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OVERVIEW OF ADDITIVE MANUFACTURING ACTIVITIES AT ARL PENN STATE | CIMP-3D

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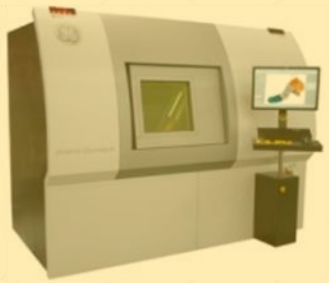
ARL Penn State
Metal Additive Manufacturing

DMG Mori Lasertec 65

GE Vtomex-M CT



FARO ScanArm HD

ExOne Innovent+

TESCAN MIRA 3 SEM

CLASSIFIED CAPABLE

Large Digital X-Ray

Large Format–High Deposition

CLASSIFIED CAPABLE

Stratasys Fortus 400 mc

3D System DMP Factory 500

HPHD

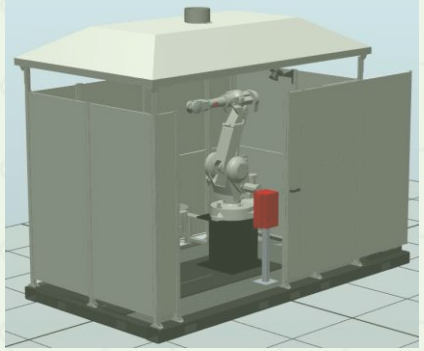
Optomec LENS

EOS M280

3D Systems ProX320

Speed3D Cold Spray

Wire Arc Additive Manufacturing



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CIMP-3D's Footprint in AM

Sensors Technologies

Process Diagnostics

Cyber Security

Simulation Technologies

Machine Control

Advanced Processing

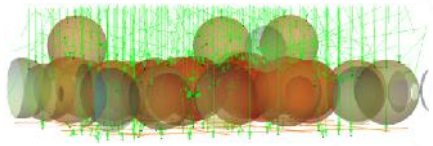
NDE/NDI

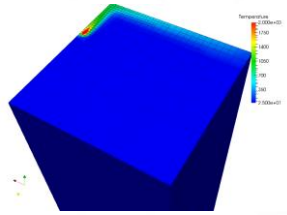
New Materials

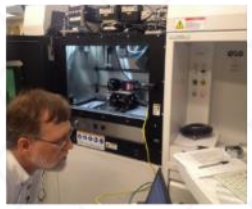
Post Processing

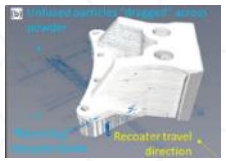
Design Optimization

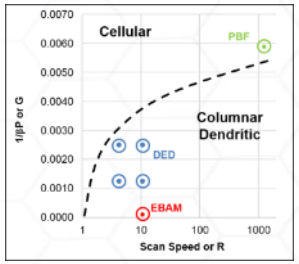
Data Management

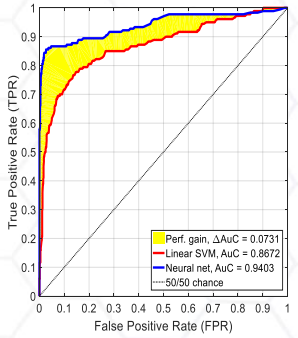












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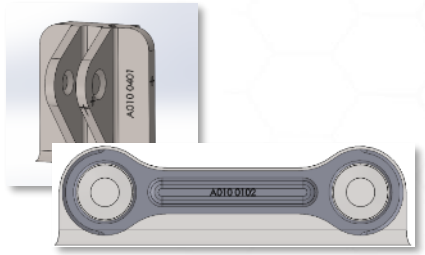
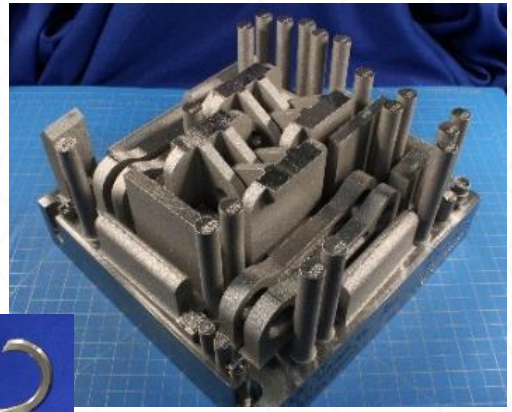
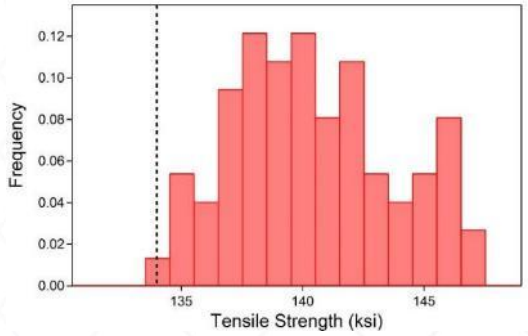
Supporting AM Deployment

