Introducing Applied Optimization (AO)

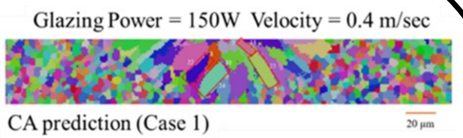
Applied Optimization
The Right Balance of Non-Conformity and Critical Thinking

Challenges: (1) Limited interoperability for the data to report results of process simulation, and to demonstrate maturity for the models, (2) Scan path data is not available on most commercial systems due to IP requirements, and (3) High-temperature material properties

Developer of Additive Manufacturing Parameter Predictor (AMP^2) software and Open Sensor Interface (OSI)

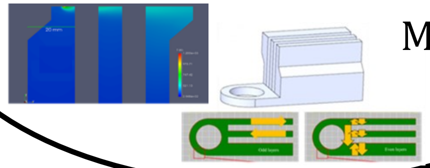
Our Awards in AM Challenges for Modeling, Scan Path Generation, and Digital Thread Analytics

AMP^2 2018
NIST
2nd Prize
Solidification Microstructure Modeling

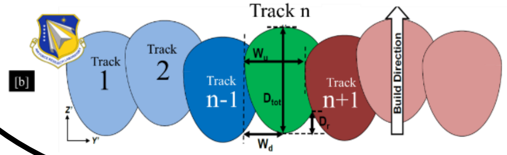


2022
America Makes
AMNOW
Phase II Award
$50,000
Metals Challenge
Digital Thread data analytics to discover flaws and trends

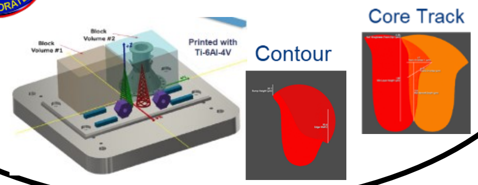
AMP^2 2017
DARPA
America Makes
$40,000
2nd Prize
Part-Scale Process Modeling



AMP^2 2020
AFRL
3rd Place
Melt Pool Modeling



ALSAM
AMP^2 2021
America Makes
$11,600
3rd Prize
Scan Path Generation



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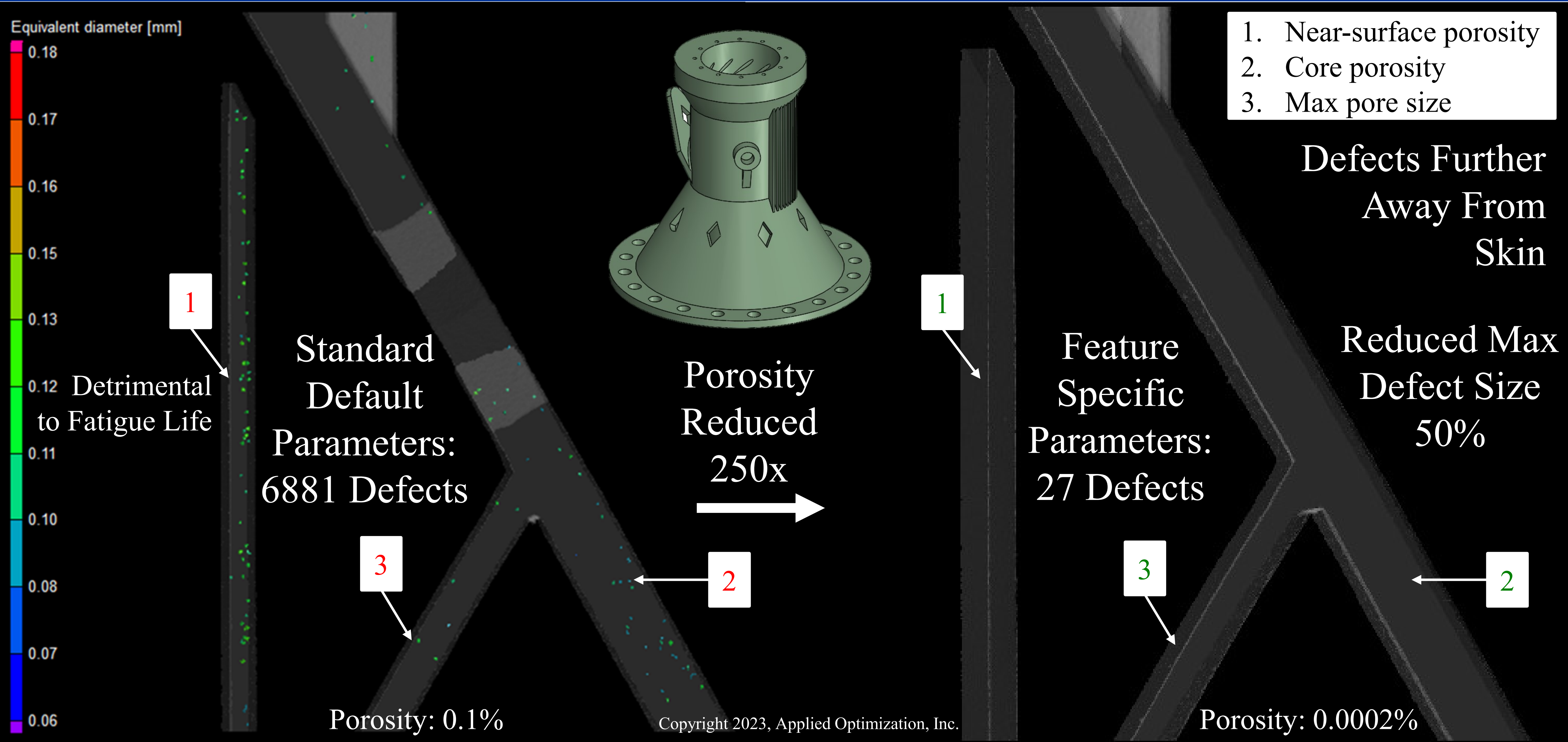
Parameter Prediction by AMP² software

