SAND2019-4417PE

Machine Development: Process Control, User Interface

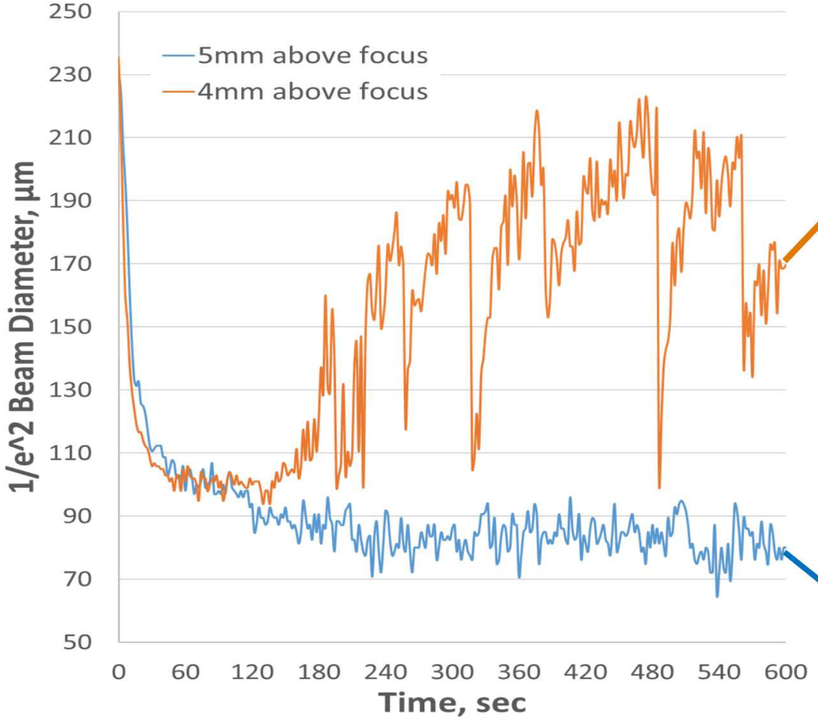
PRESENTED BY

Bradley Jared, David Saiz, Josh Koepke, Matthew Roach

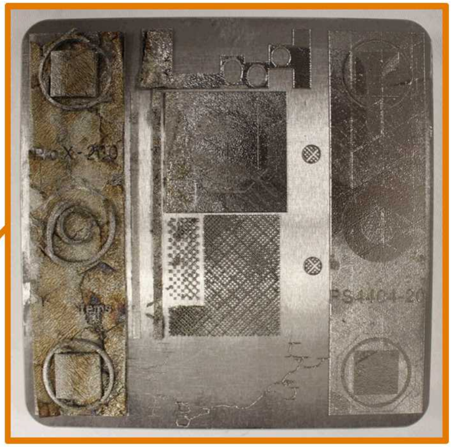
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

SAND 2018-8025 C

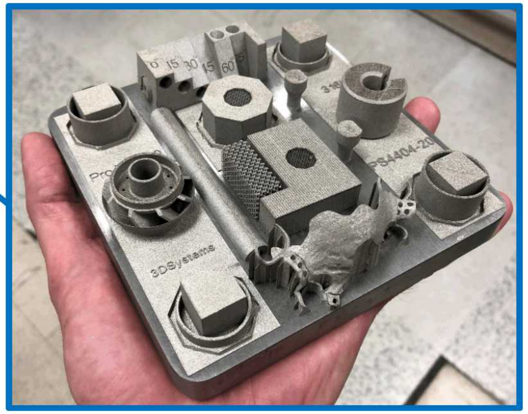
Machine Metrology is Critical to Assure Part Quality



