Research Spotlight Forum

1.7.2020 | Advanced Manufacturing

SAND2019-15225PE

Metal Additive Manufacturing

Bradley Jared, PhD, Materials Engineering and Manufacturing S&T

Sandia
National
Laboratories

Georgia Institute of Technology

ILLINOIS

PURDUE UNIVERSITY

THE UNIVERSITY OF TEXAS AT AUSTIN

THE UNIVERSITY OF NEW MEXICO

NM STATE UNIVERSITY

NEW MEXICO TECH
SCIENCE · ENGINEERING · RESEARCH UNIVERSITY

U.S. DEPARTMENT OF ENERGY

NNSA
National Nuclear Security Administration

ABOUT YOURSELF

microsystems-enabled photovoltaics (*MEPV*) *module,* Jared, *Opt Exp*, 2014

BS (UTK, '94), MS (NCSU '96), PhD (NCSU '99) in Mechanical Engineering
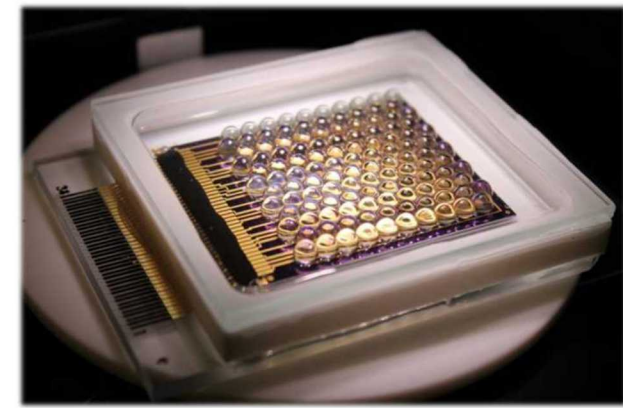- Corning ('99-02), 3M ('02-07), Sandia ('07-present)
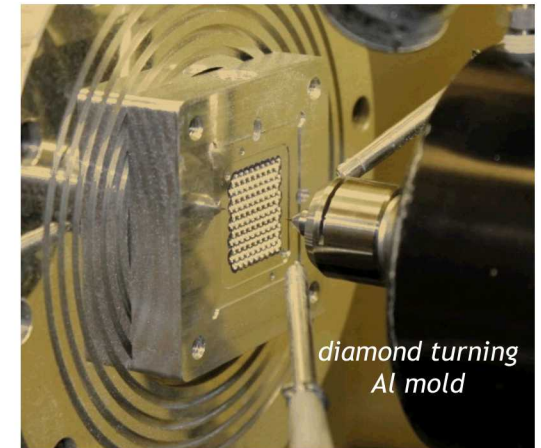
Research
- precision manufacturing: diamond turning, micro-machining, laser processing, metrology, opto-mechanical systems, precision design & assembly
- additive manufacturing: material assurance, laser-powder bed fusion, in-situ monitoring, machine metrology, process-structure-properties, process optimization, structural meta-materials, design optimization, design for AM
- AM metal team: 4 staff, 2 technicians, 2 post-docs, 1 student
  - larger AM effort across Sandia encompasses multiple sites, centers, projects, >100 people over past 3-5 years

