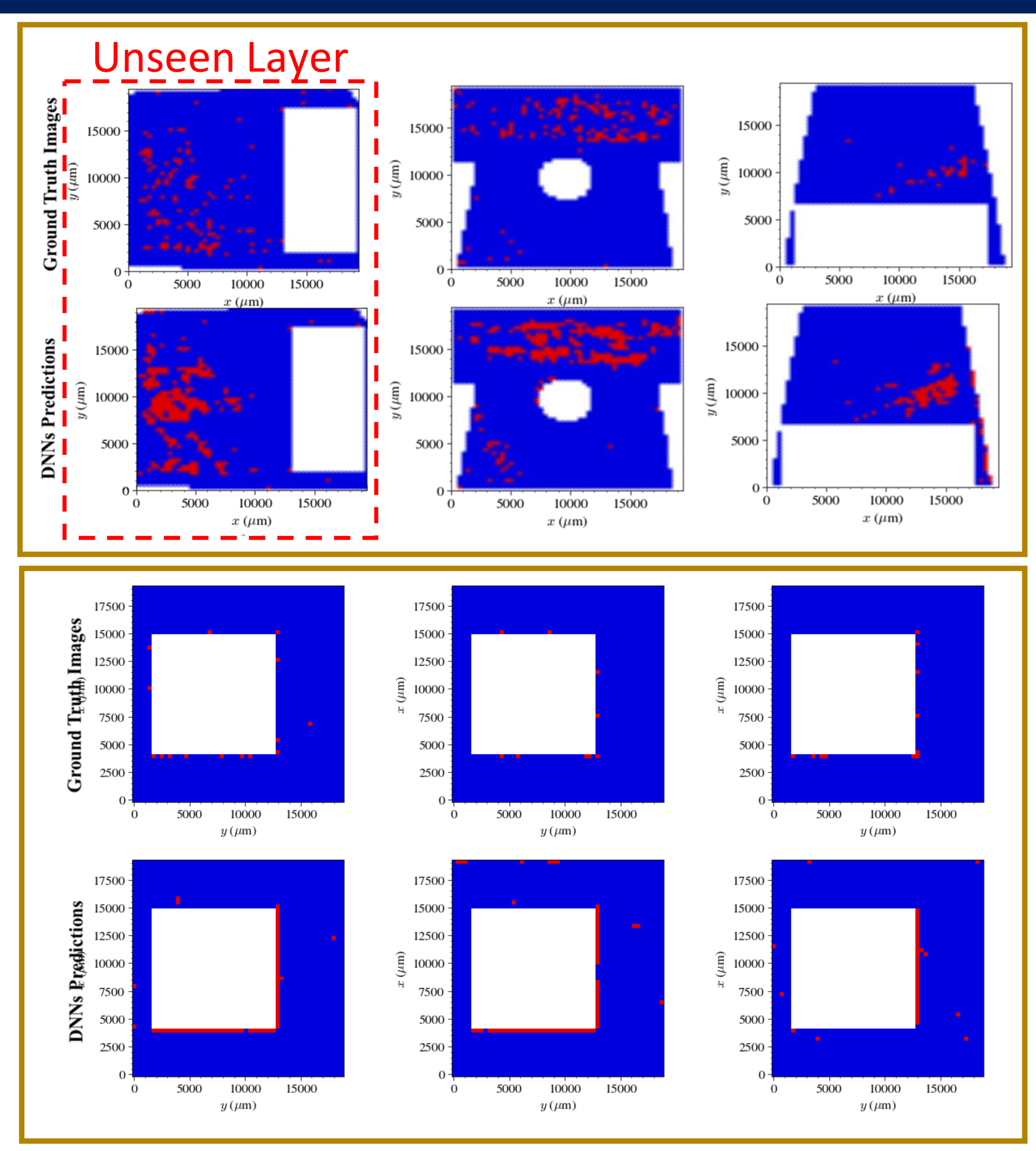
### Highly Unbalanced Dataset Problem
### Solution: Oversampling




| | Porous Pixels | | | | | |
|---|---|---|---|---|---|---|
| | Total Number of Pixels | 29 - 33 um | 33 - 36 um | 36 - 51 um | 51 - 62 um | 62+ um |
| Total Count | 175812 | 262 | 87 | 81 | 2 | 3 |
| % | 100 | 0.1490 | 0.0495 | 0.0461 | 0.0011 | 0.0017 |