Design, Development, Characterization, Testing







Installation & Flight

NAVAIR marks first flight with 3-D printed, safety-critical parts.

http://www.navair.navy.mil/index.cfm?fuseaction=home.NAVAIRNewsStory&id=6323

CIMP-3D

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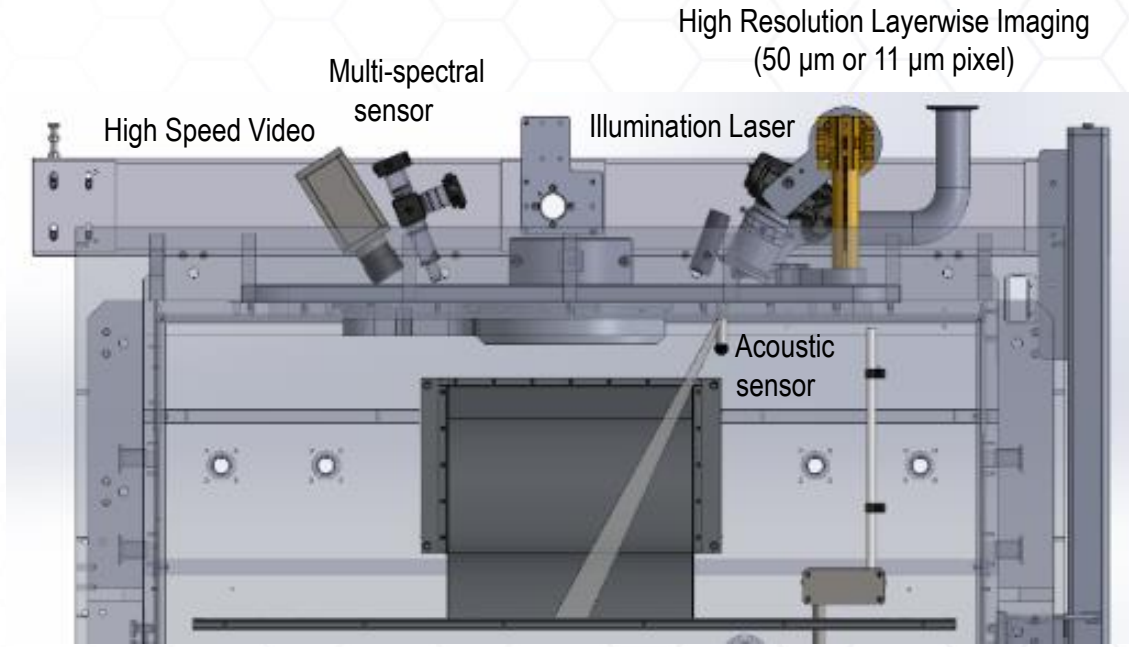
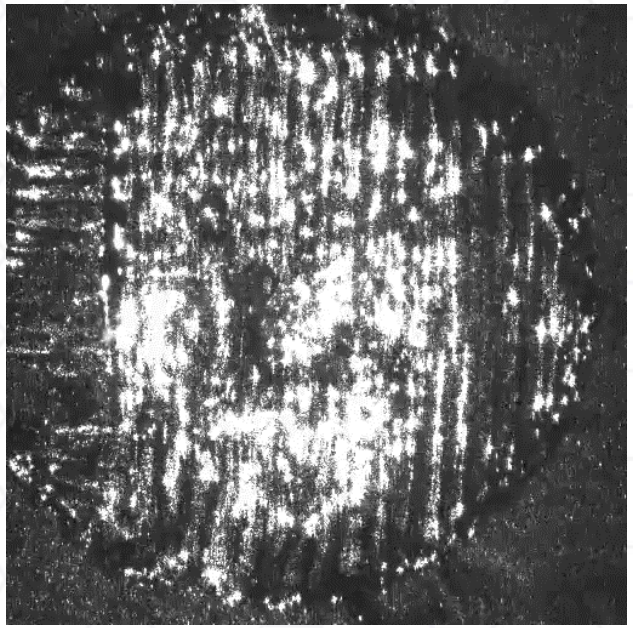
Integrated Advanced Sensing & Control on Commercial PBFAM Systems

Sensors Integrated into 3D Systems ProX 320 (and other systems):