Additional keywords
- computed tomography, qualification, product acceptance, high performance computing, ICME, material testing & characterization, machine learning
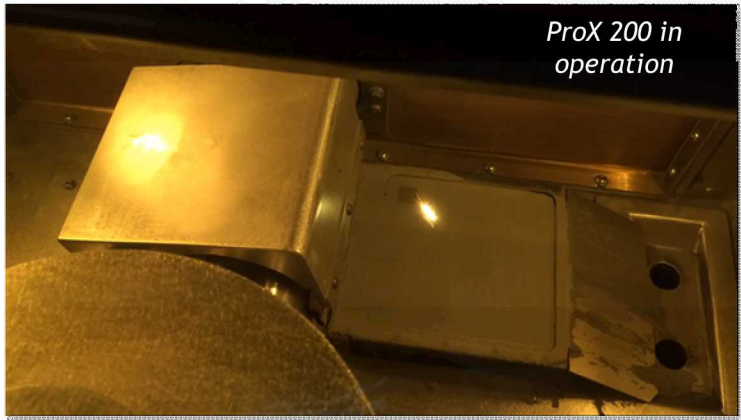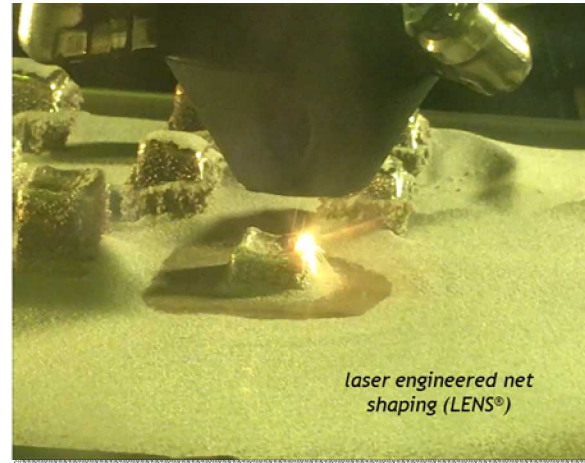

diamond turning Al mold

fs laser meso spring on a penny

Metal Additive Processes

Laser powder bed fusion

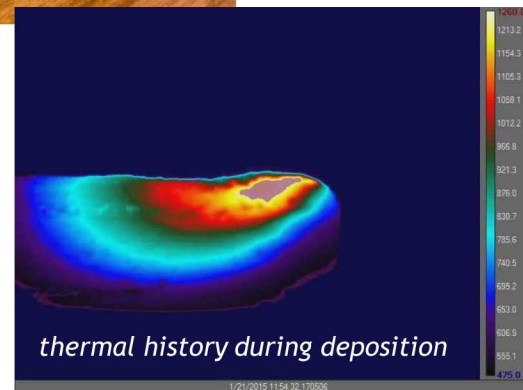ProX 200 in operation

316L SS lattice part

melt pool motion, nominal settings

Laser Engineered Net Shaping (LENS)

laser engineered net shaping (LENS®)

multi-material Hiperco core w/304L exterior

thermal history during deposition

Wire-feed

Ti-6Al-4V printing

3" diameter Ti-6-4 cylinder

melt pool monitoring

Shaun Whetten

Research Spotlight Forum
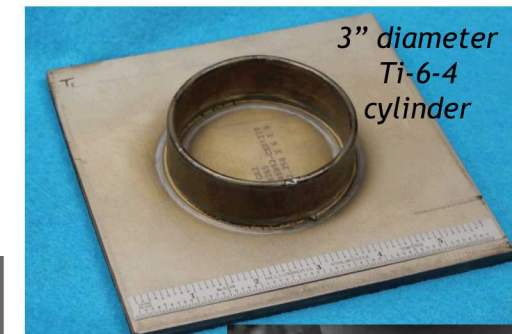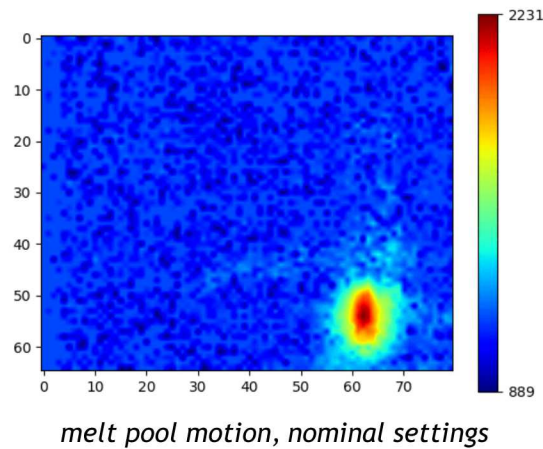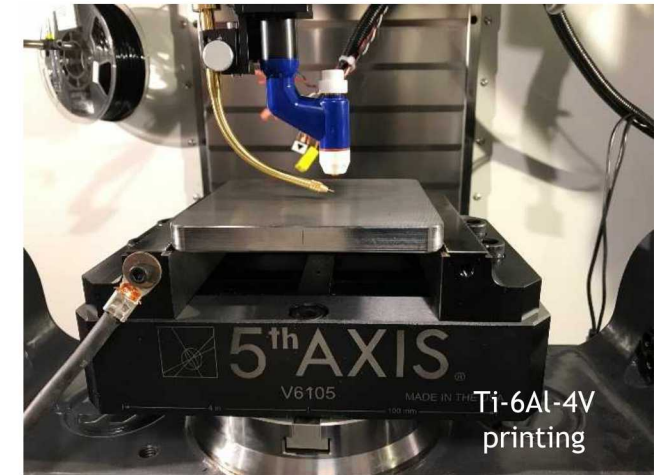
Material Assurance