250x Reduction in Defects using Track-by-Track Feature-Specific Parameters (FSP)



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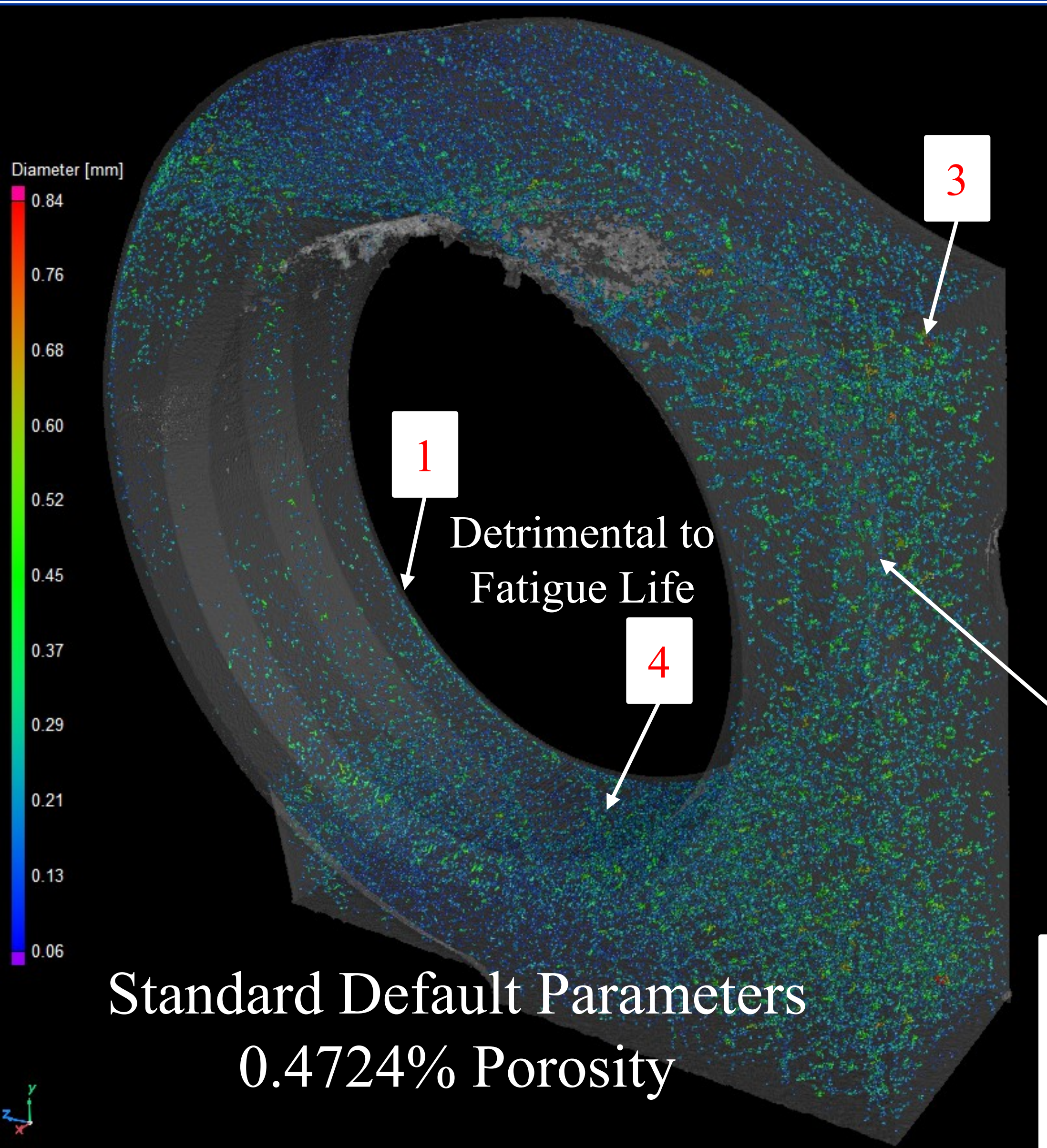
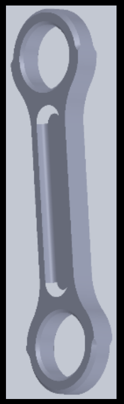
Feed-Forward Control (FFC) of Laser Powder Bed Fusion