1. High-resolution/high-magnification imaging system (six (6) differing lighting schemes)
2. Two (2) high-speed/high-magnification video
   - Coaxial camera with 405 nm BP filter / Front-facing camera with 520 nm BP filter
   - 25,000 fps
3. Optical Process Emissions (*100 kHz)*
   - Spectrometer
   - Multi-Spectral Sensors
4. Acoustic sensors *(192 kHz)*
5. Thermal Imaging
6. DMP Melt Pool sensor
7. Laser-based powder height measurement





Corbin D.J., Nassar, A.R. Reutzel E.W., Krane, M.H., Overdorff, R. (2019) *Investigation Of PBFAM Flaw Formation Through High-Speed Video Monitoring* 30th Annual International Solid Freeform Fabrication Symposium – An Additive Manufacturing Conference.

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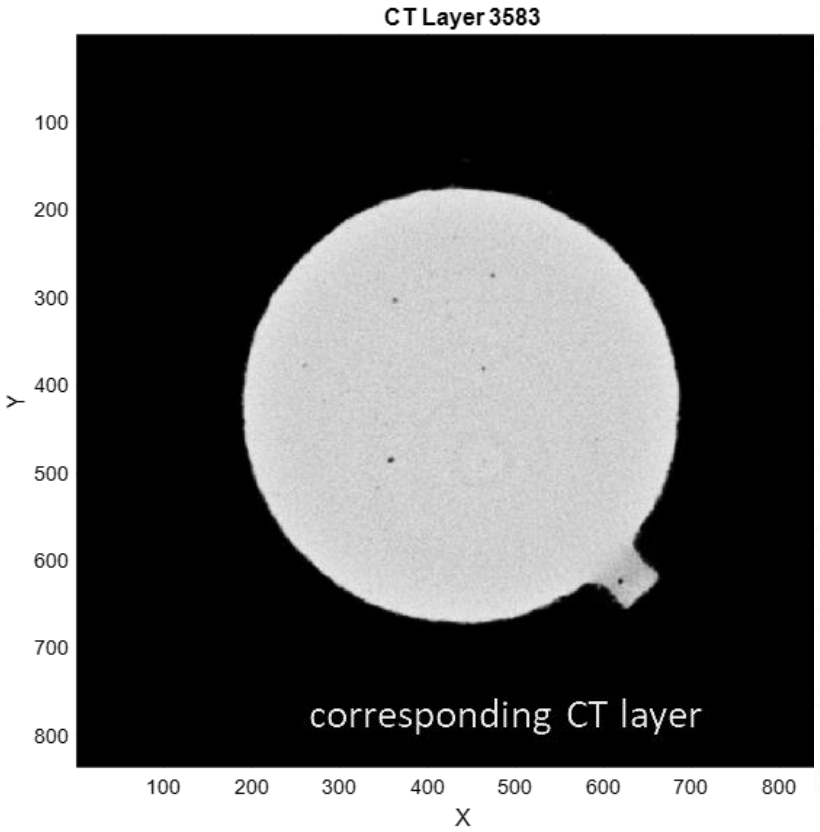
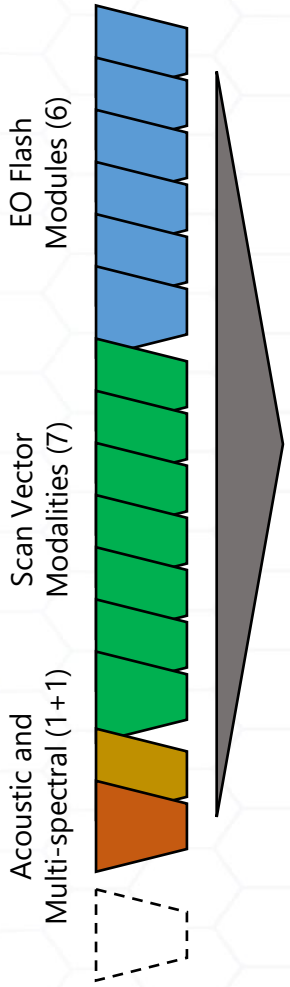
Advanced Sensing, Defect Detection, and Process Control

