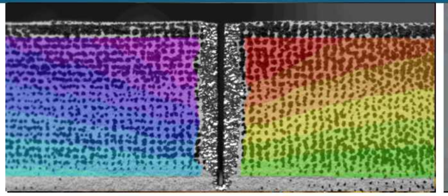
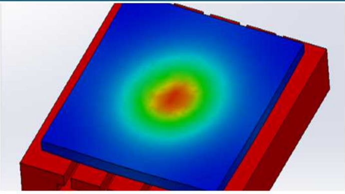
SAND2018-7895PE

Applications of Additive Manufacturing





PRESENTED BY

Shaun Whetten

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Outline

- Additive Manufacturing at Sandia
- Modeling of Additive Manufacturing
- Characterization
- Unique applications of AM

Additive Manufacturing at Sandia (More Than Just 3D Printing)

Overview

- There is much more to additive manufacturing than just printing parts
- What does the video show is involved in additive manufacturing research?
- What challenges are there?

Sandia Labs Additive Manufacturing Program
https://youtu.be/YCEr3FzSr_M

Residual Stress

- Rapid heating and cooling during print causes residual stress buildup
- Stress buildup causes distortion, warping, and even cracking of printed part
- Problematic when higher tolerances or repair jobs are desired
- Stress often manifests itself in substrate deformation

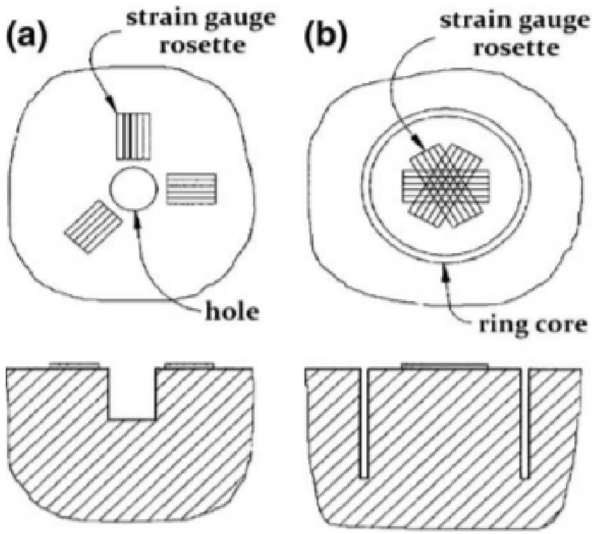
Methods Toward Residual Stress

Non destructive

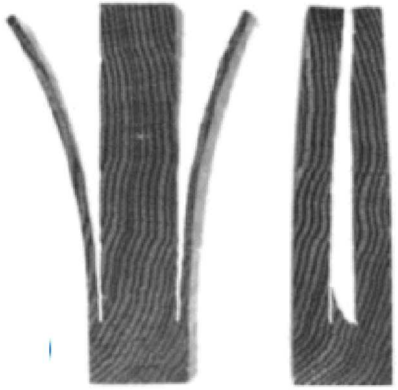
- Neutron Diffraction and X-ray Diffraction
- Sensitive to different materials and geometry

Destructive/Relaxation

- Use fundamental quantities such as displacements or strain
- Calculations can be made to solve for residual stress
- Remove a section of specimen, then measure displacement



(a) Hole drilling method [1]
(b) Ring core method [1]

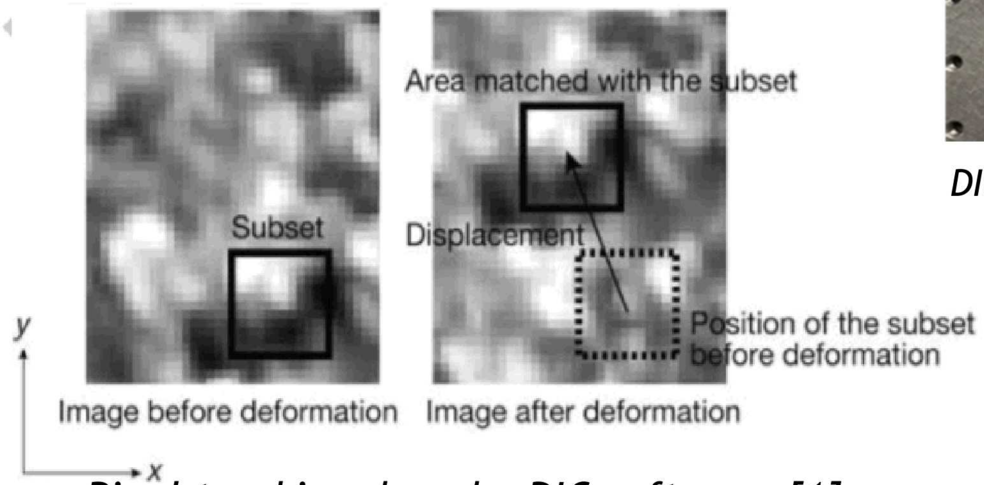


Slitting Method [1]

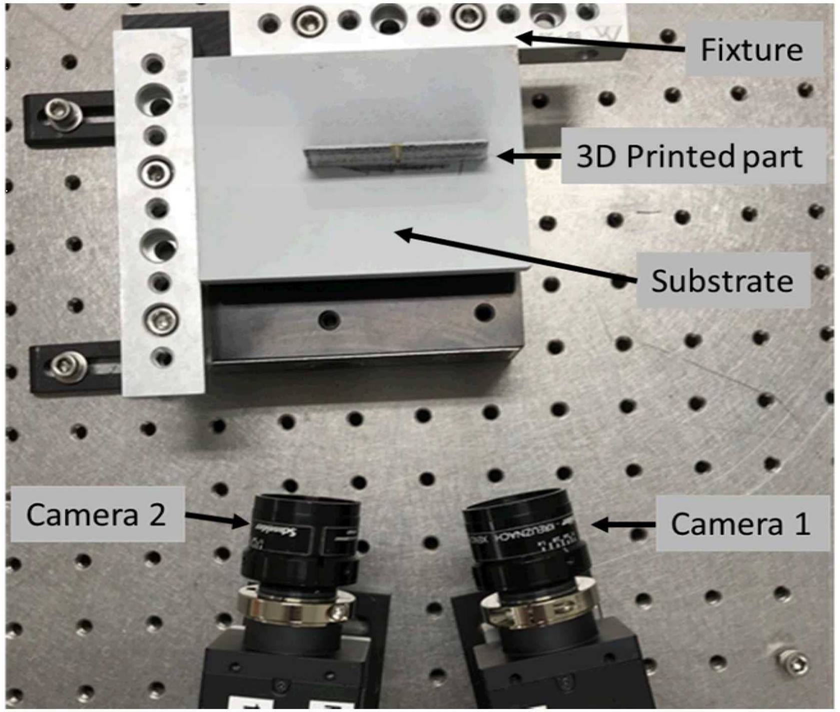
[1] Schajer, G.S. Relaxation Methods for Measuring Residual Stresses: Techniques and Opportunities

Digital Image Correlation (DIC)

- Uses photos of part from before and after material removal to measure distortion
- Non contact measurement
- Macro or micro scale



Pixel tracking done by DIC software [1]