Material formation concurrent w/geometry
- want to predict part/material performance
  - feedstock certs inadequate for performance
  - **how to ID a bad part?**
    - complexity isn't "free"
    - requires significant design margins and/or rigorous post-process inspection / validation

Quantify <u>critical</u> material defects & <u>useful</u> signatures
- D-tests, NDE, process monitoring, mod-sim, ?

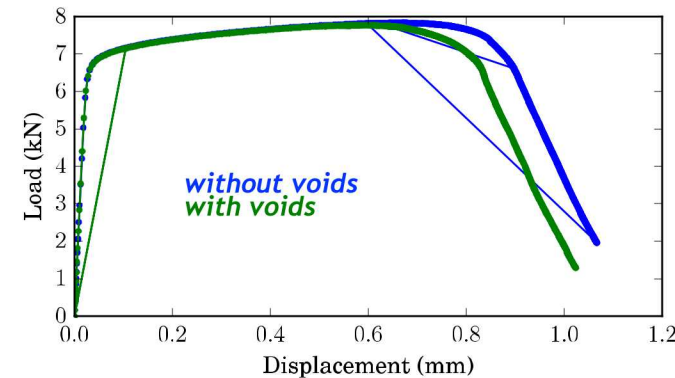Understand mechanistic impacts on properties
- build process-structure-property relationships to predict **margins & reliability**
- characterize stochastic response to design for **uncertainties**
- provide scientific basis for qualification of AM metals for high consequence applications
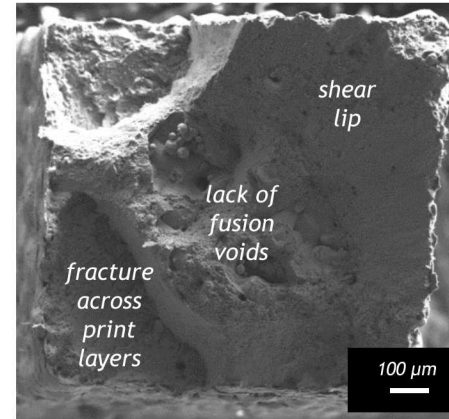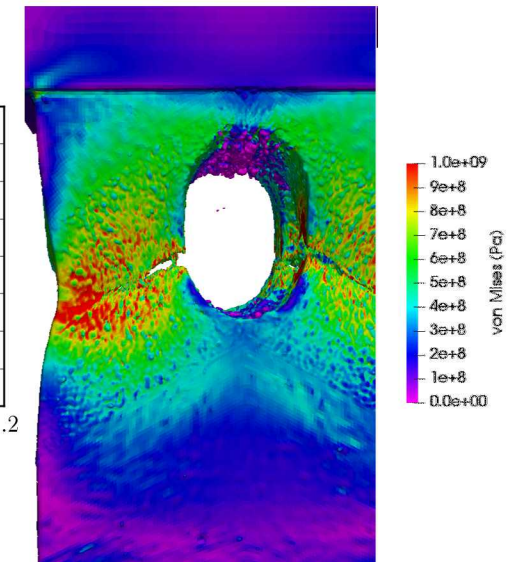