beam diameter variations w/original f-theta lens

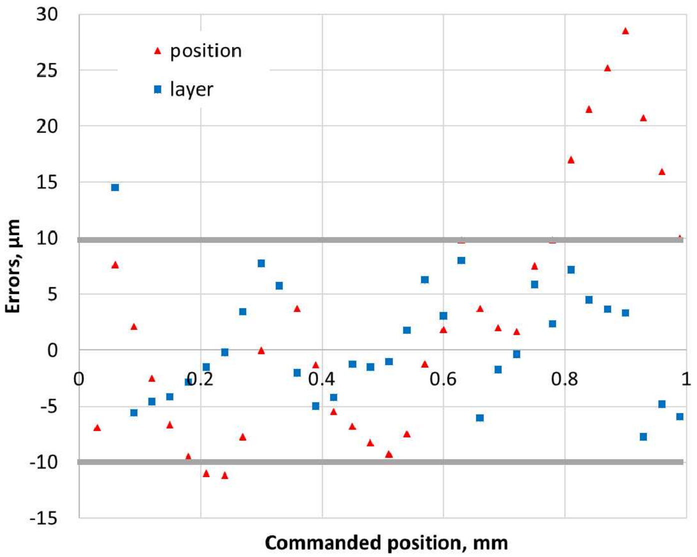


nominal focus offset

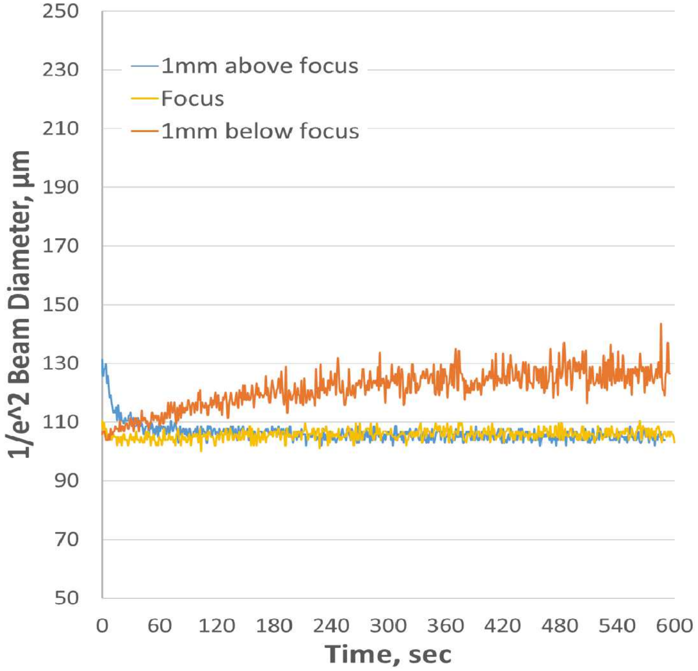


5mm focus offset

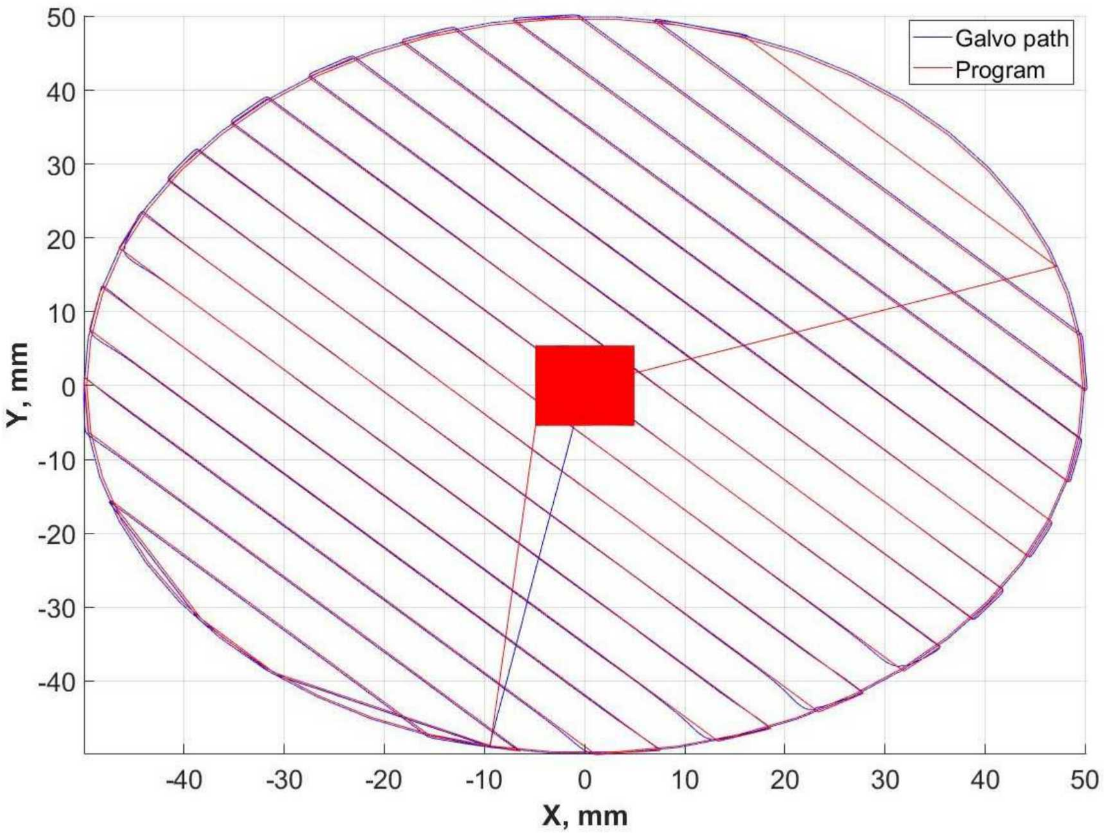
layer thickness errors



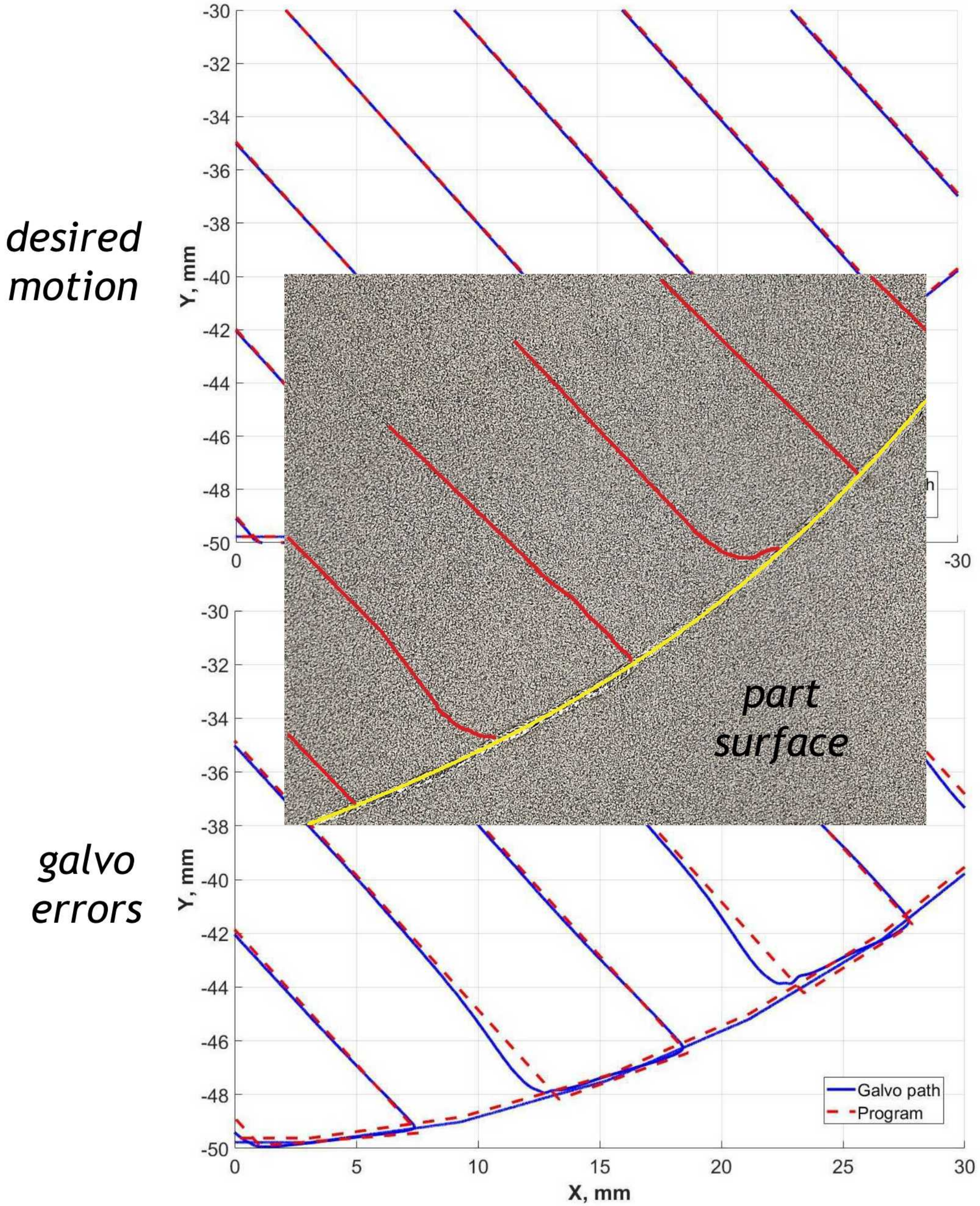
upgraded f-theta lens response



Real-Time Machine Monitoring Reveals Process Perturbations



ARCS output for a simple test pattern



- Archive, Research, Control, Synchronization (ARCS)
  - Penn State, 3D Systems collaboration
- motion @ 100kHz

There are Multiple Potential Melt Pool Signatures for Interrogation

Thermal
- Stratonics ThermaViz two-color pyrometer
- IR cameras: FLIR C2, A310 & SC6811

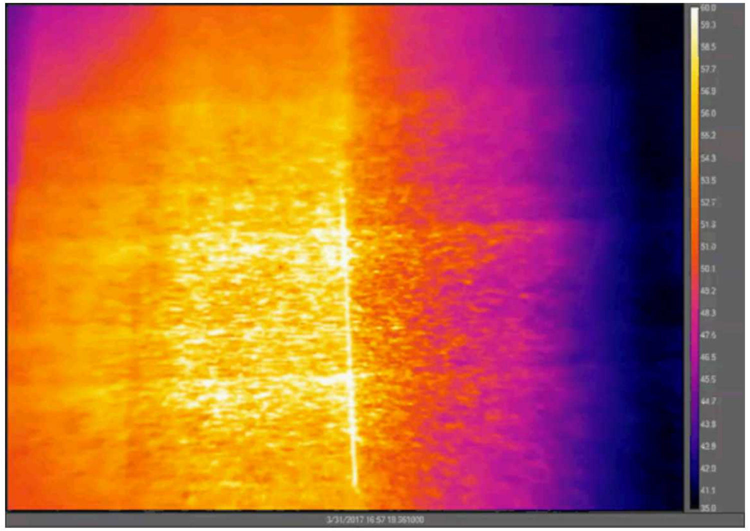