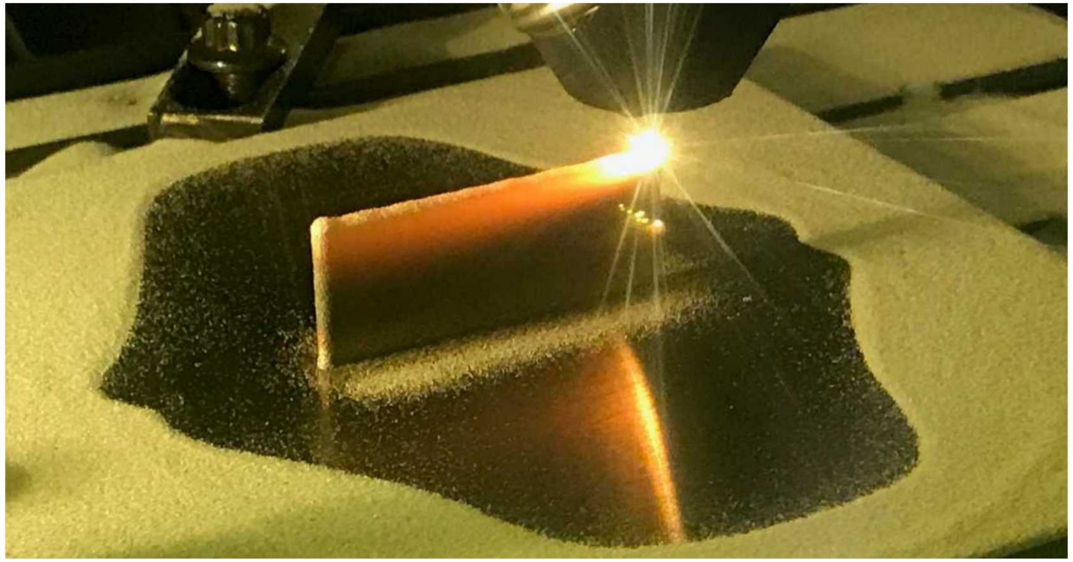
DIC setup for measuring stress relaxation

Cameras- 12MP Point Grey Grasshoppers.
Lenses- Schneider 17mm.

[1] Yoneyama, S. Digital Image Correlation

Material Relaxation Study

- 4 substrate clamps, one in each corner of the substrate
- 3 samples printed at each bed temperature of 50°C, 150°C, 250°C, 350°C, and 450°C
- Printed a 2.0” x 0.04” x 1.0” thin wall
- Should have generalized stress methods results

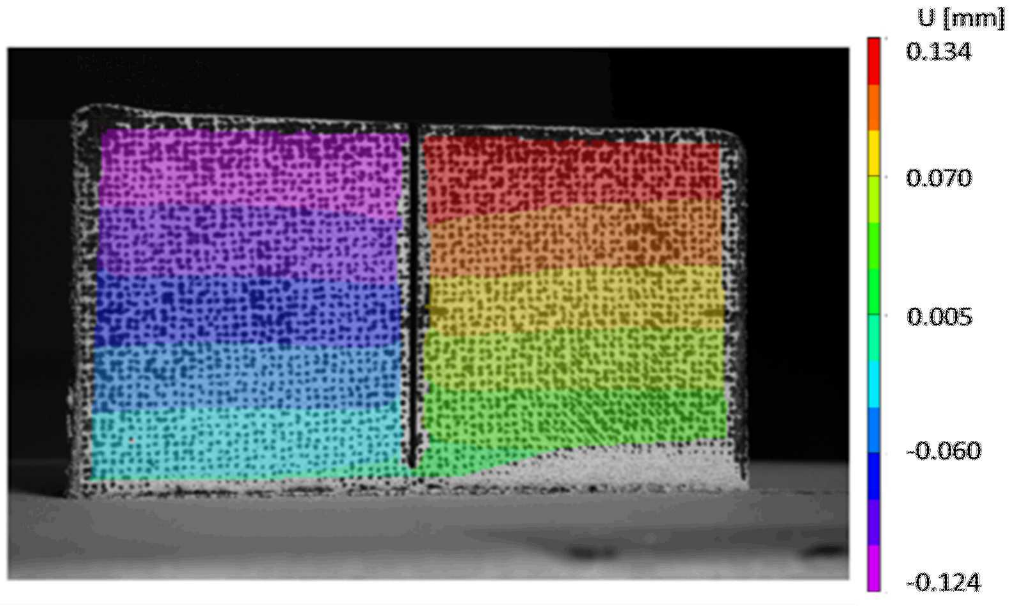


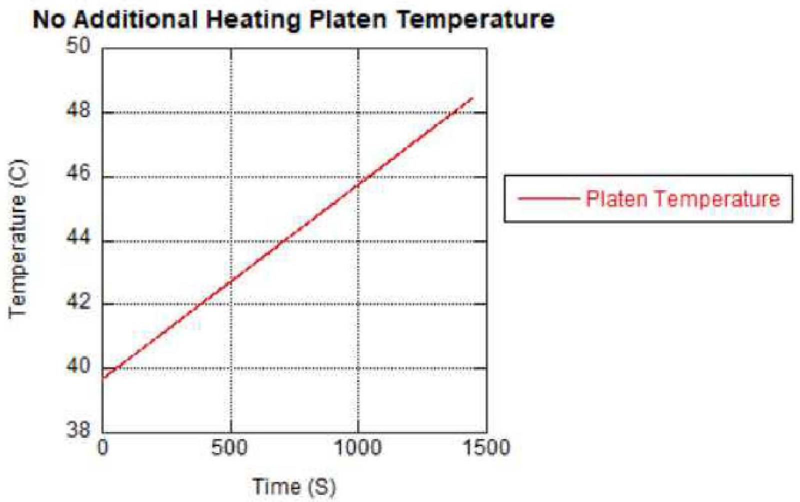
Process Parameters

Laser Power	400[W]
Powder Feedrate	6.5 [g/min]
Layer Thickness	0.25 [mm]
Hatch Spacing	N/A
Parameter Deposition Speed	400 [mm/min]
Infill Deposition Speed	N/A

DIC 50℃ Results

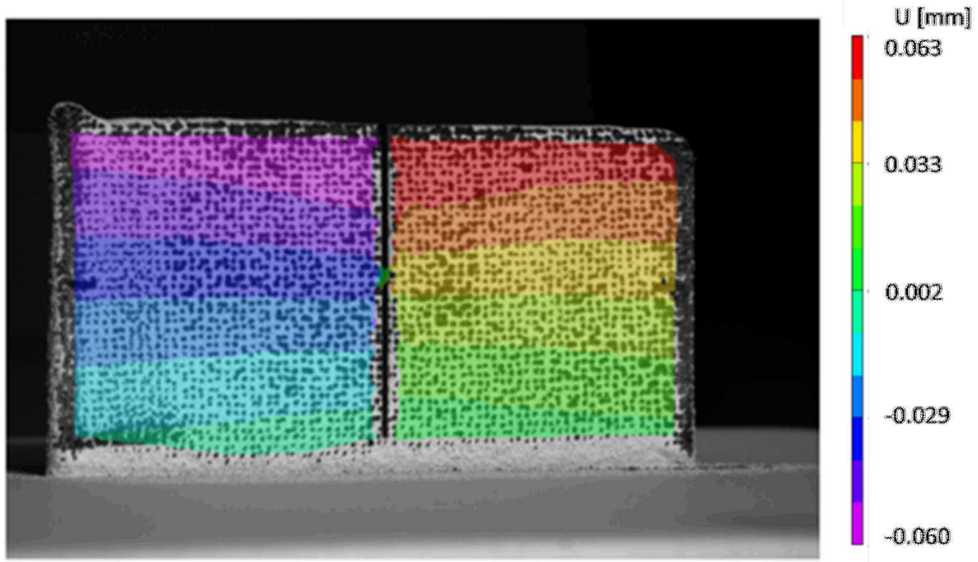
- Platen temperature of >50℃
- Maximum deformation of 0.134 mm
- Deformation is in expected direction
- Increasing substrate temperature due to laser source