17-4PH dogbone fracture surface
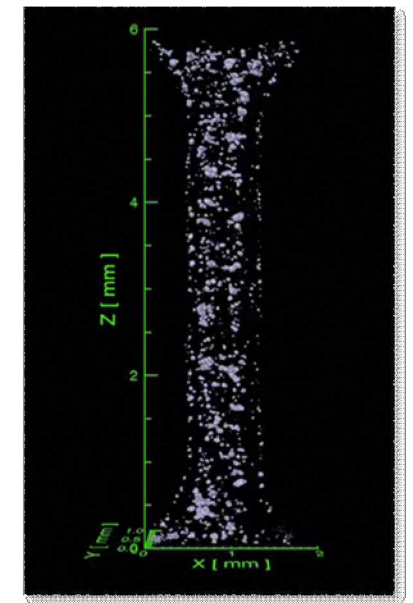
17-4PH dogbone porosity

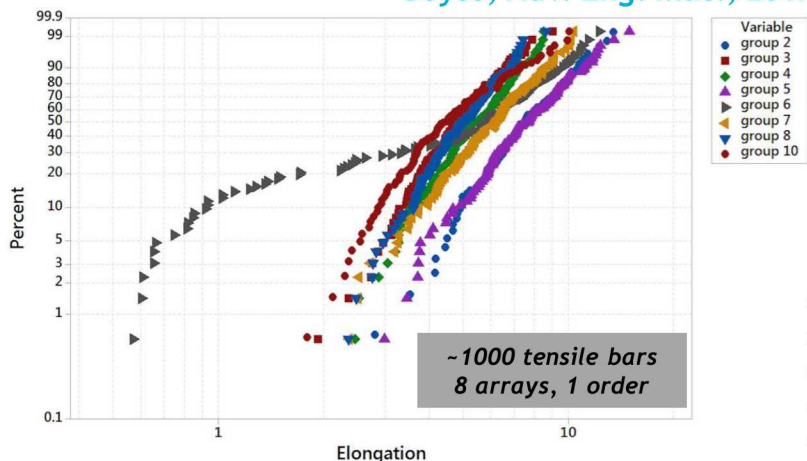

material response changes w/voids & surface roughness

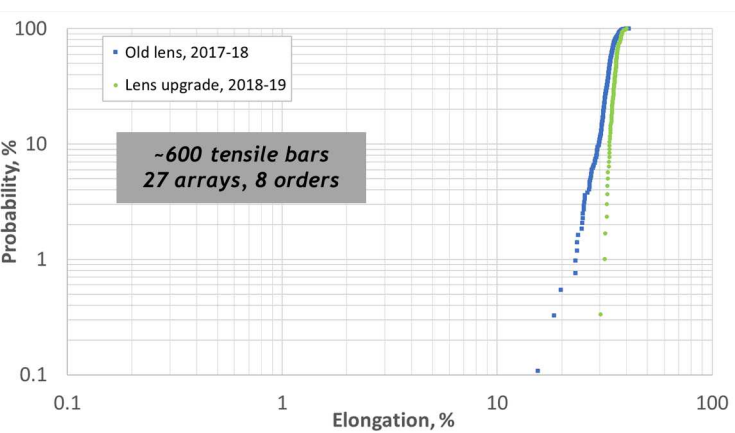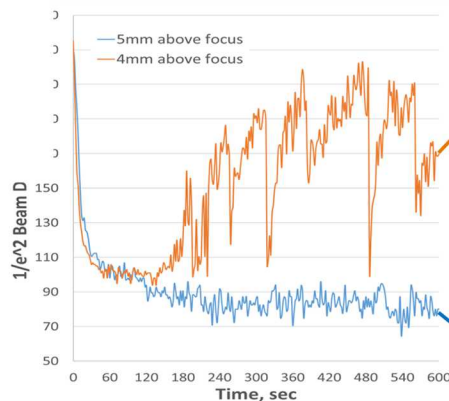*Kyle Johnson, Kyle Karlson, Brad Boyce*