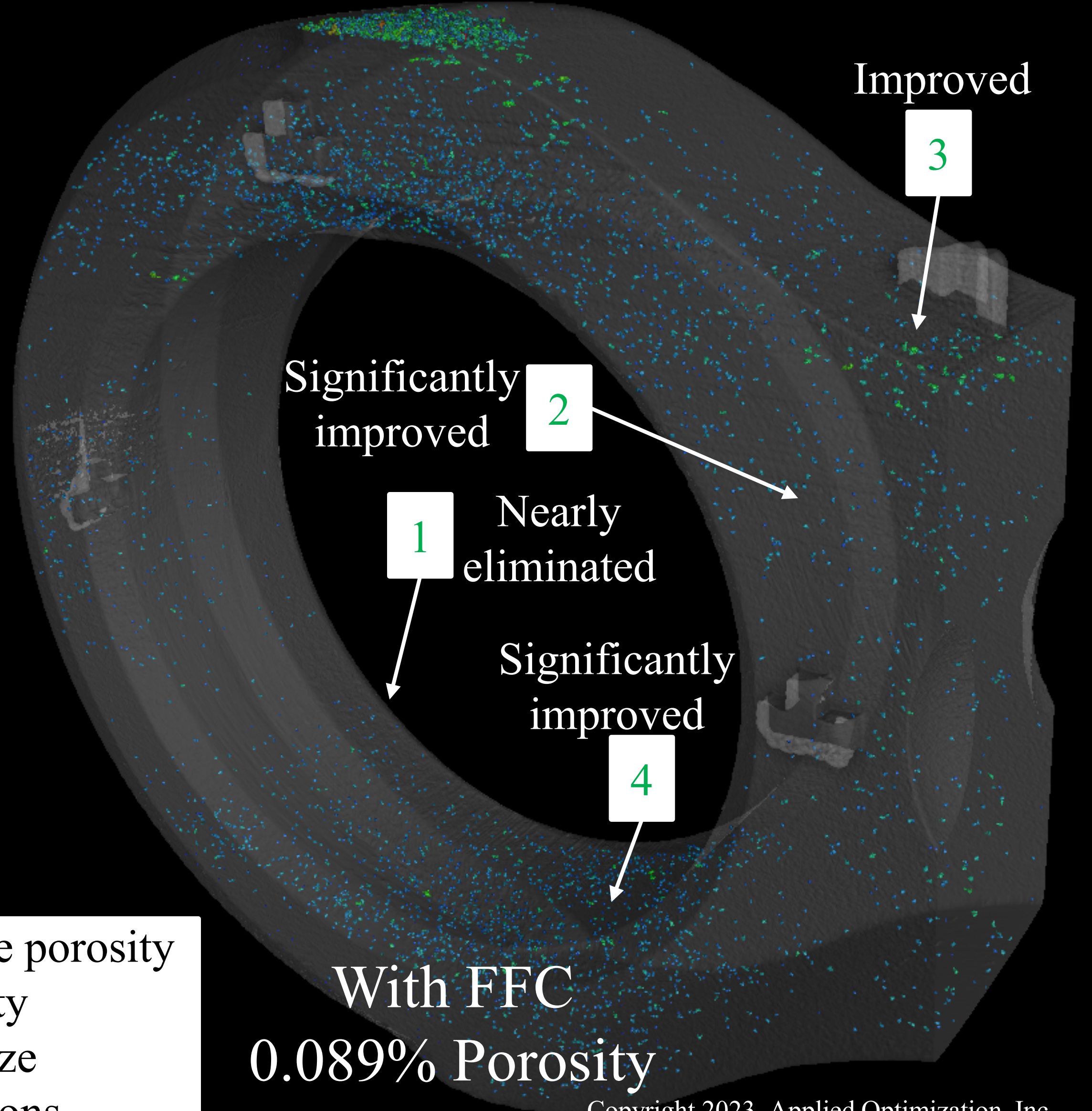
Layer-by-Layer Process Control (Its methods drew upon the understanding gained using process simulation)