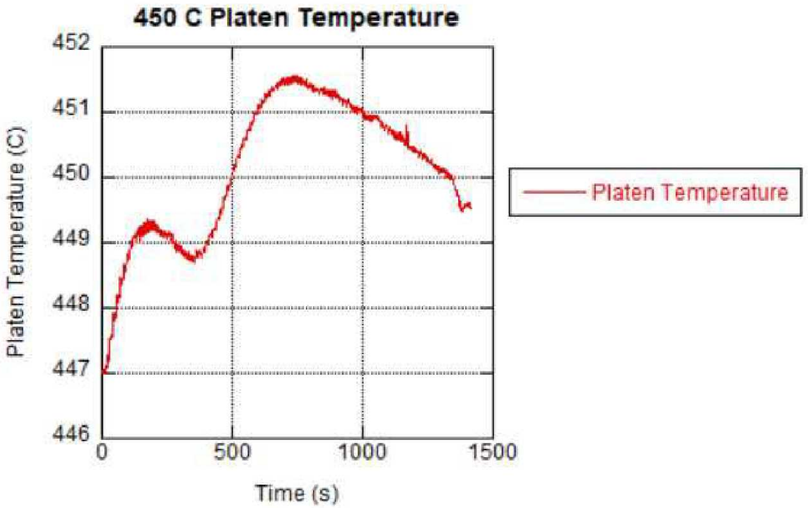




DIC 450℃ Results

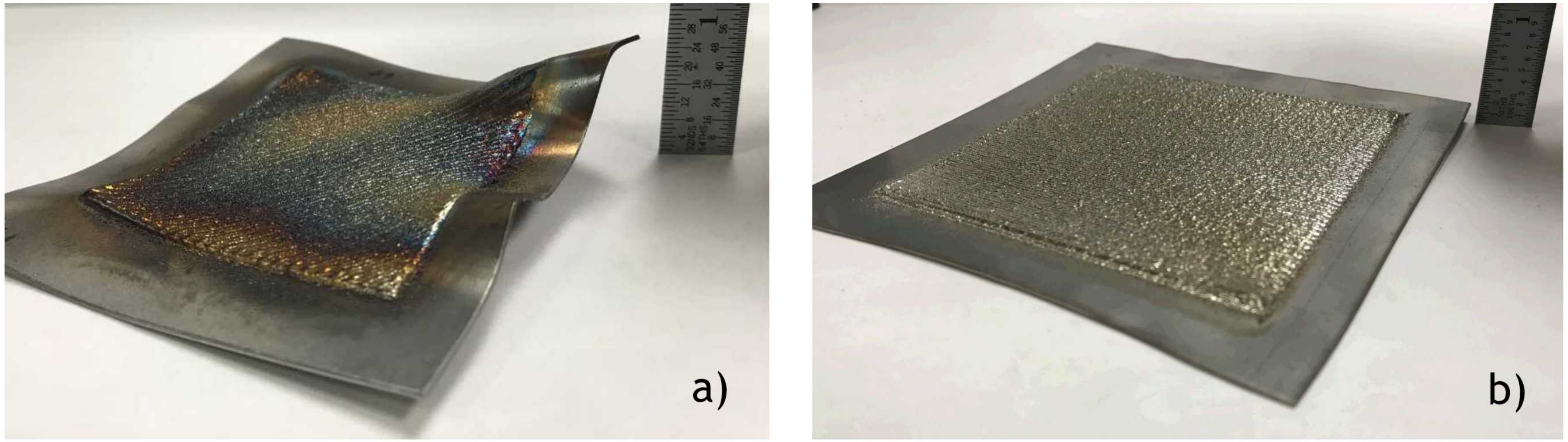
- Platen temperature of 450℃
- Maximum deformation of 0.063 mm (Less than half of no heat added sample
- Deformation is in expected direction
- 0.063 mm < 0.134 mm which suggests significant stress reduction





Test parts

- Heating the platen reduces stress by minimizing thermal gradient and reducing cooling rate of melt pool
- Improved results shown by printing pad on 0.030" shim stock



Printing of 3 layer pad on 0.030" shim stock a)No added platen heat. b) Platen temperature of 450°C.

Modeling of Additive Manufacturing

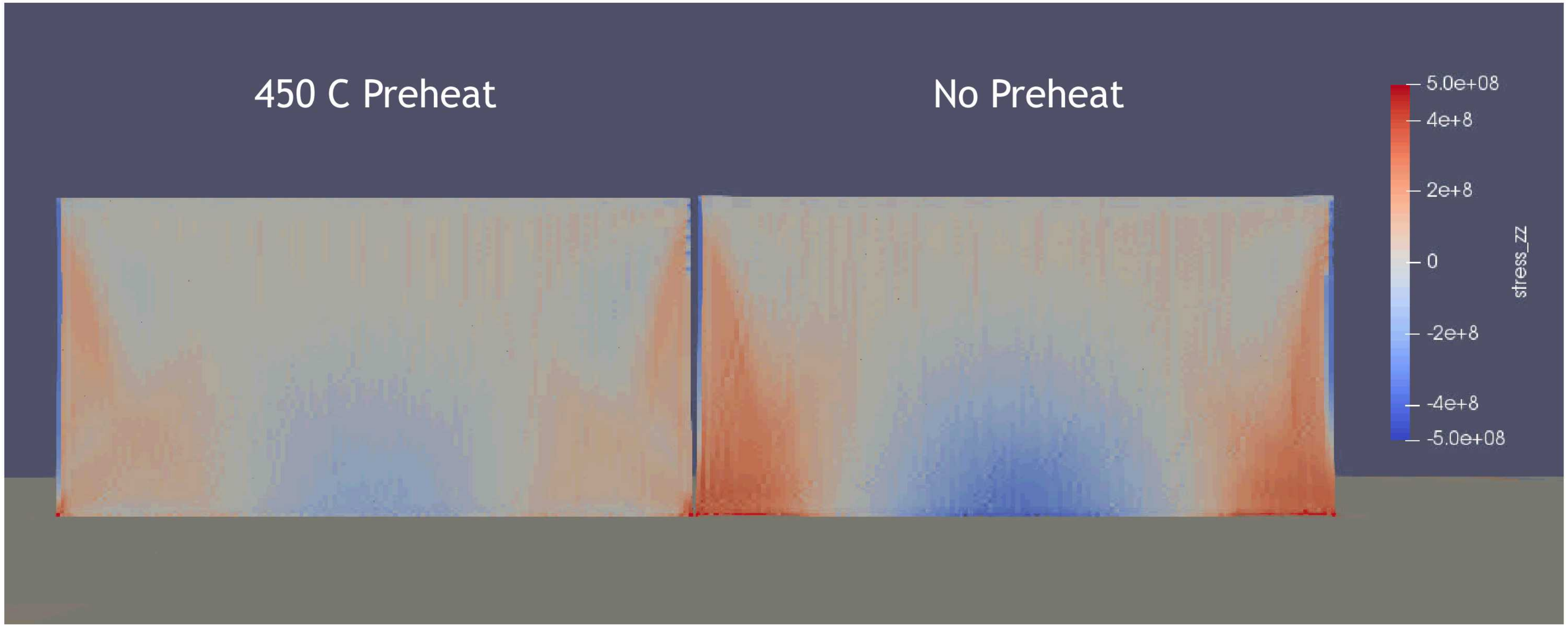
Residual Stress Modeling

Ongoing Work – Baseplate Preheat Studies

- Models part being printed
- Shows how stress is developed in the part
- Shows clamps being released in the printer
- Future work still needs to show the slit being cut into the part