Research Spotlight Forum

Process Optimization

Boyce, Adv. Eng. Mat., 2017

Heiden, Add. Mfg., 2019

Virgin: 7.90 g/cm³
Reused: 7.81 g/cm³

~1000 tensile bars
8 arrays, 1 order

early 17-4PH dogbones from external vendor

~600 tensile bars
27 arrays, 8 orders

316L SS dogbones from internal machine over past 2 years

nominal focus offset

beam diameter variations w/original f-theta lens

5mm focus offset

Research Spotlight Forum
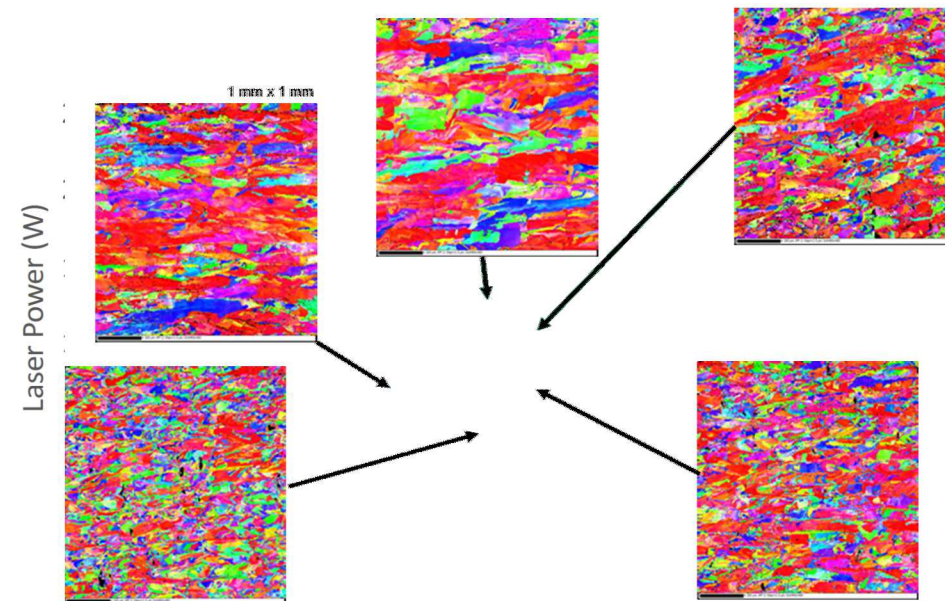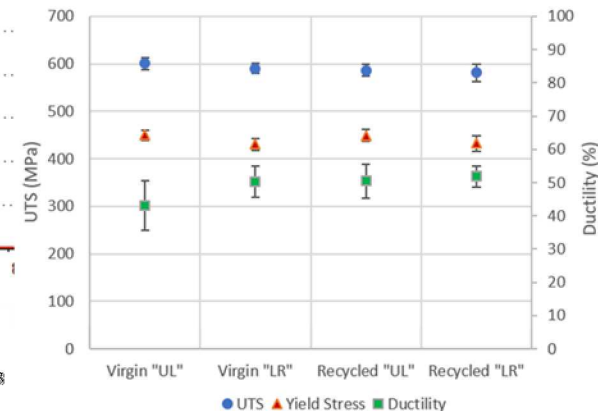
Josh Koepke, MS Thesis, UNM Dept of ME, 2019