Standard Default Parameters
0.4724% Porosity



Porosity Reduced by: 81%



With FFC
0.089% Porosity

1. Near-surface porosity
2. Core porosity
3. Max pore size
4. Critical regions

AO

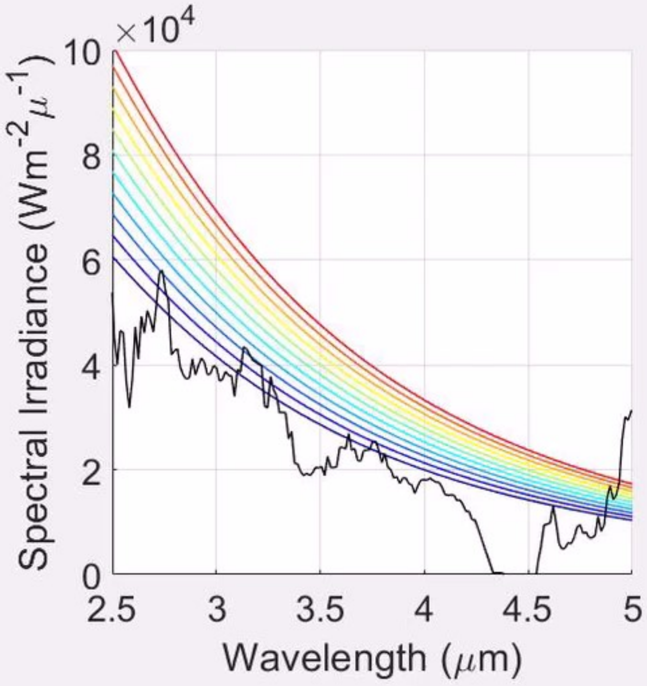
Parameter Prediction by AMP² software

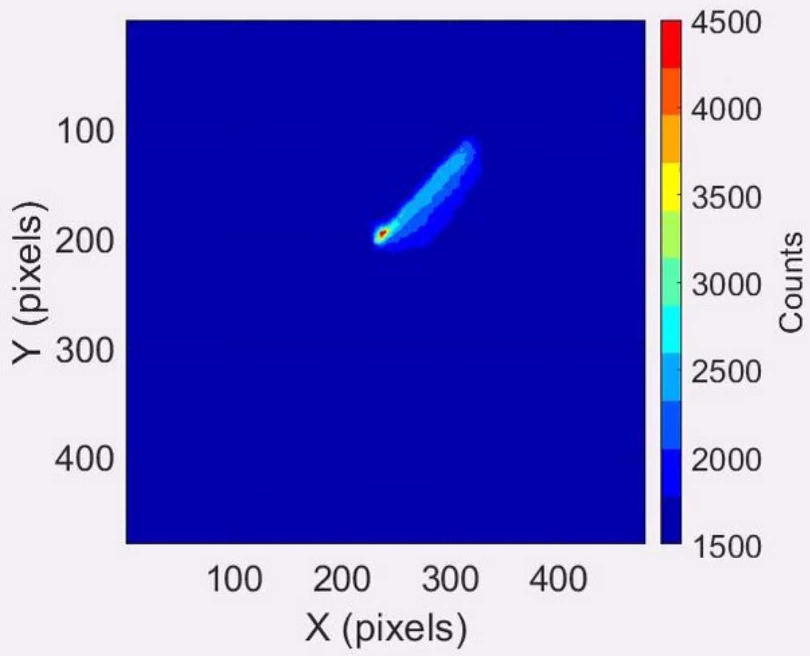
Track-by-Track High-Resolution In-Situ Sensing Data for the Entire Build to Validate FSP predicted by Process Simulations