Optical
- Photron PhotoCam Speeder V2 high speed cameras
- blue light illumination
- Ocean Optics LIBS2500plus spectrometer
- Keyence LJ-V7020 & LJ-V7200 laser line scanners

Acoustic
- audio microphone, acoustic emission

3D Systems Open Protocol platform
- PSU multi-spectral sensor

Managing & analyzing data streams is crucial
- large
- non-linear correlations

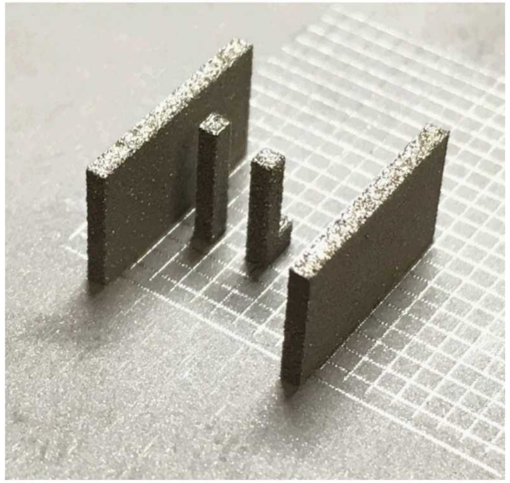
ThermaViz installed in the ProX 200



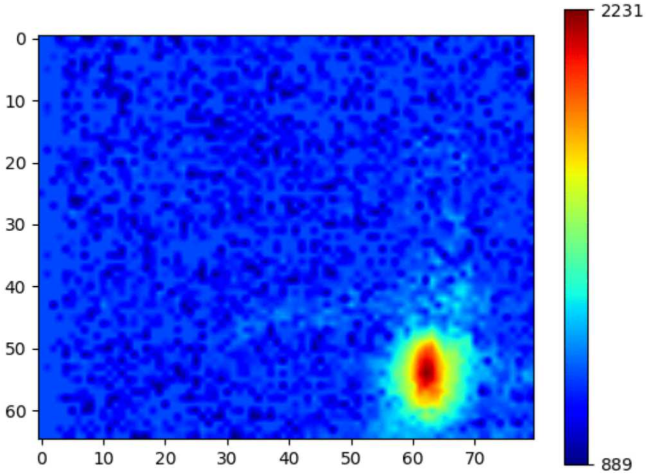
FLIR A310, laser on plate, ~100W, 1.4m/sec, 125μm hatch, 100μm beam dia.

Photron high speed optical melt pool video

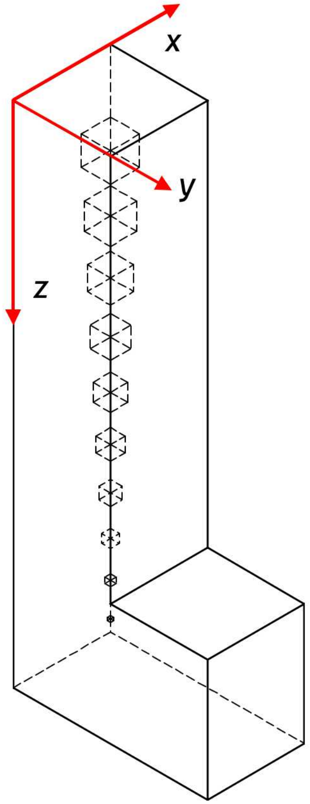
Detecting Features & Defects Using Two Color Pyrometry