Defect Detection

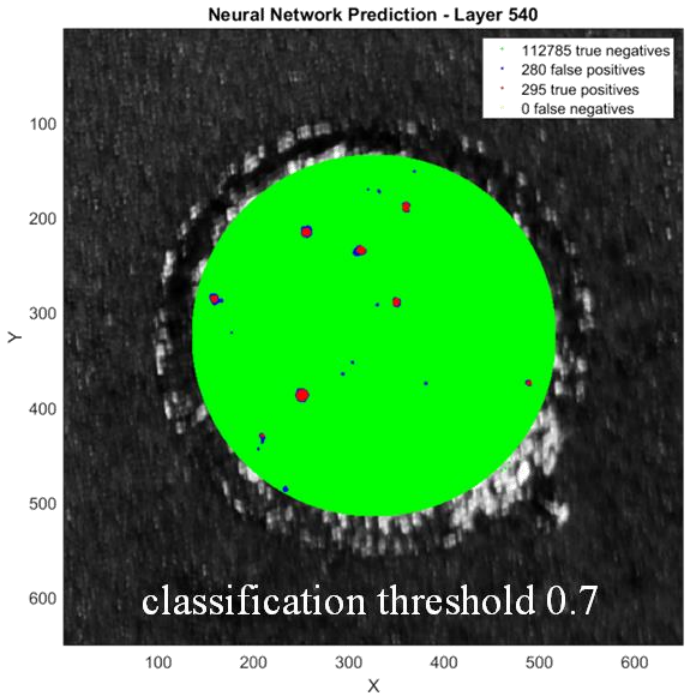
Ground Truth - CT Scan

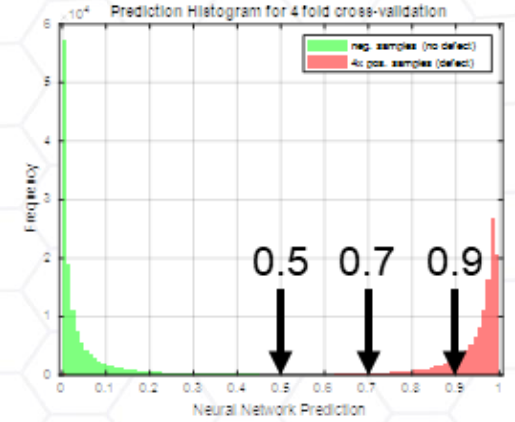


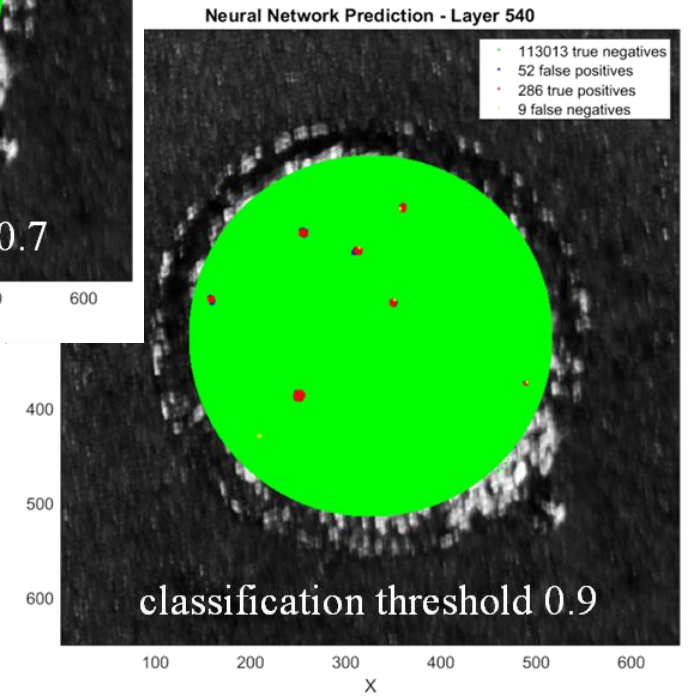
MultiLayer NN



Neural Network Prediction





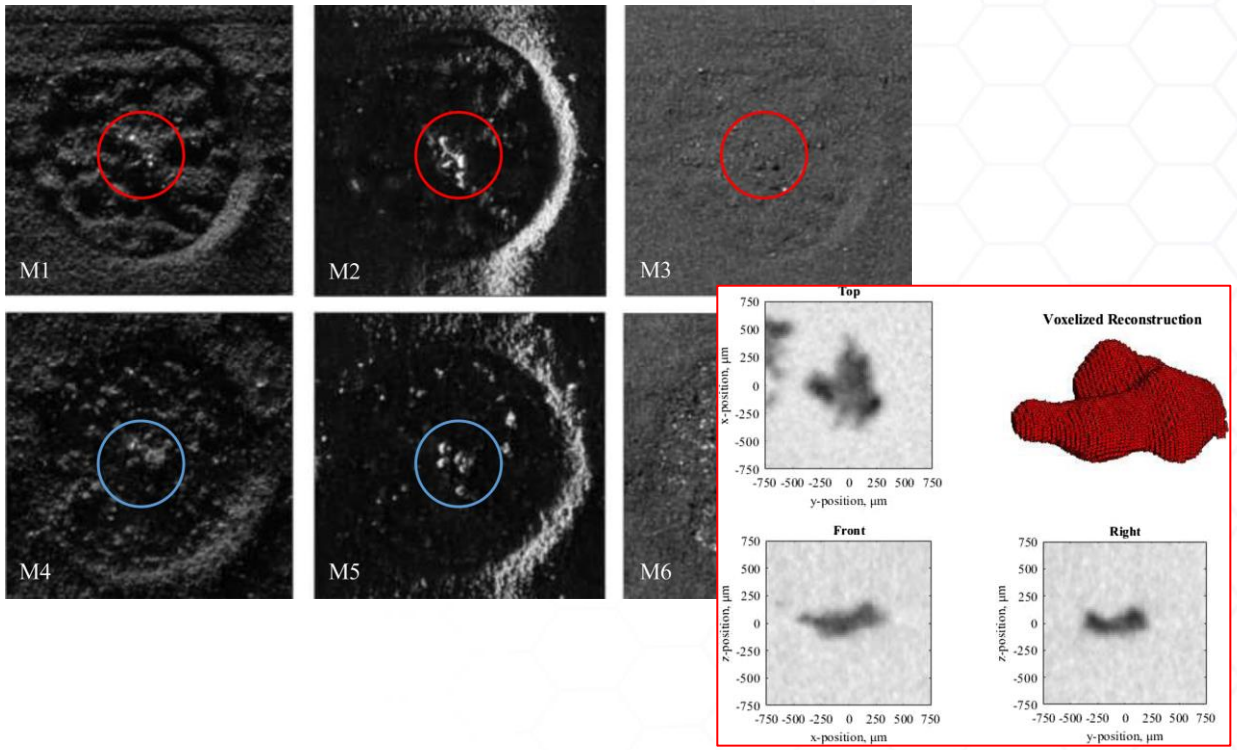