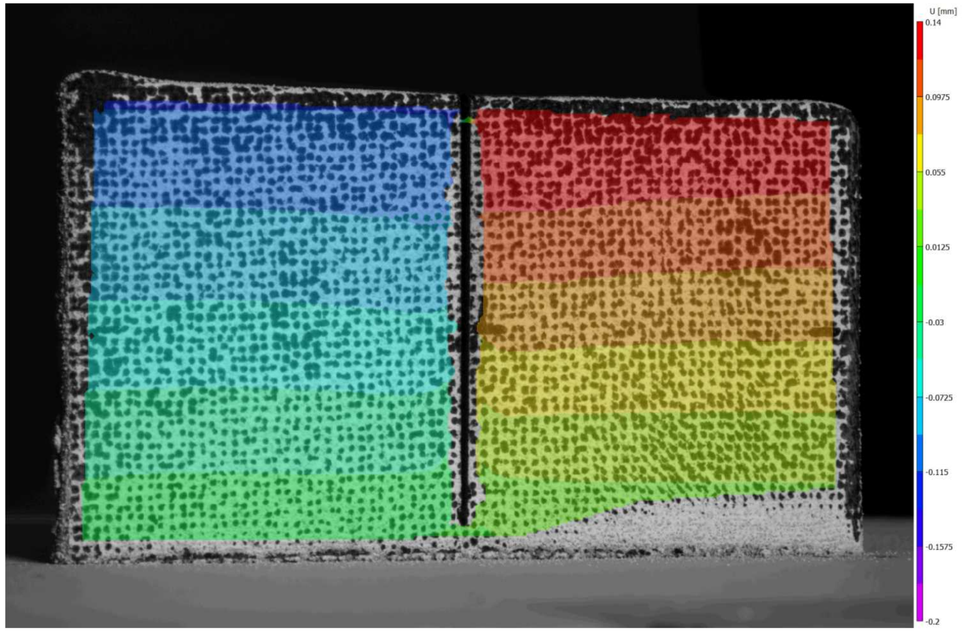
Residual Stress Modeling

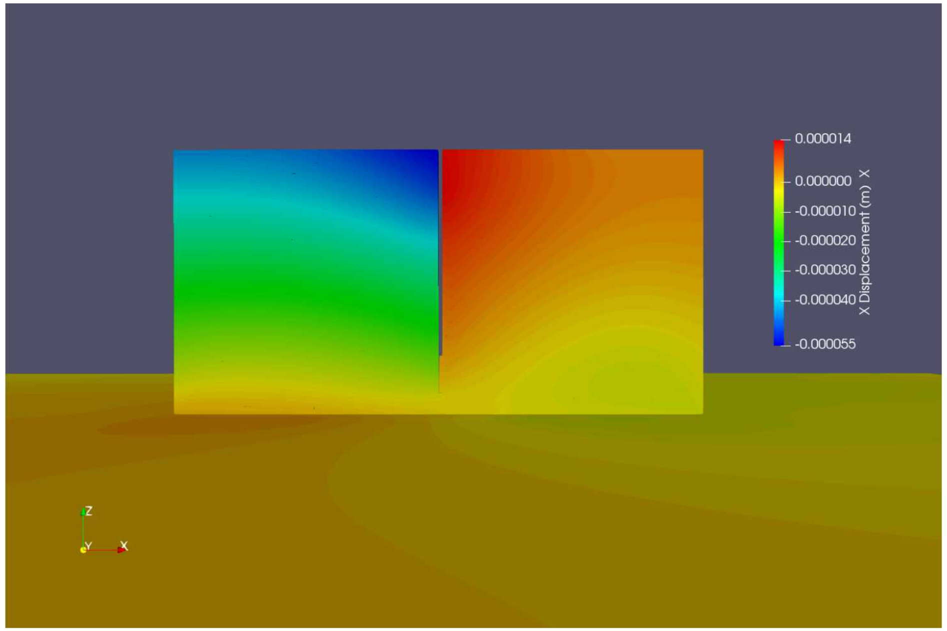
Temperature of print bed and residual stress accumulation



Residual Stress Modeling for 50°C

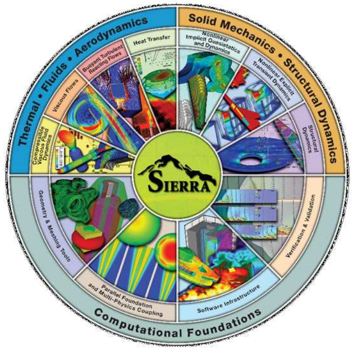
Model and experimental result are similar