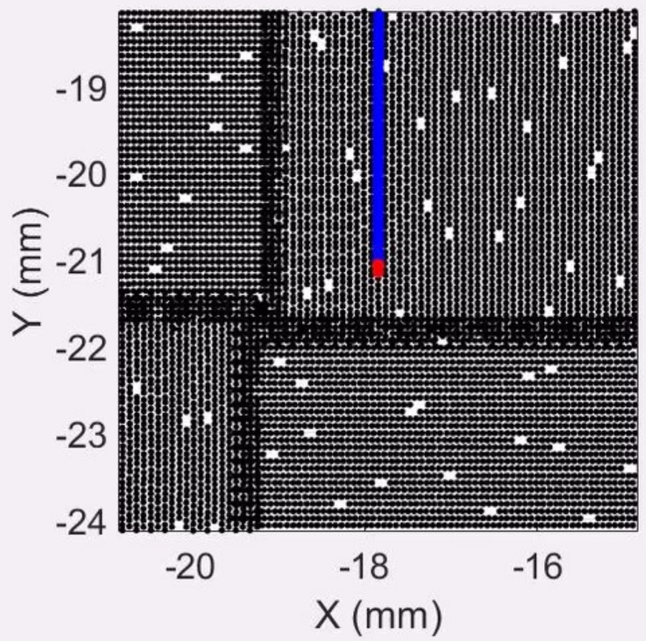
Melt pool Data (Our 1st Experiment)
MWIR Spectrometer Data (SM32Pro)
1.5 – 5 µm waveband
FOV: 1x4 mm², SNR ~1-3

Adjacent to Melt pool
MWIR Thermal Imager Data (FLIR)
500x500 pixels, 3-5 micron waveband
70 µm resolution, Pixel resolution: 39 µm