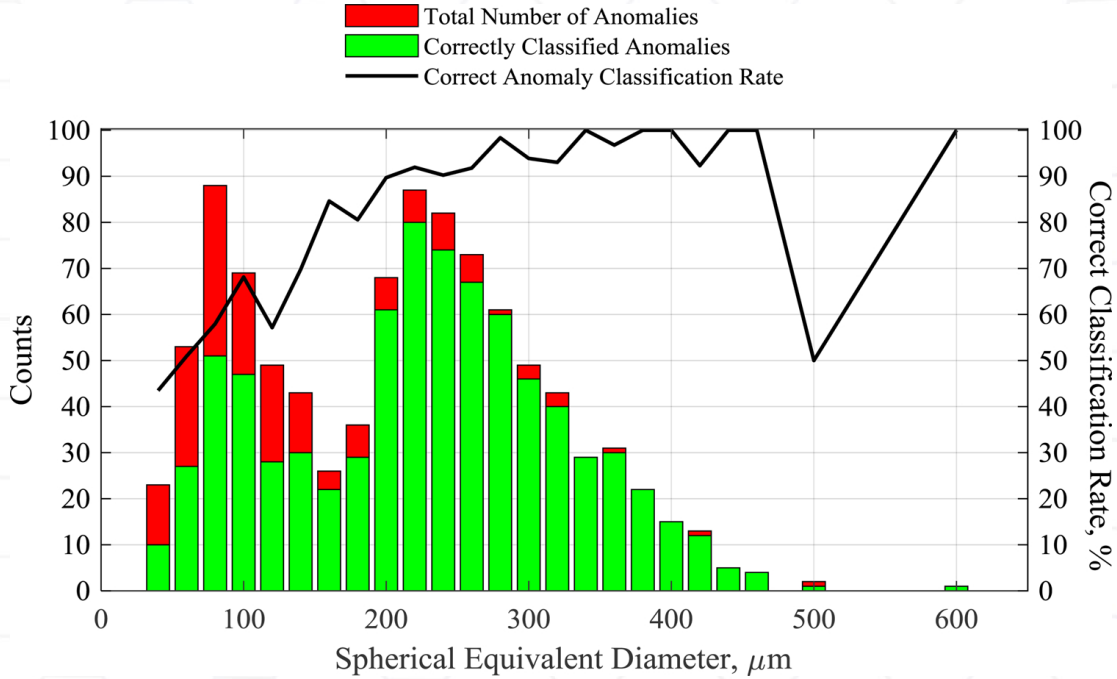
Petrich, J., Snow, Z., Corbin, D., & Reutzel, E. W. (2021). Multi-Modal Sensor Fusion with Machine Learning for Data-Driven Process Monitoring for Additive Manufacturing. Additive Manufacturing, 102364.