## +95% True Positive Ratio on Test Set

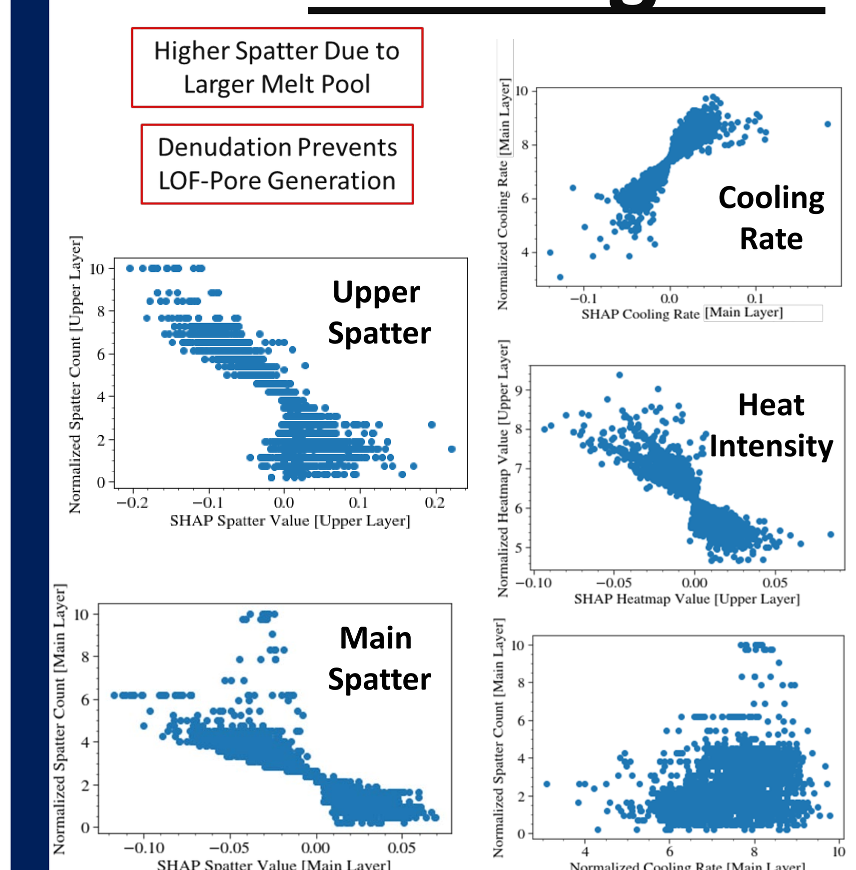



## Feature Importance Analysis

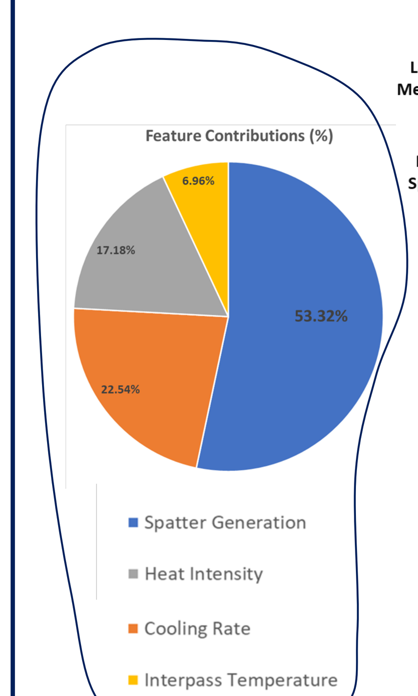
### LOF Regime

Higher Spatter Due to Larger Melt Pool

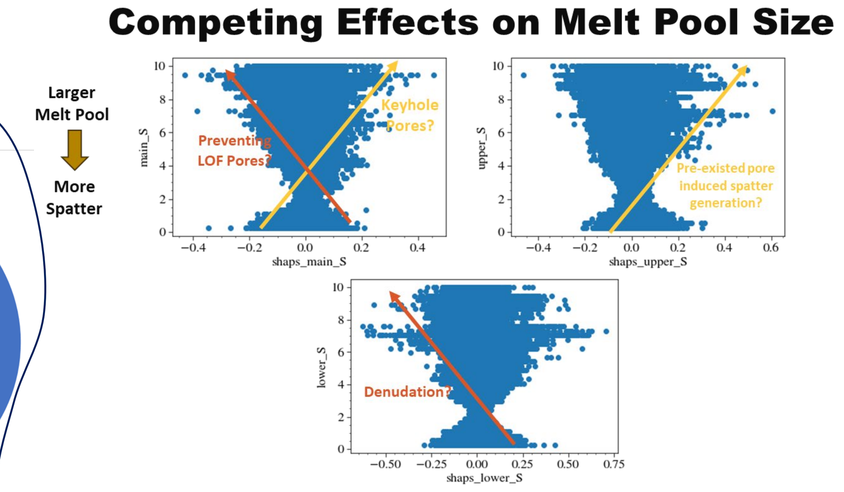
Denudation Prevents LOF-Pore Generation



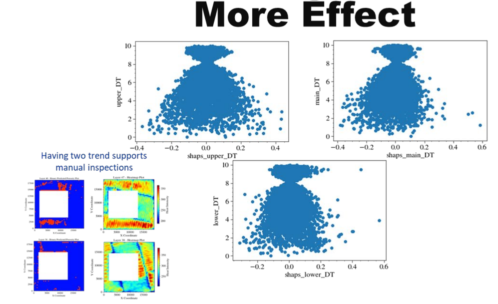

### Standard Regime




**Competing Effects on Melt Pool Size**




**Lower Cooling Rates Have More Effect**



## Conclusions

- **95%** of total pores could be predicted both in LOF and standard regime in the test set.
- The most crucial feature for porosity prediction is the spatter generation in both standard and LOF regimes.
  - Competing effects in standard regime
  - Denudation and larger melt pool prevents pore generation in LOF regime
- The cooling rate is the second most dominant feature.
  - While lower cooling rates fix the LOF pores, sometimes they may cause keyhole pore generation.