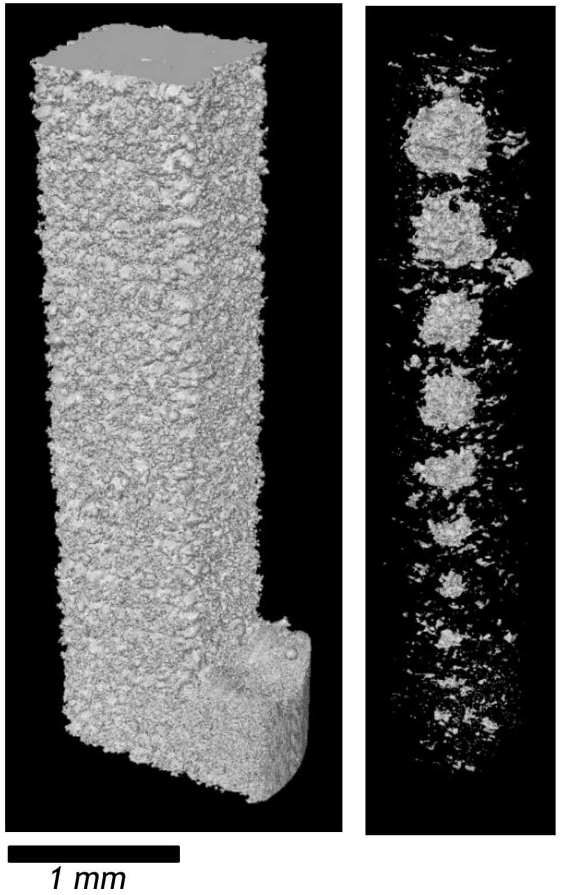
1x1x5mm 316L SS column w/support walls



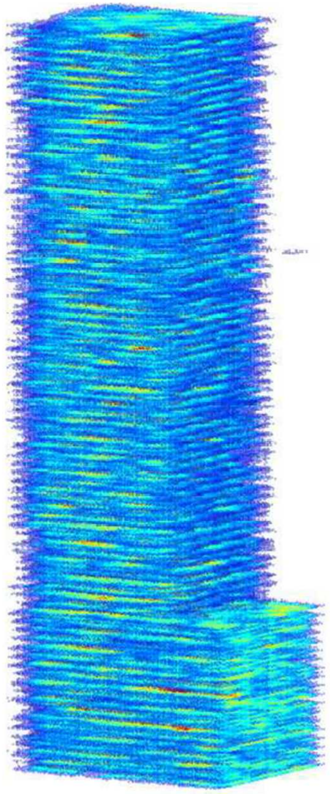
melt pool motion, nominal settings



captured hole structure design



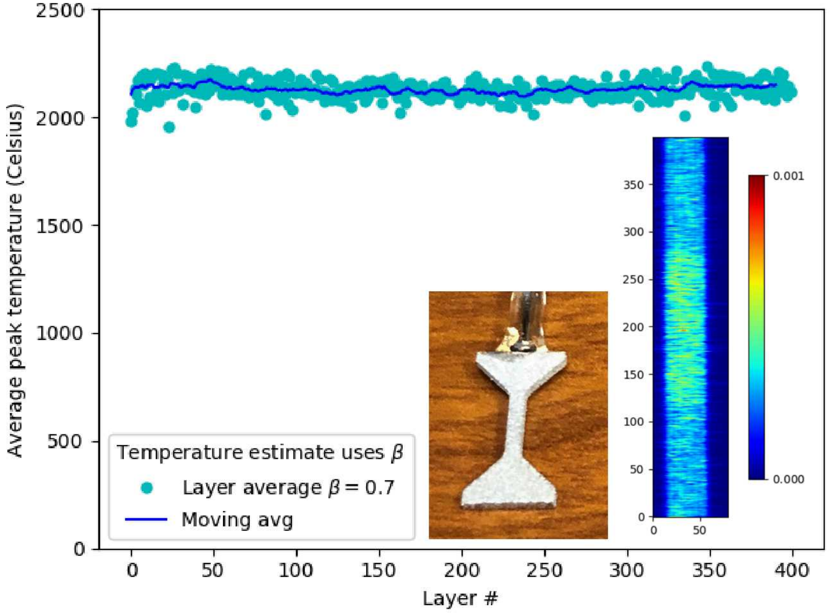
μCT reconstruction

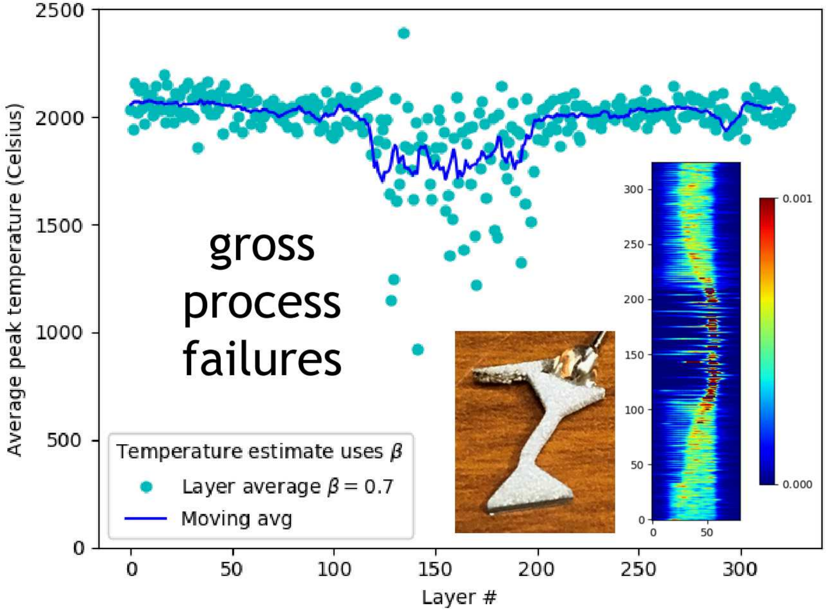


two color pyrometer data reconstruction

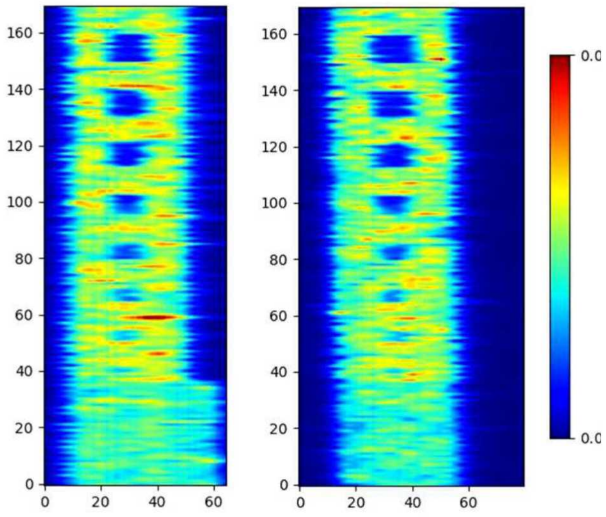
Mitchell, Dagel, Madison, Ivanoff, Swiler, Koepke, Jared