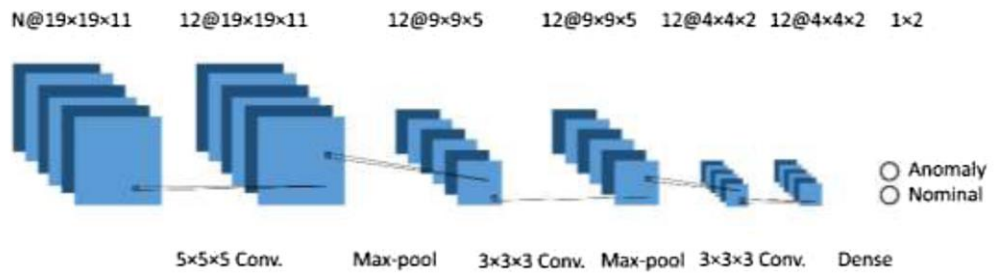
Advanced Sensing, Defect Detection, and Process Control

Defect Detection

Layer-wise imaging, combined with supervised learning using CT-ground truth is capable of identifying stochastic lack of fusion.







Z. Snow, B. Diehl, E. Reutzel, A. Nassar, Toward in-situ flaw detection in laser powder bed fusion additive manufacturing through layerwise imagery and machine learning, Journal of Manufacturing Systems. 59 (2021) 12–26. https://doi.org/10.1016/j.jmsy.2021.01.008.

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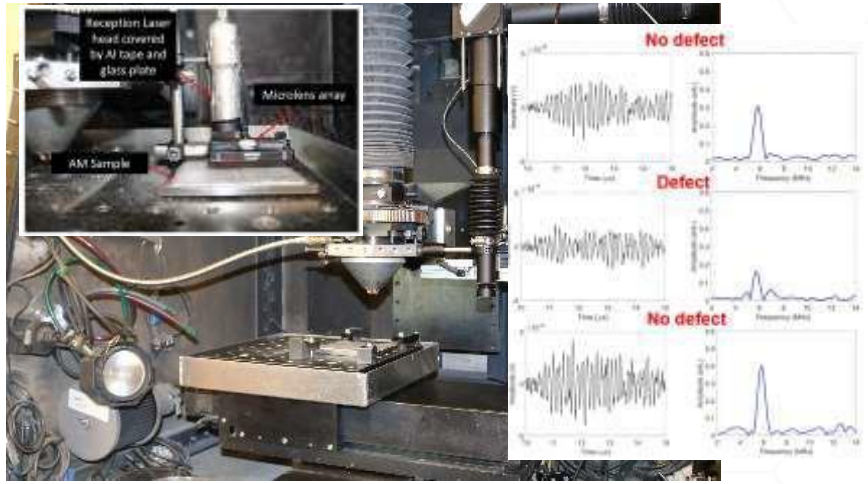
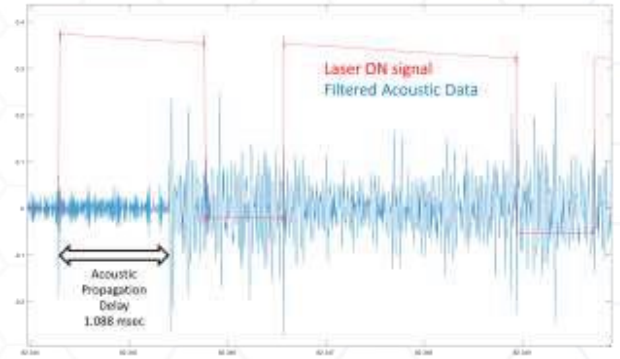
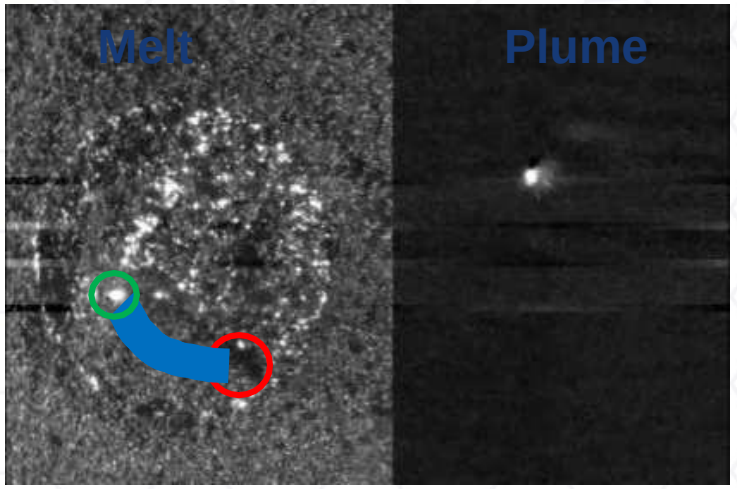
Some Additional Quality Control Activities