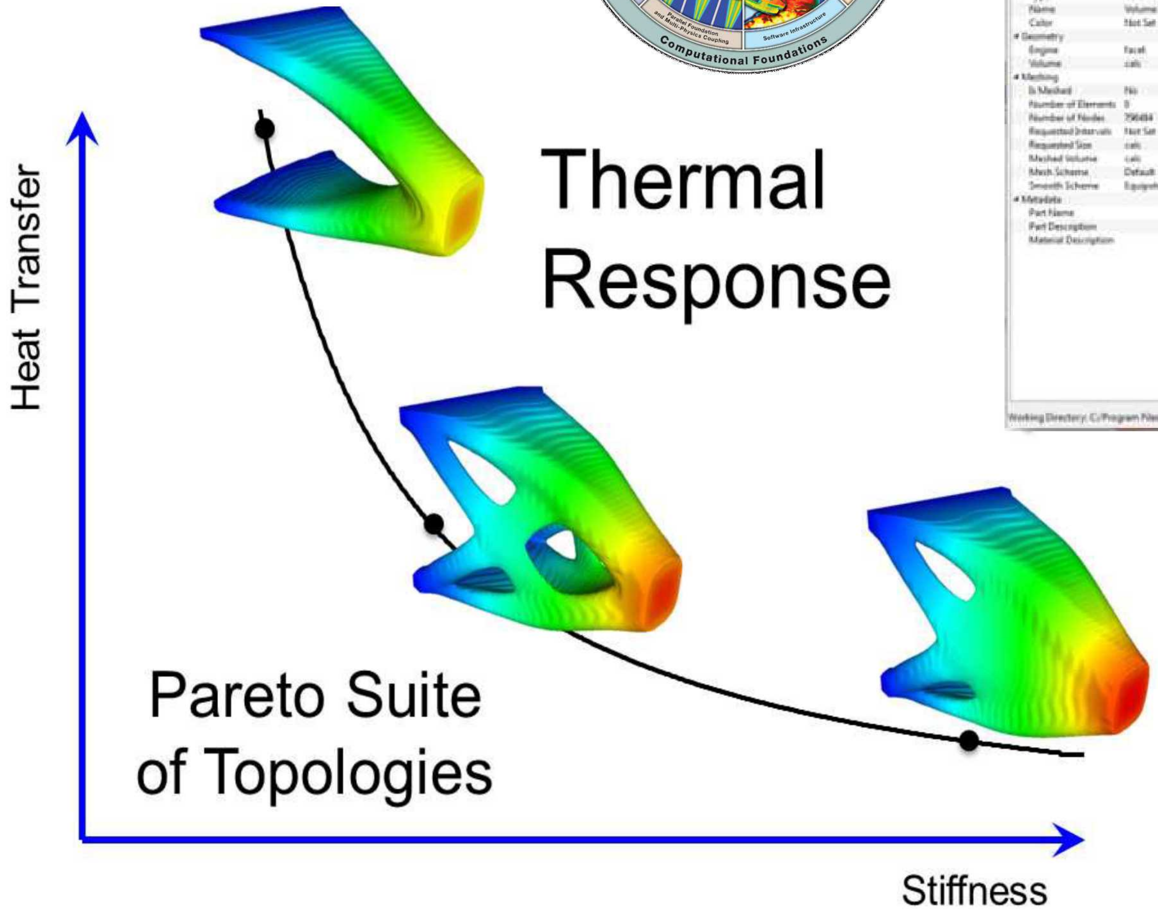




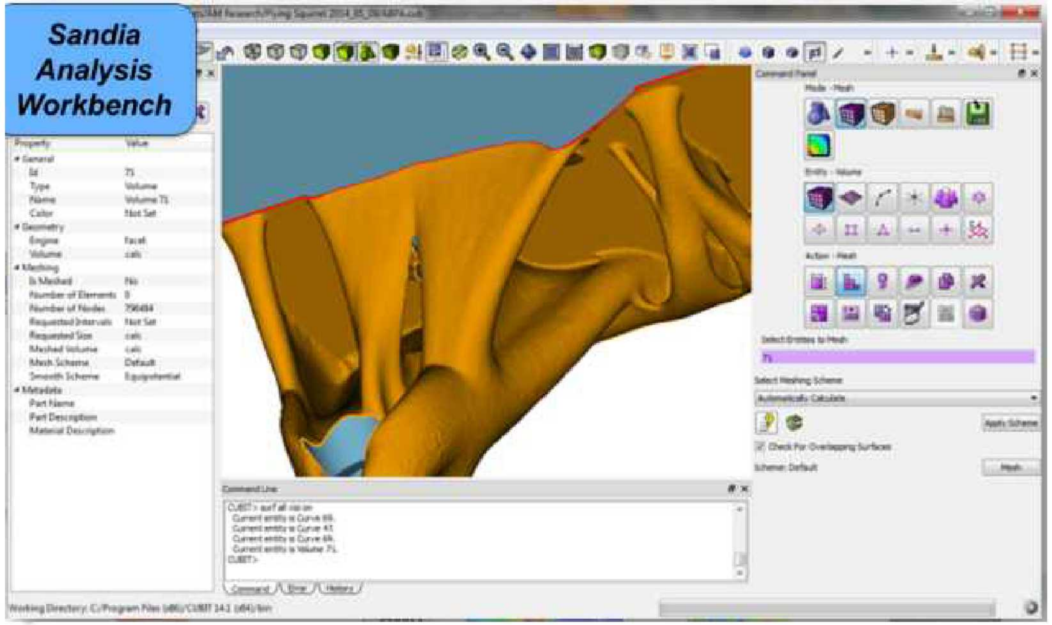
*Cut path needs to be adjusted

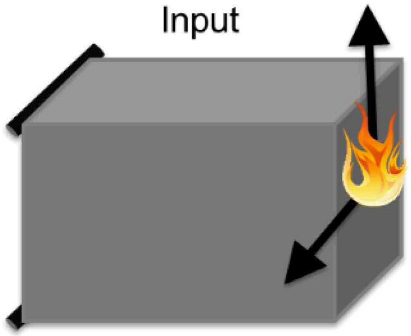
Topology Optimization





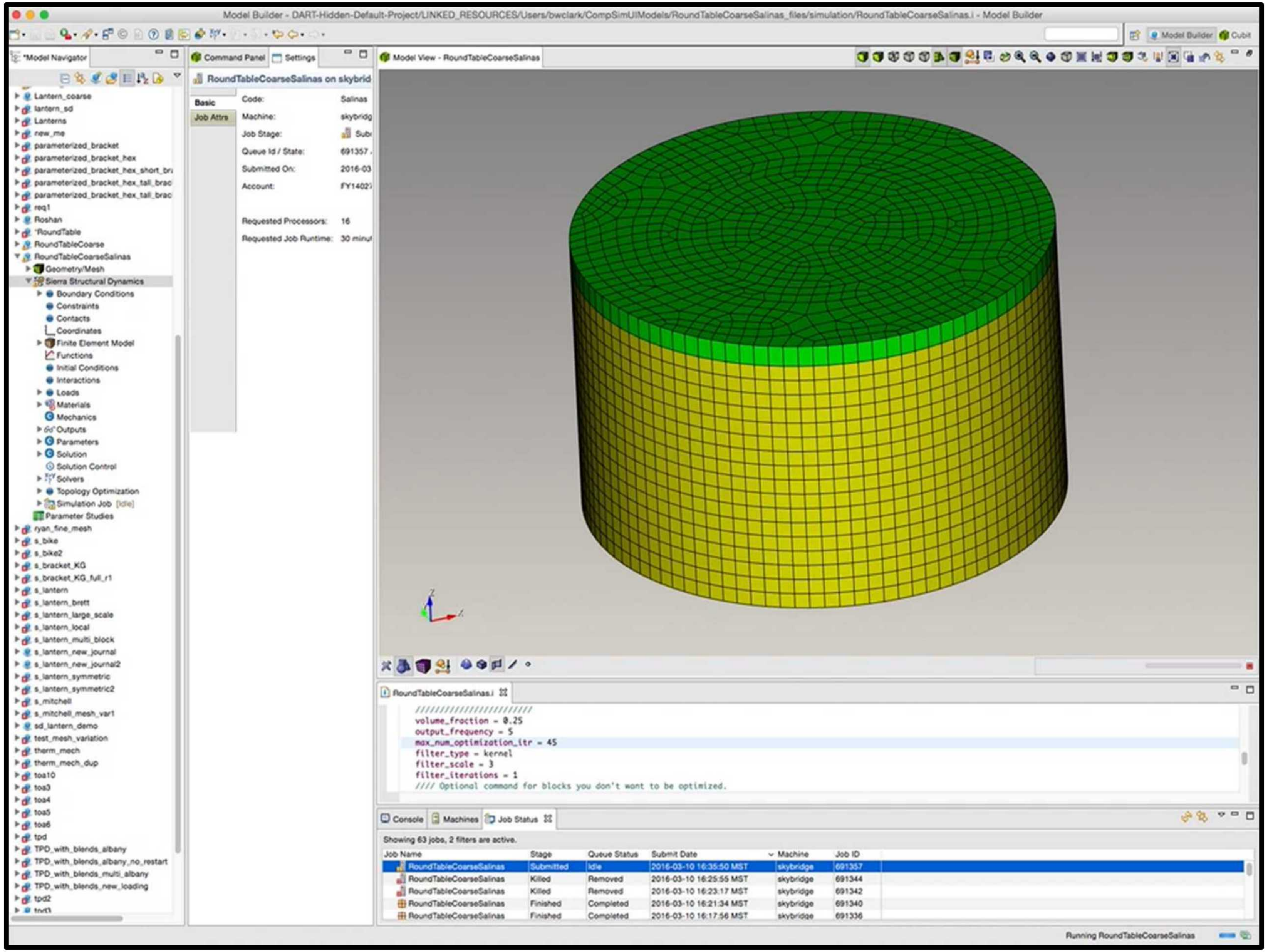
User Friendly Interface