Correlating Process Signatures w/Material Structures

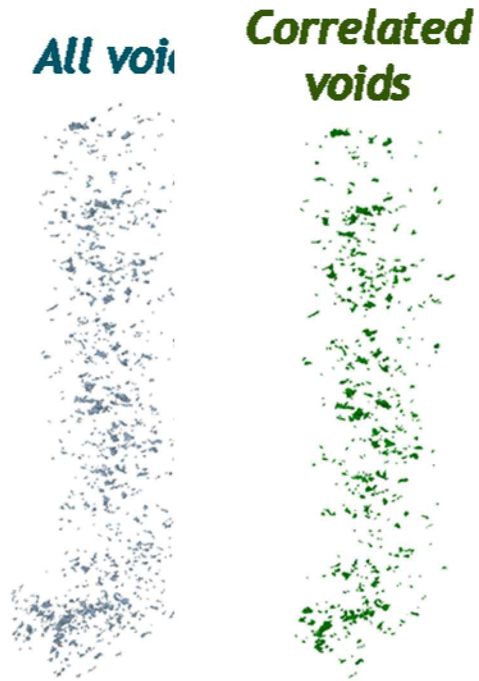


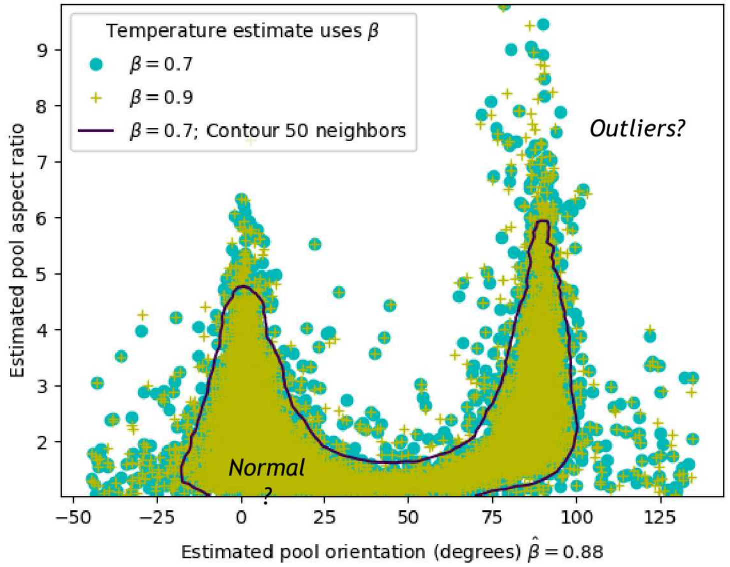


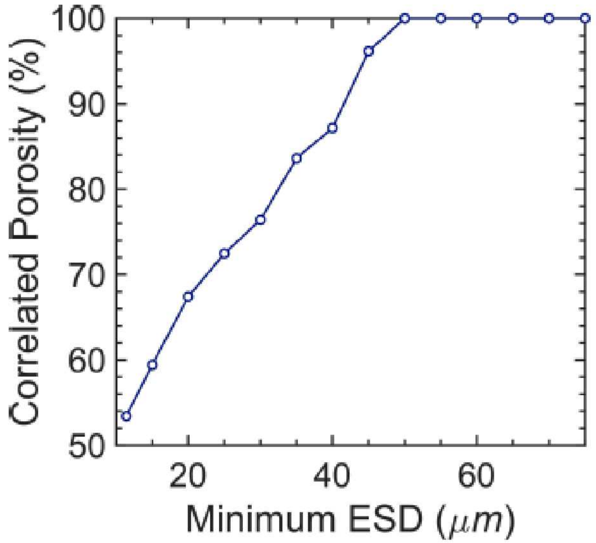
melt pool outliers via ***machine learning*** correlate local void porosity



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







Pyrometry Linked to Pores in Additively Manufactured Metals, Mitchell, in process

Post Processing: Machining

PRESENTED BY

Bradley Jared, David Saiz, Clint Holtey

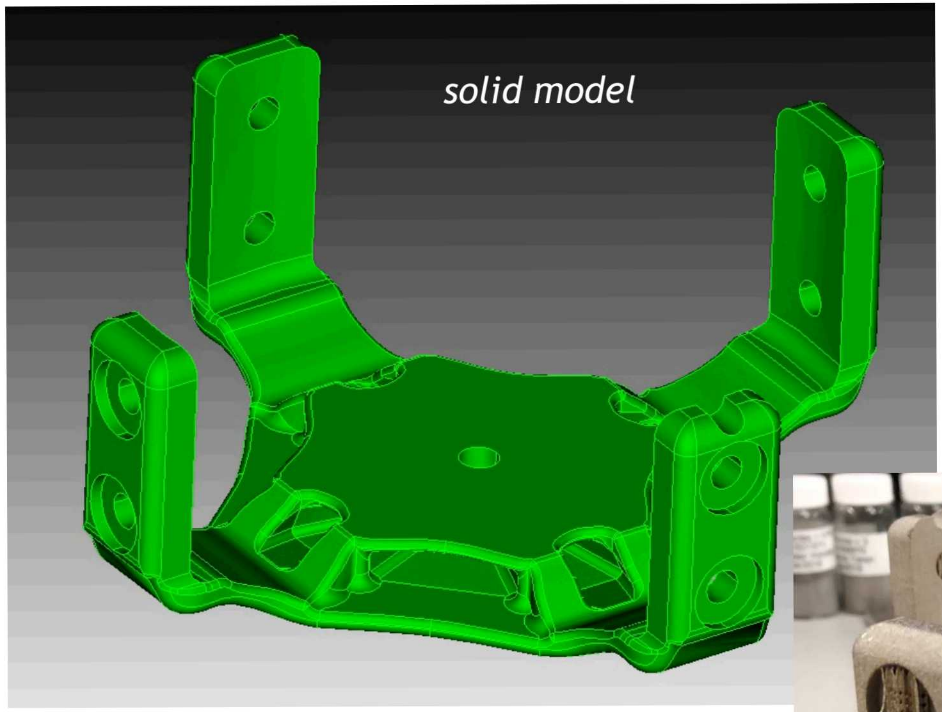
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND 2018-8025 C