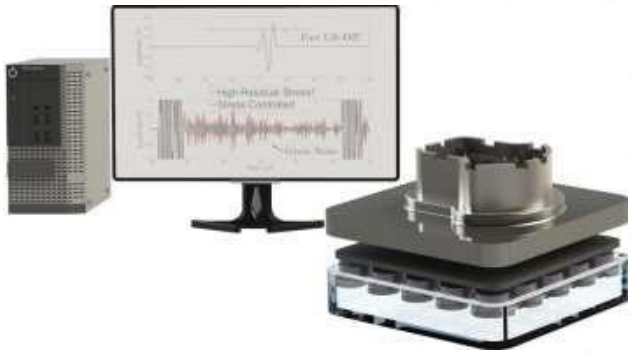
In-situ, non-linear ultrasonic testing (UT)
(w/ Lissenden, PSU ESM)



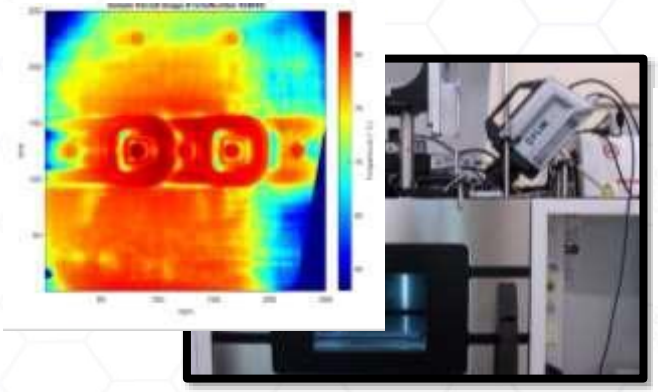
Airborne Acoustic Emissions



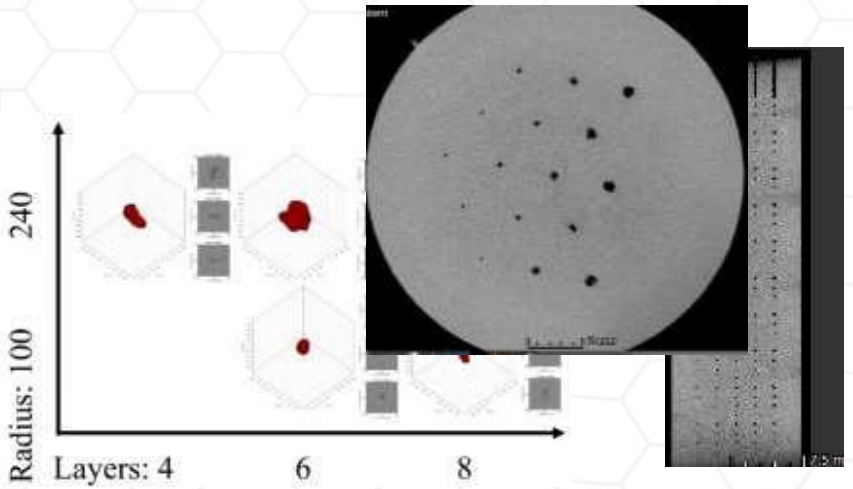
Multi-spectral high-speed imaging



In-situ Multi-modal longitudinal/shear wave sensors(UT) for PBF (w/ Kube, PSU ESM)