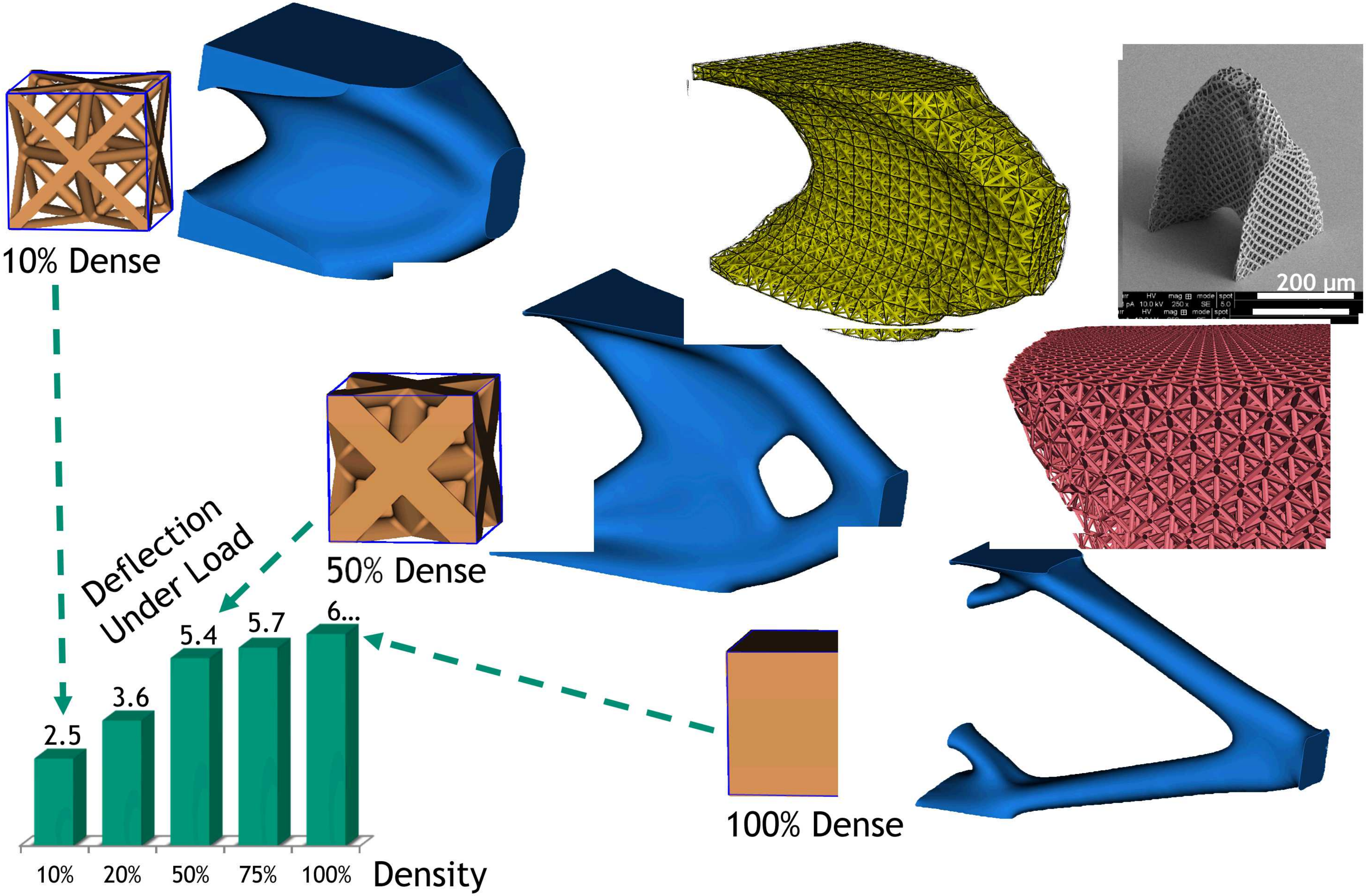


Topology Optimization

- Start off entering volume and shape constraints
- Enter thermal or mechanical loads
- Run optimizer to find optimal shape for a given application
- Parts can be optimized for thermal, mechanical, stiffness, etc.