Boresight Location
Data is registered with Scan Path Track Vectors





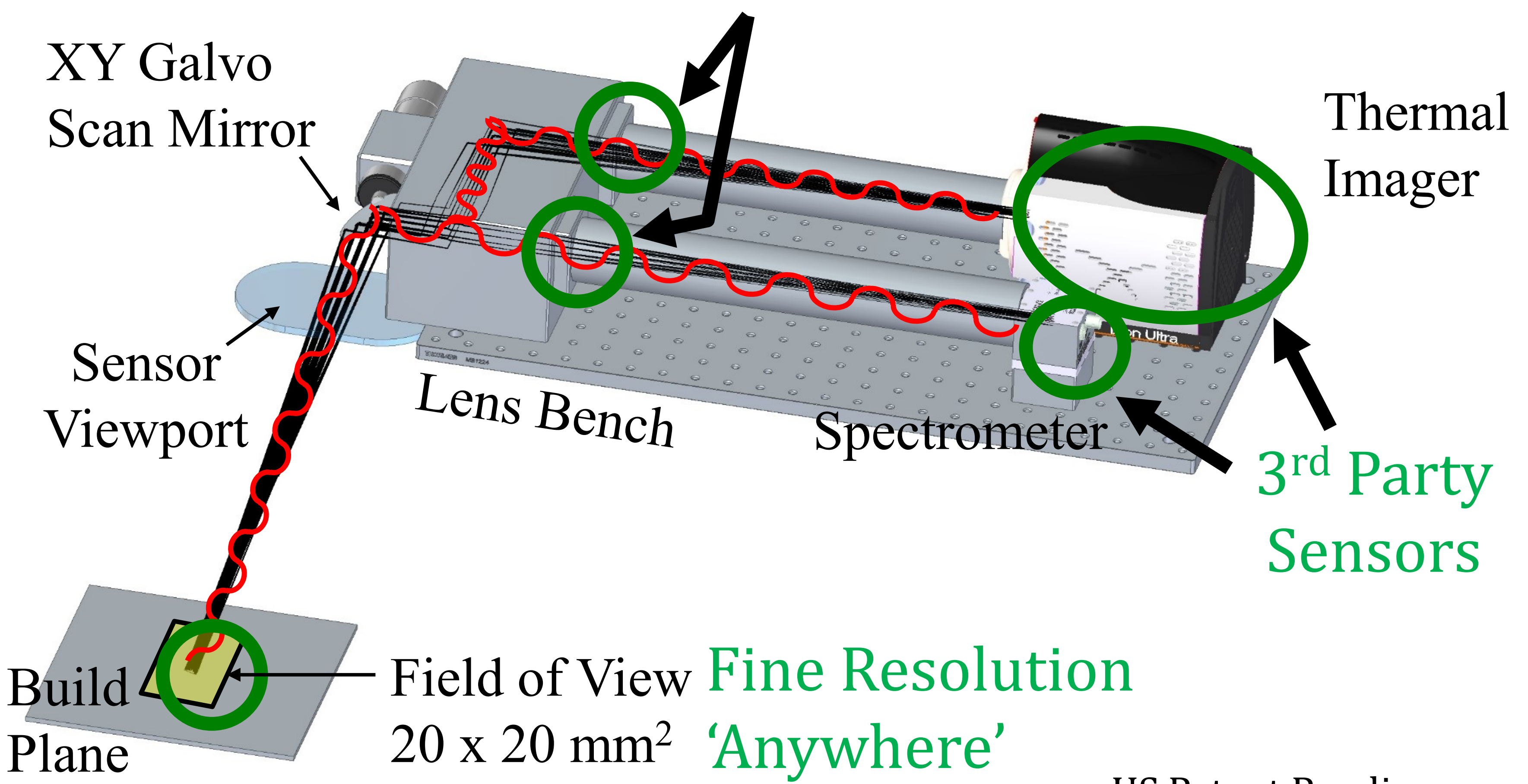


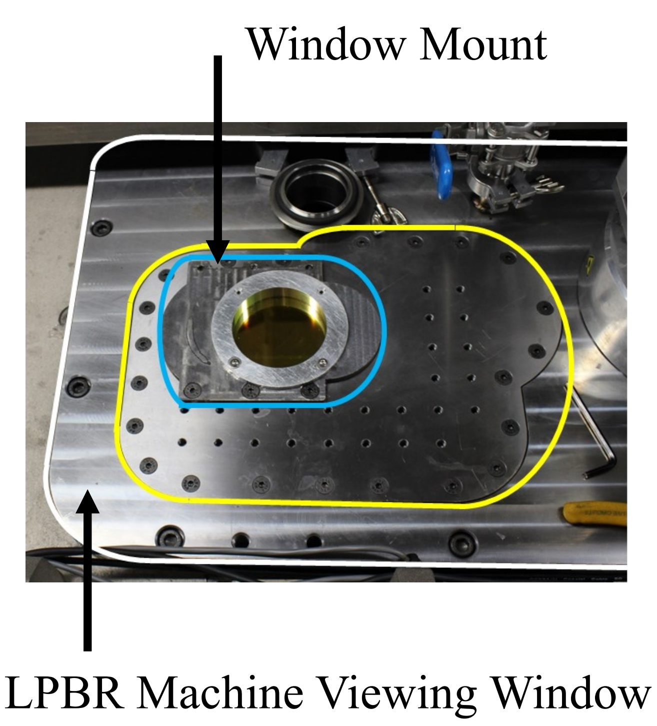
This data was collected in April 2023 for ~400 layers. Such data can be collected anywhere on the build plane.
We had a low SNR (~1 to 3), we are modifying the optics design to significantly increase the SNR

Open Sensor Interface (OSI)

Track-by-Track In-Situ Sensing to:
(1) Validate FSP, and (2) Control the LPBF Process

Challenges: (1) Data management, interoperability and reusability for the cross-correlation data from in-situ sensing and physics-based models, (2) To navigate IP issues for commercial systems





US Patent Pending: 17/202,945

Difficulties to Transition Products

- We do not need it
  - AM part quality is good enough
    - Need improvement for critical parts
      - Who is going to pay for it
        - Need to prove mechanical properties
- Demonstration of maturity metrics for the models
  - Repeatability and reliability
    - Need material and scan path data
- People challenge at customer facilities
  - Consistent availability of a trained person
- CMMC Level 2 compliance
  - High cost + Lack of people

Data Needs and Challenges

For enhancing the value proposition for Additive Manufacturing

- Limited interoperability and reusability of data to report
  - Process simulation results
    - Part-specific predictions
      - Feature specific parameters
    - Cross-correlation with in-situ sensing
    - Schema for a Technology Data Package
    - Evidence of higher TRL
- Fulfilment of IP requirements for proprietary systems, e.g.,
  - Unavailability of scan path
    - Neutral interface for data exchange
      - Reduce work-in-progress costs
- High-temperature material properties data
  - We can generate properties using thermodynamic modeling
    - Experimental data is very limited, particularly for liquid phase
- Insufficient metadata in the historical project records to
  - Validate and mature models