Calibrated IR Imaging



Surrogate Flaw Formation

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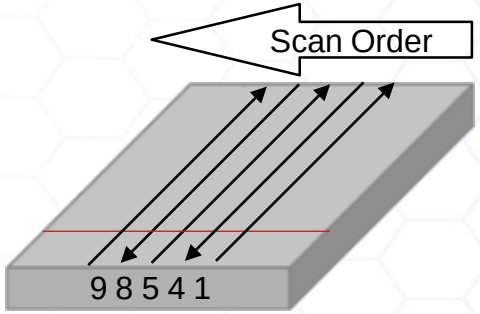
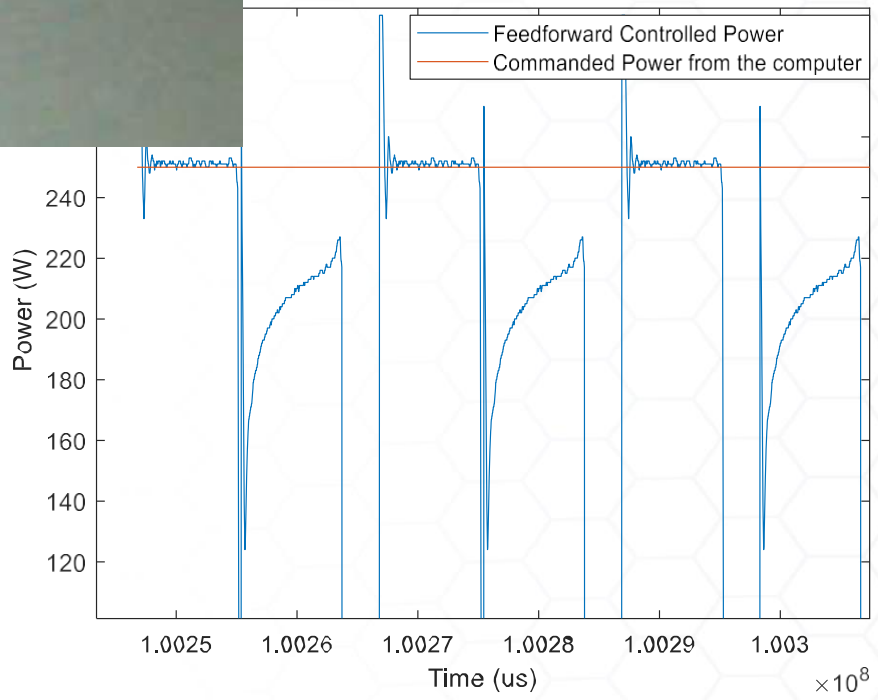
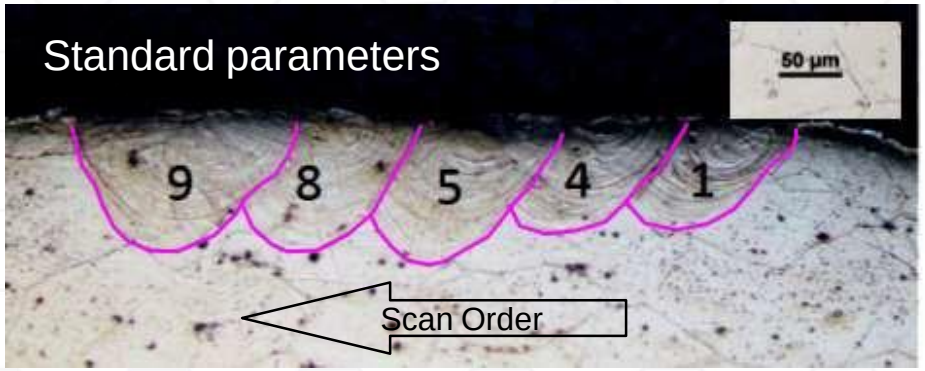
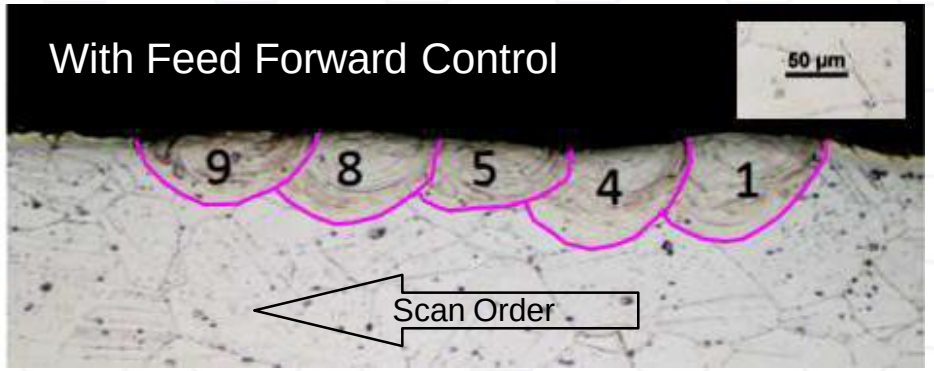
In-Situ Process Monitoring
Feed-Forward Control for PBF AM









Wang Q. , Michaleris, P. Irwin, J.E., Ren Y., Stutzman, C.B., Nassar, A.R (2019) *Model- based Feedforwar d Control of Laser Powder Bed Fusion Additive Manufacturing* Additive Manufacturing

Feed Forward Control is effective in modifying melt pool geometry.

In this case, it overcorrected.

C. B. Stutzman, A.R. Nassar, D.J. Corbin, J. Irwin, P. Michaleris, Q. Wang (2019) *A Machine-agnostic Feedforward Controller for Commercial Powder Bed Fusion Systems* 30th Annual International Solid Freeform Fabrication Symposium – An Additive Manufacturing Conference

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