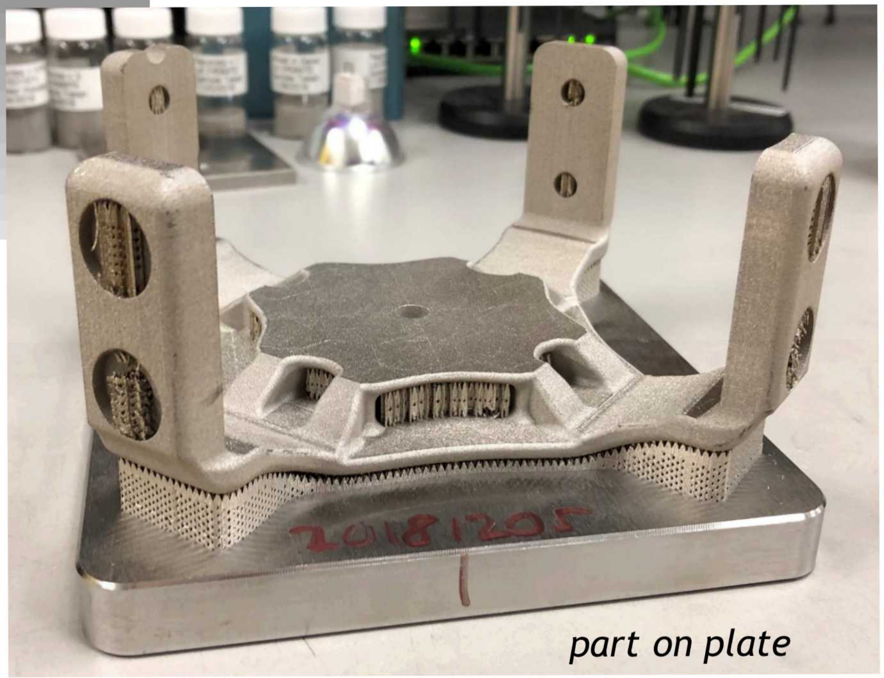
Topology Optimized Part from Sandia's PLATO Code

Design
- complex TO for light-weighting
- load bearing structure
- assembly tolerances on mating features

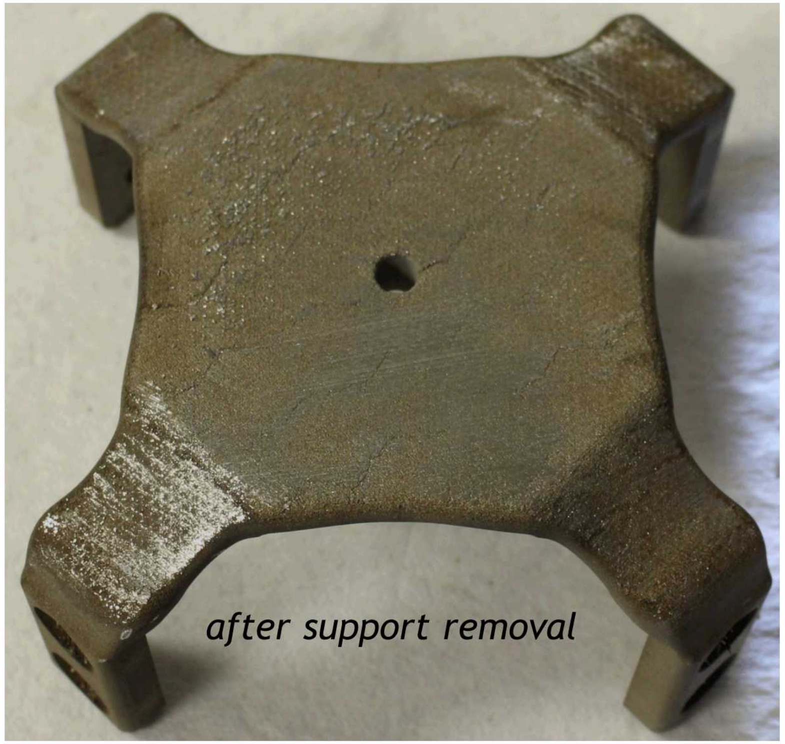
Printed on ProX 200
- 316L stainless steel

Post-processing
- build plate & support removal
- tumble polishing
- machine mating surfaces
- metrology