Qualification Tomorrow

316L SS dogbone array with 25 dogbones, 1x1mm gauge

"Changing the Engineering Design & Qualification Paradigm"
- leverage AM, in-process metrology & HPC to revolutionize product realization
- accelerating design to production

material / part performance simulation

Quantify & Optimize

AM Process

Guide

Measure

Performance Predictions

Exemplar Performance

AM 17-4PH tensile dogbone (above) & stress-strain response

In-Situ Measurements

Alinstante Properties

Predict

Inform

Exemplar Models

Process Models

Materials Models

Heckman, *Mat. Sci. Eng. A*, 2019

All voids   Correlated voids
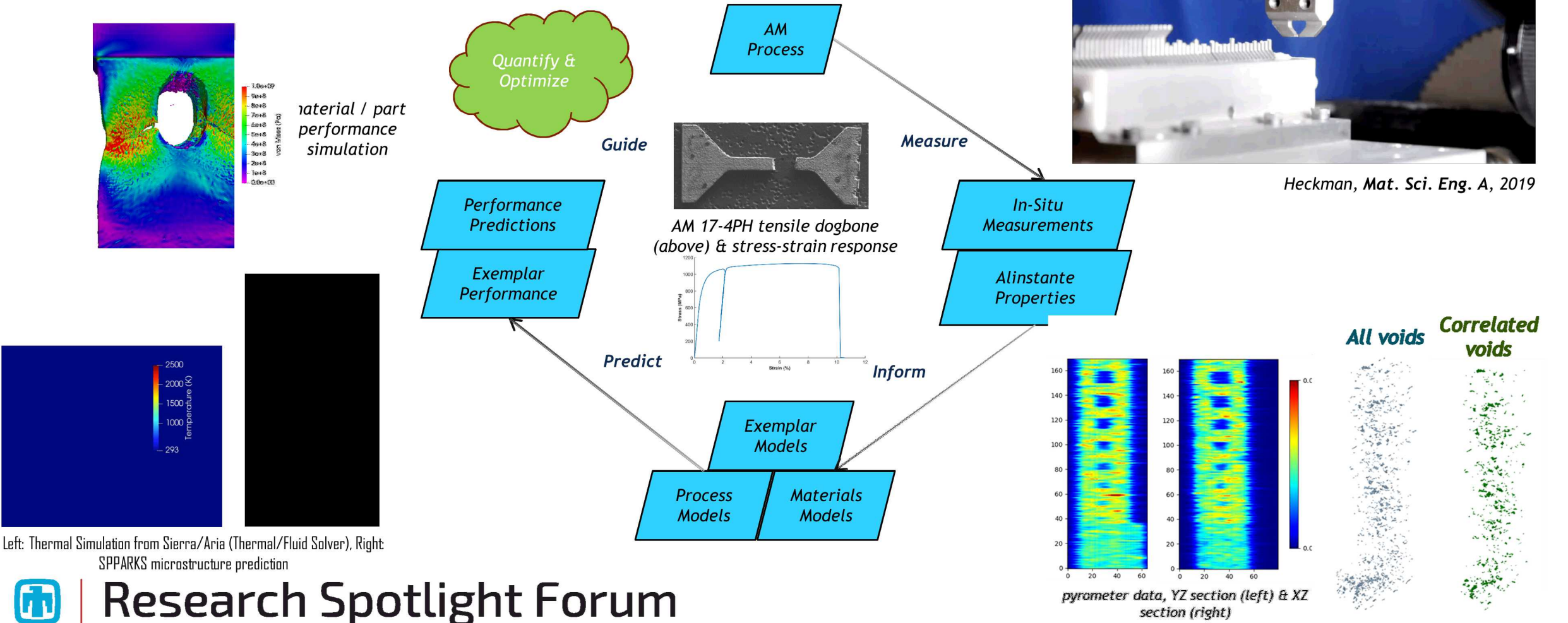
Left: Thermal Simulation from Sierra/Aria (Thermal/Fluid Solver), Right: SPPARKS microstructure prediction

pyrometer data, YZ section (left) & XZ section (right)

Research Spotlight Forum

FUNDING SOURCES

Lab Directed Research & Development

NNSA: Additive Coordination Team, Advanced Certification and Qualification
- supporting work by Carolyn Seepersad (UT-Austin), Chris Saldana (GT)

Sandia mission programs