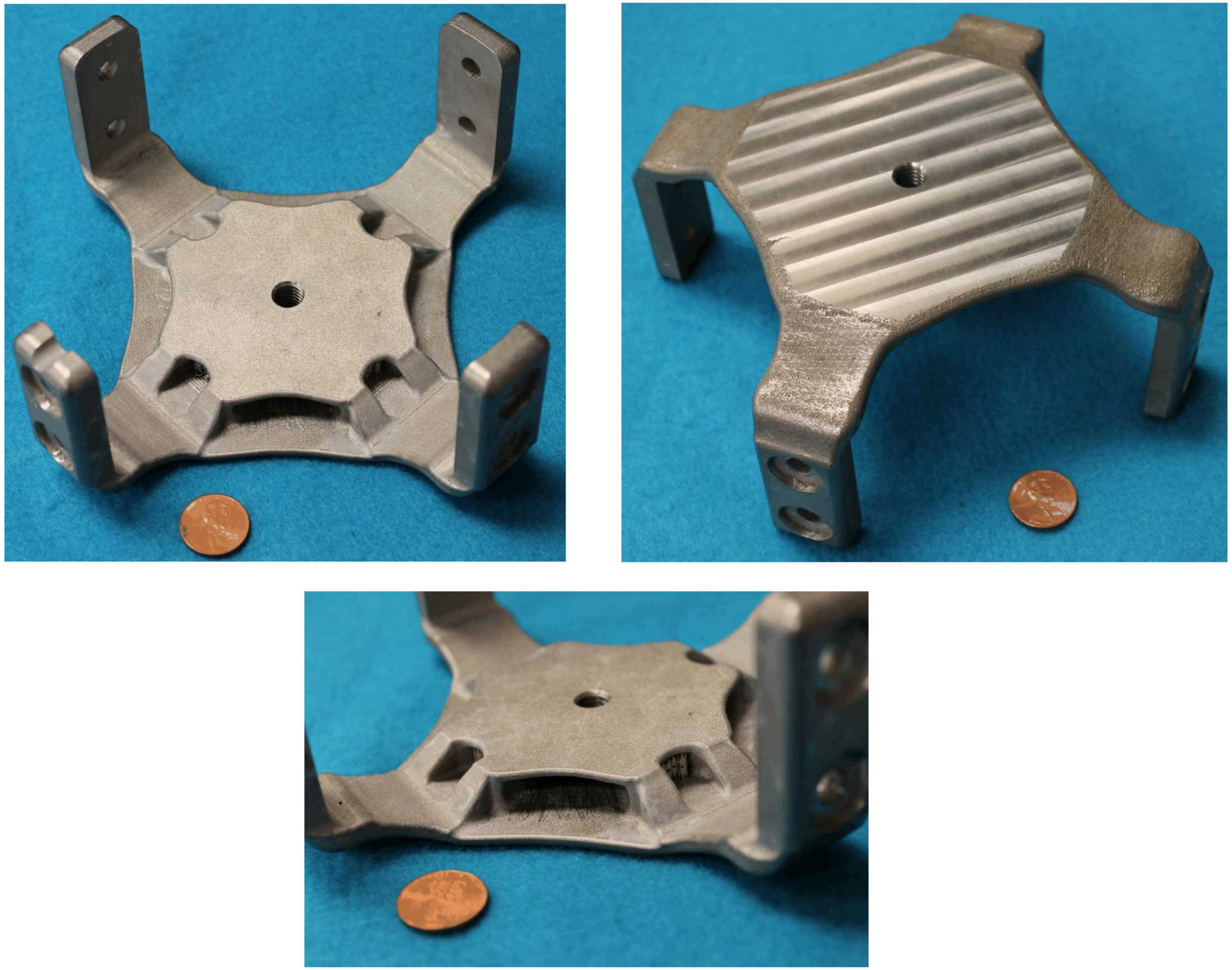




Post-Processing Results



after support removal



final part after polishing, machining & manual support removal

Tumble Polishing

Simple, efficient & inexpensive

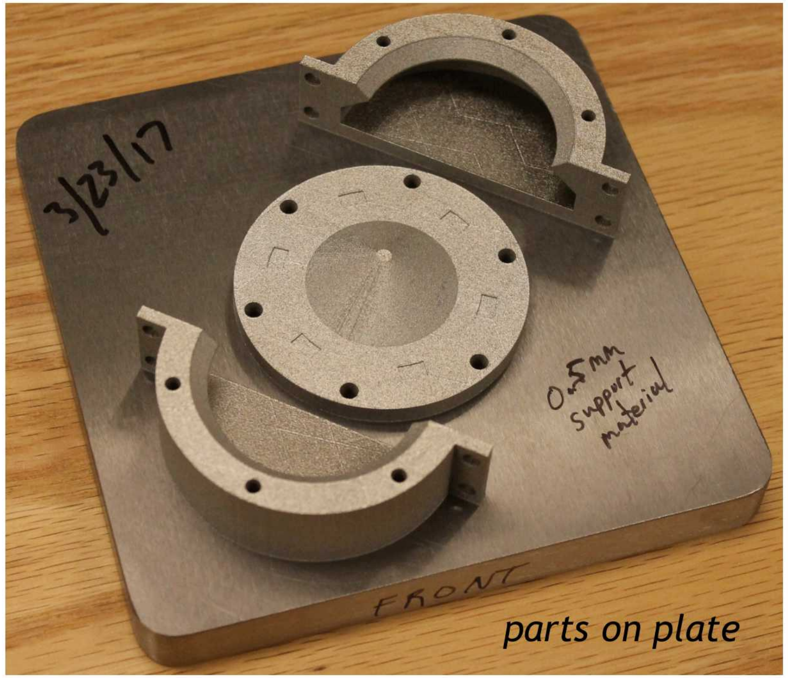
- improves finish ~2x
- better S_a than electro-polishing
- standard, unattended process in our lab

Gentle

- minimal dimensional impact
- applied to lattices

Challenges

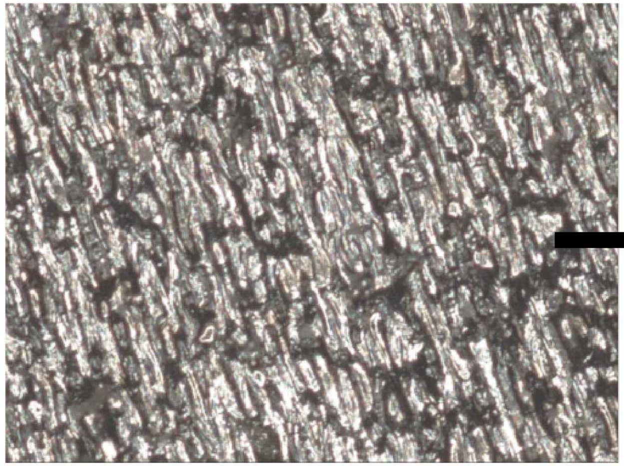
- light, hollow parts "float"
- access to internal features



parts on plate

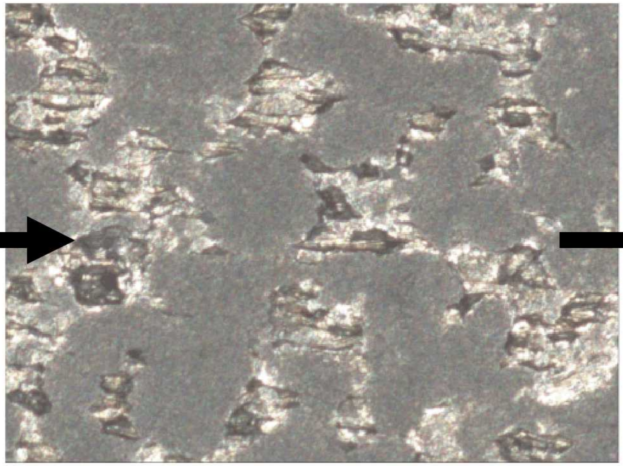
tumble polisher

as printed, S_a = 11.85μm

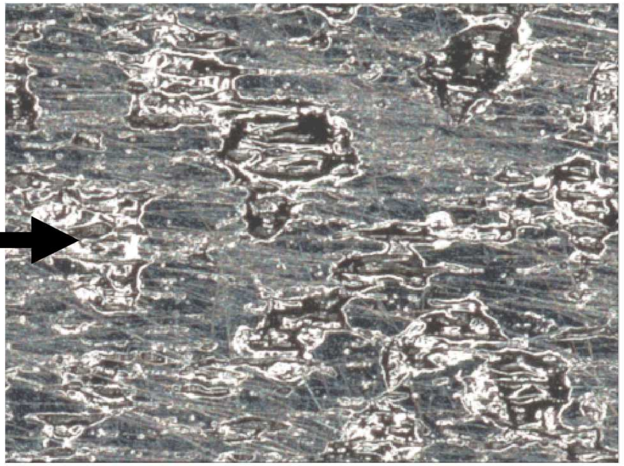


3hr tumble polish, S_a = 6.94μm

12hr tumble polish, S_a = 5.60μm



EP, S_a = 6.78μm



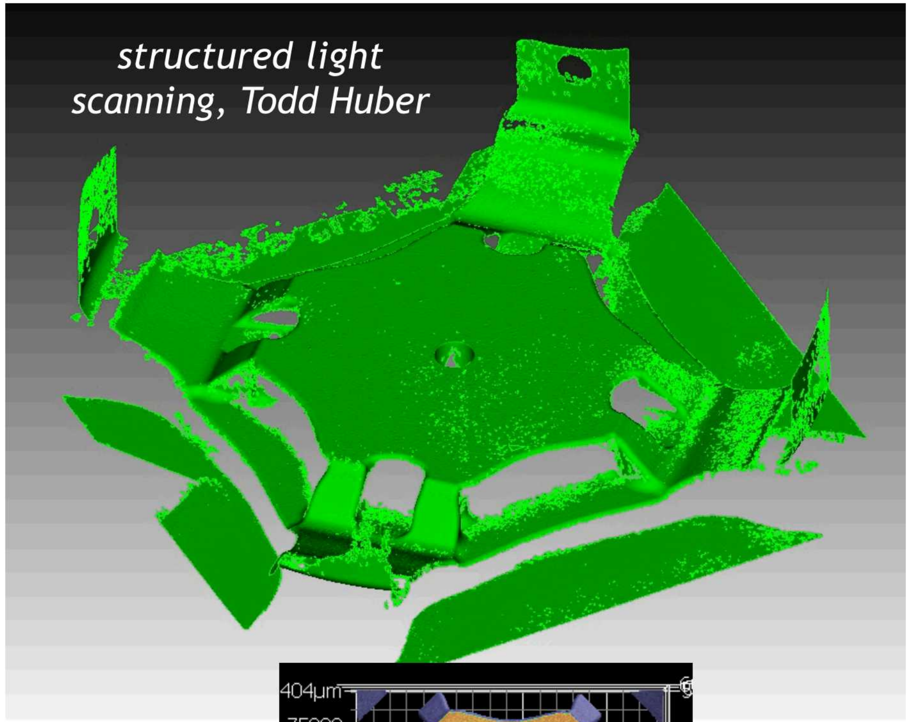
Metrology

Measuring complex topologies is non-trivial

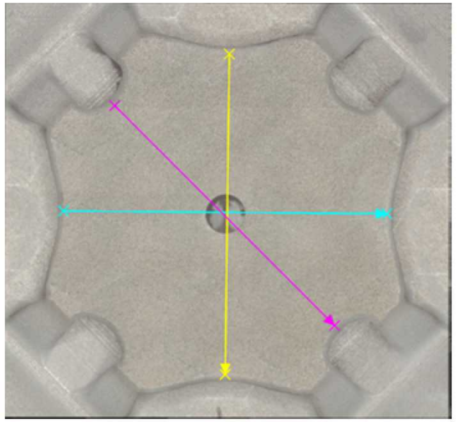
- access
- slopes
- surface roughness
- data management & analysis

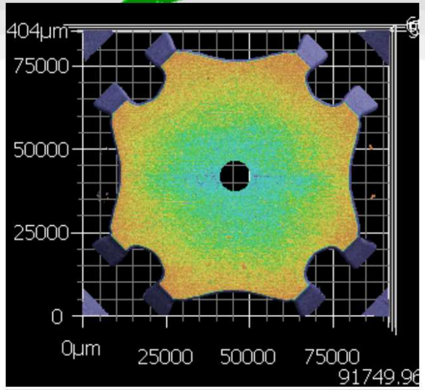
Significant part distortion

- build plate & part
  - top surface of legs parallelism to center plane
    - on plate = 25-100µm
    - off plate = 280-300µm
- will part mate assembly
- where are proper datums?
  - surface finish acerbates (printing, supports)

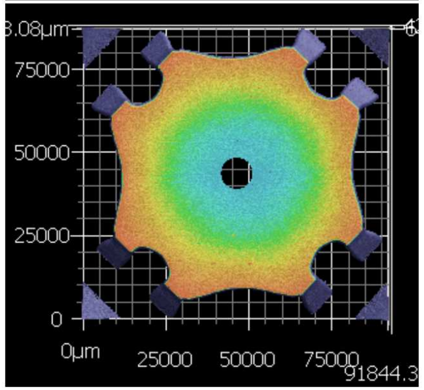


structured light scanning, Todd Huber





part on plate, form = 68.2µm



part removed, form = 188.2µm