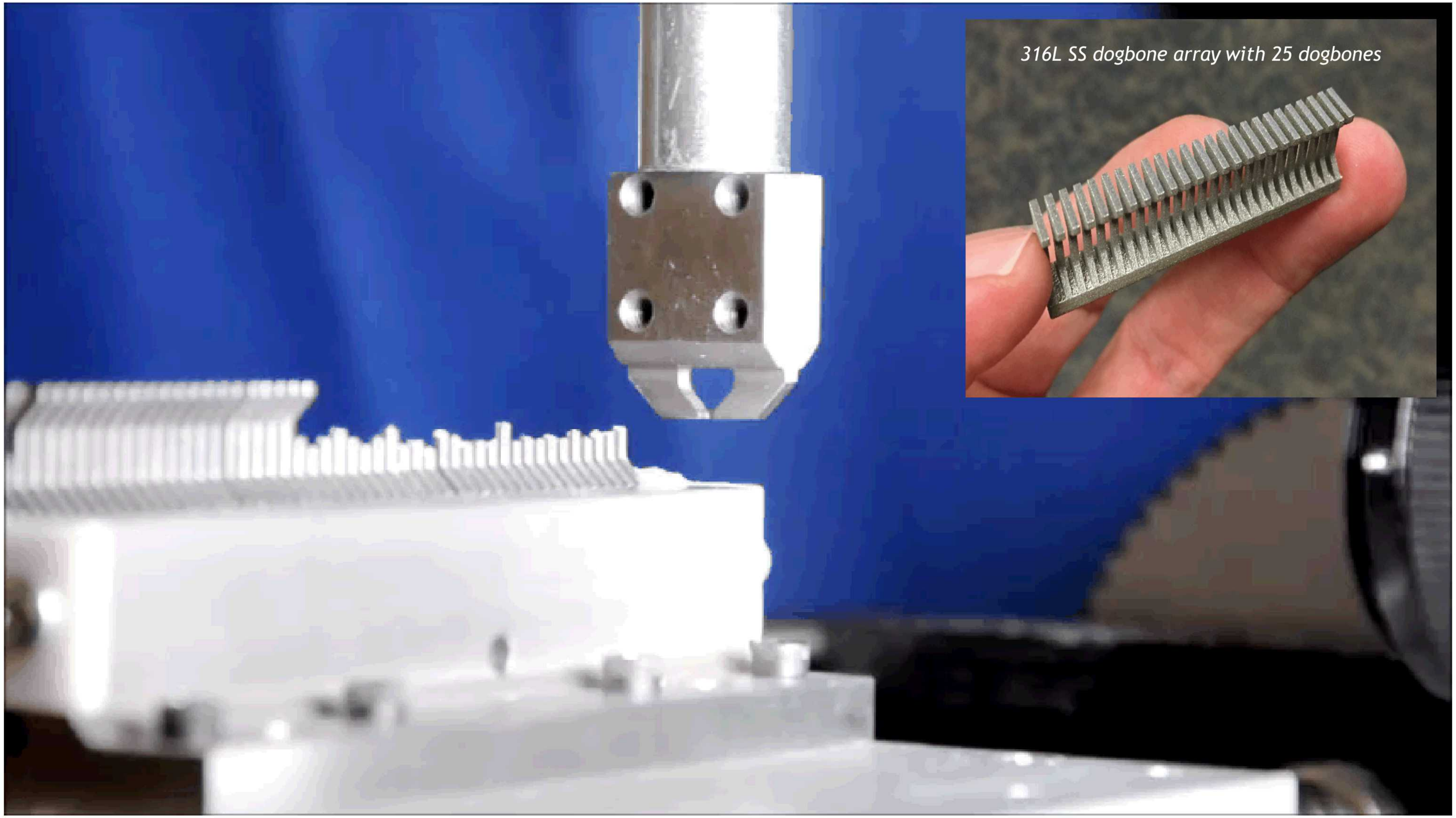


Optimizing Stiffness at a Fixed Mass

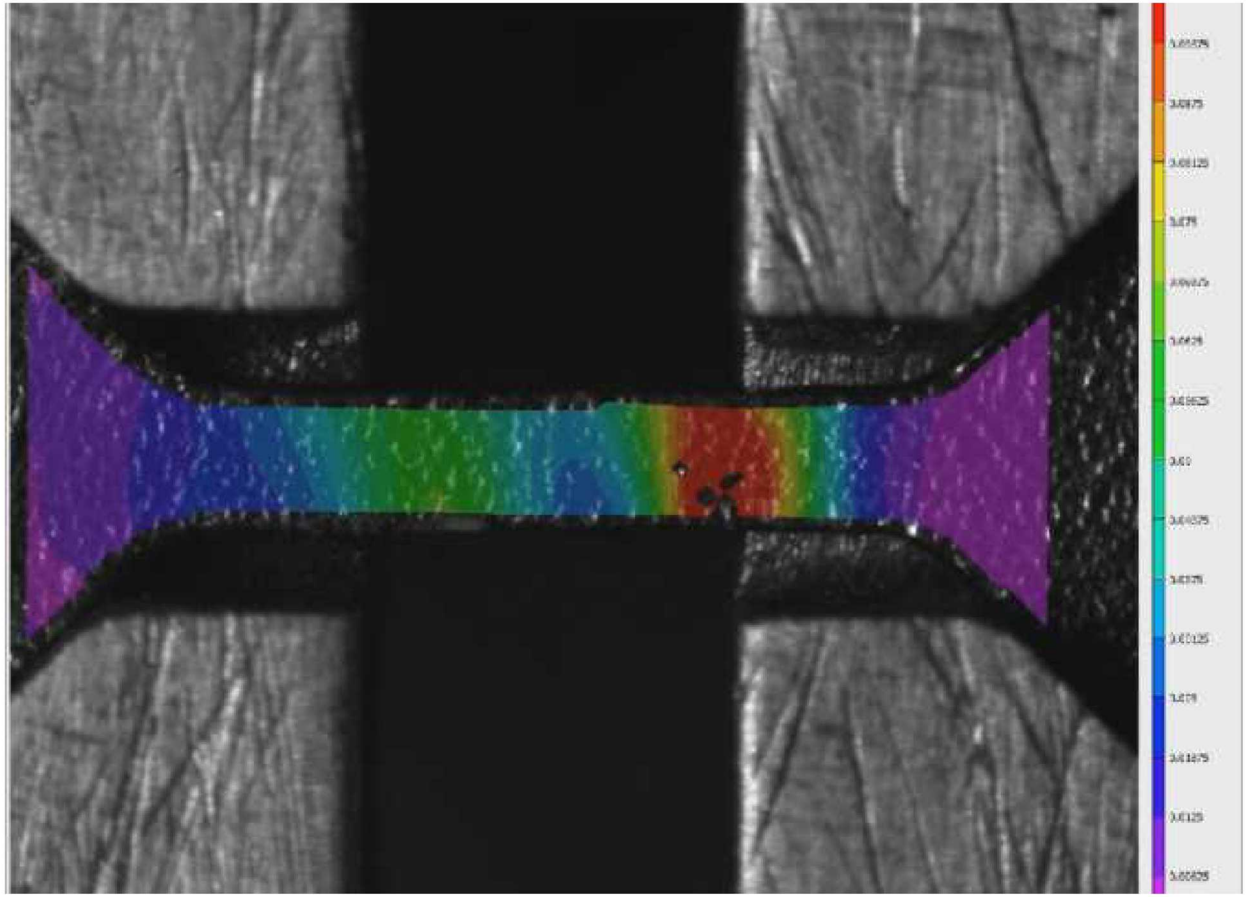


Characterization of AM Parts

High Throughput Tensile Testing

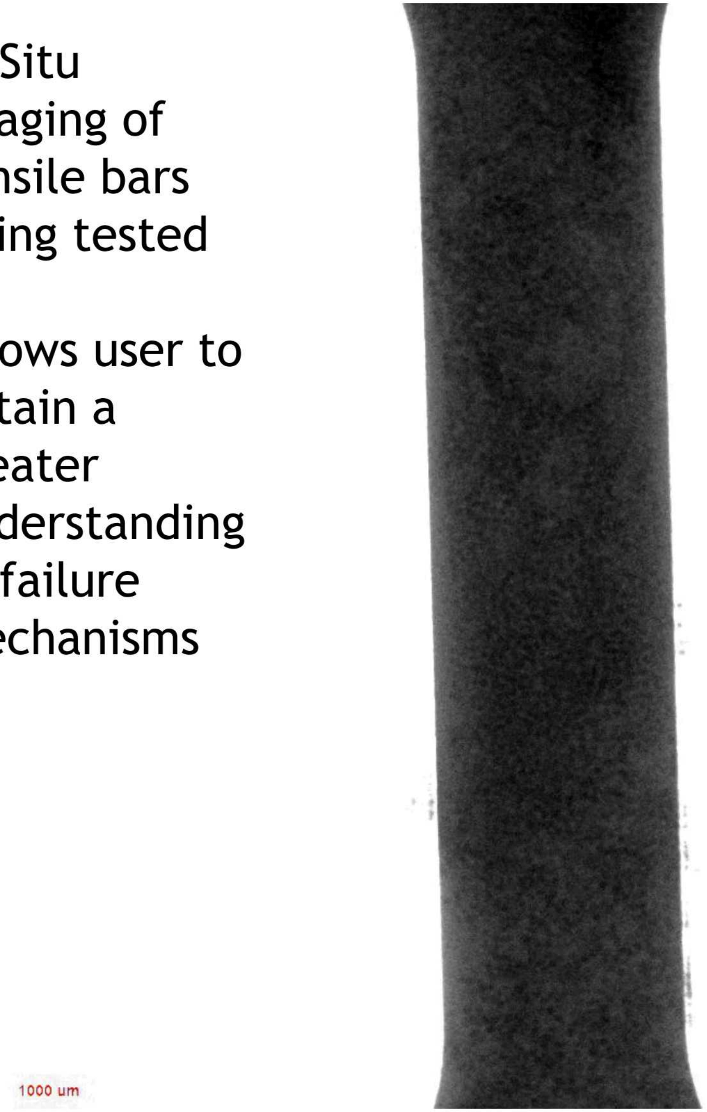


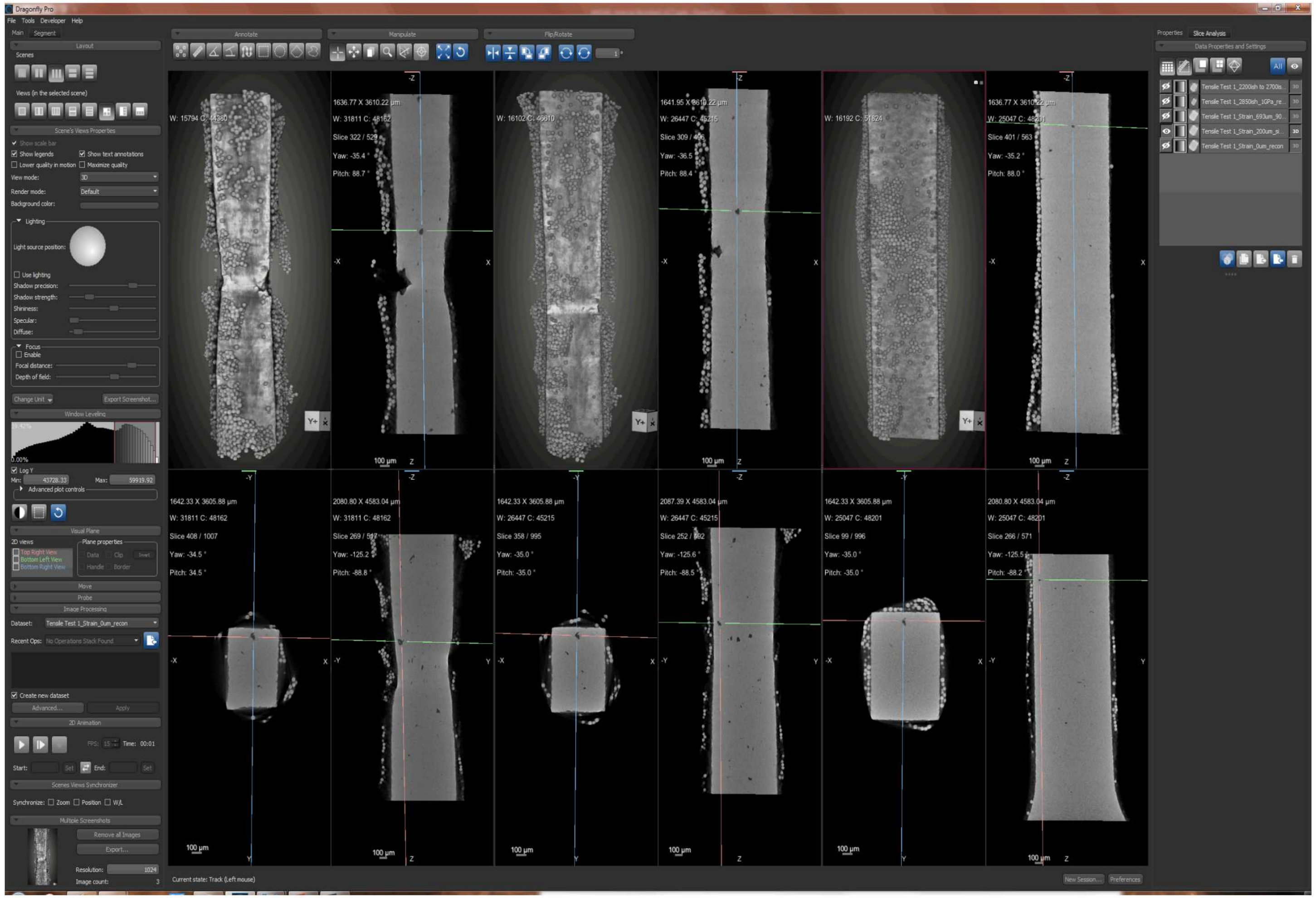
High Throughput Tensile Testing with Digital Image Correlation



X-Ray Imaging

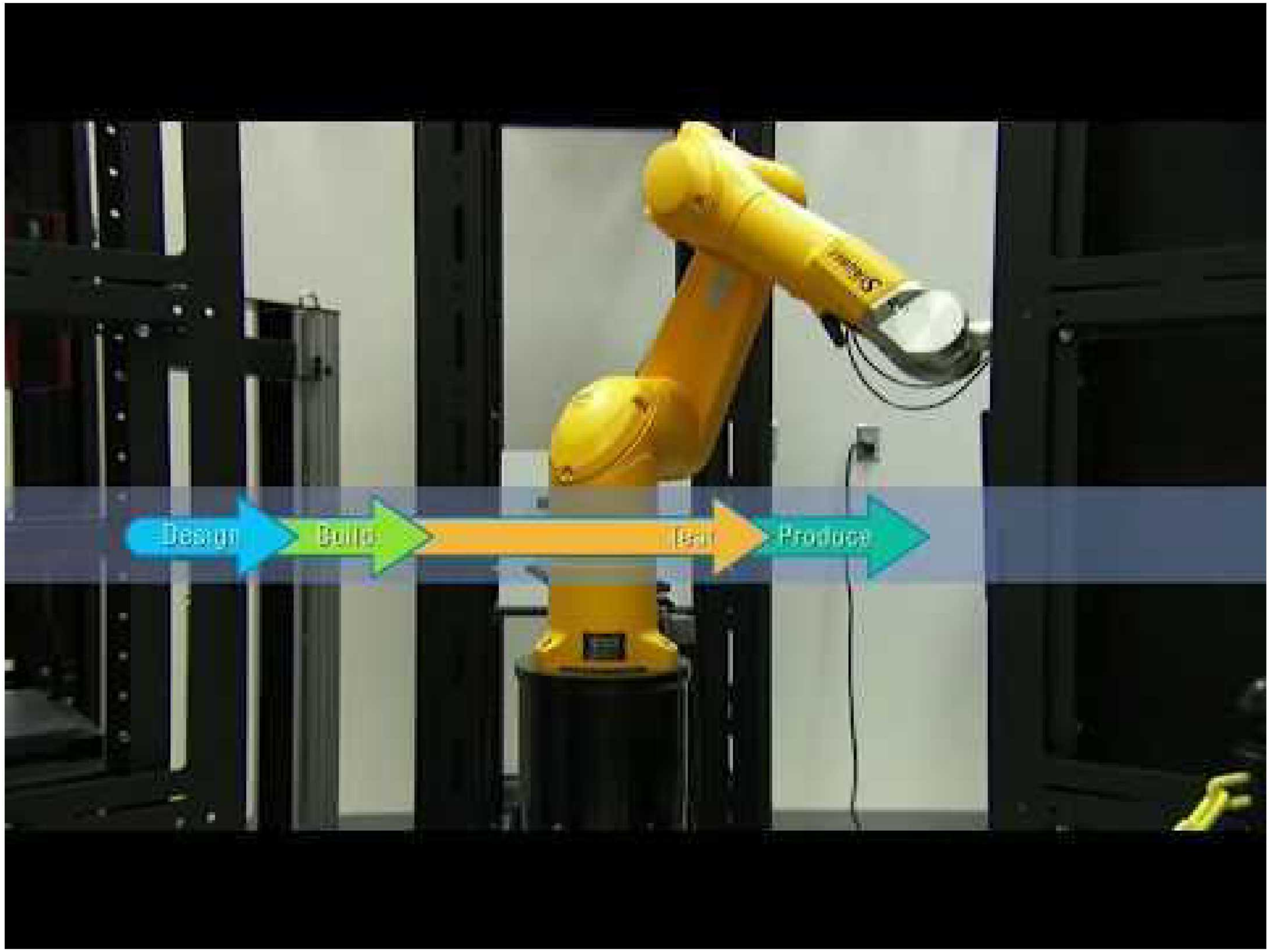
- In-Situ imaging of tensile bars being tested
- Allows user to obtain a greater understanding of failure mechanisms





Alinstante

- Automated testing
- Can be expanded or adapted for various applications and manufacturing needs
- Takes expertise or legacy knowledge out of the testing equation



Alinstante: A Robotic Workcell for High Throughput Automation
https://youtu.be/6UKxxU3ukoQ

Unique applications of Additive Manufacturing

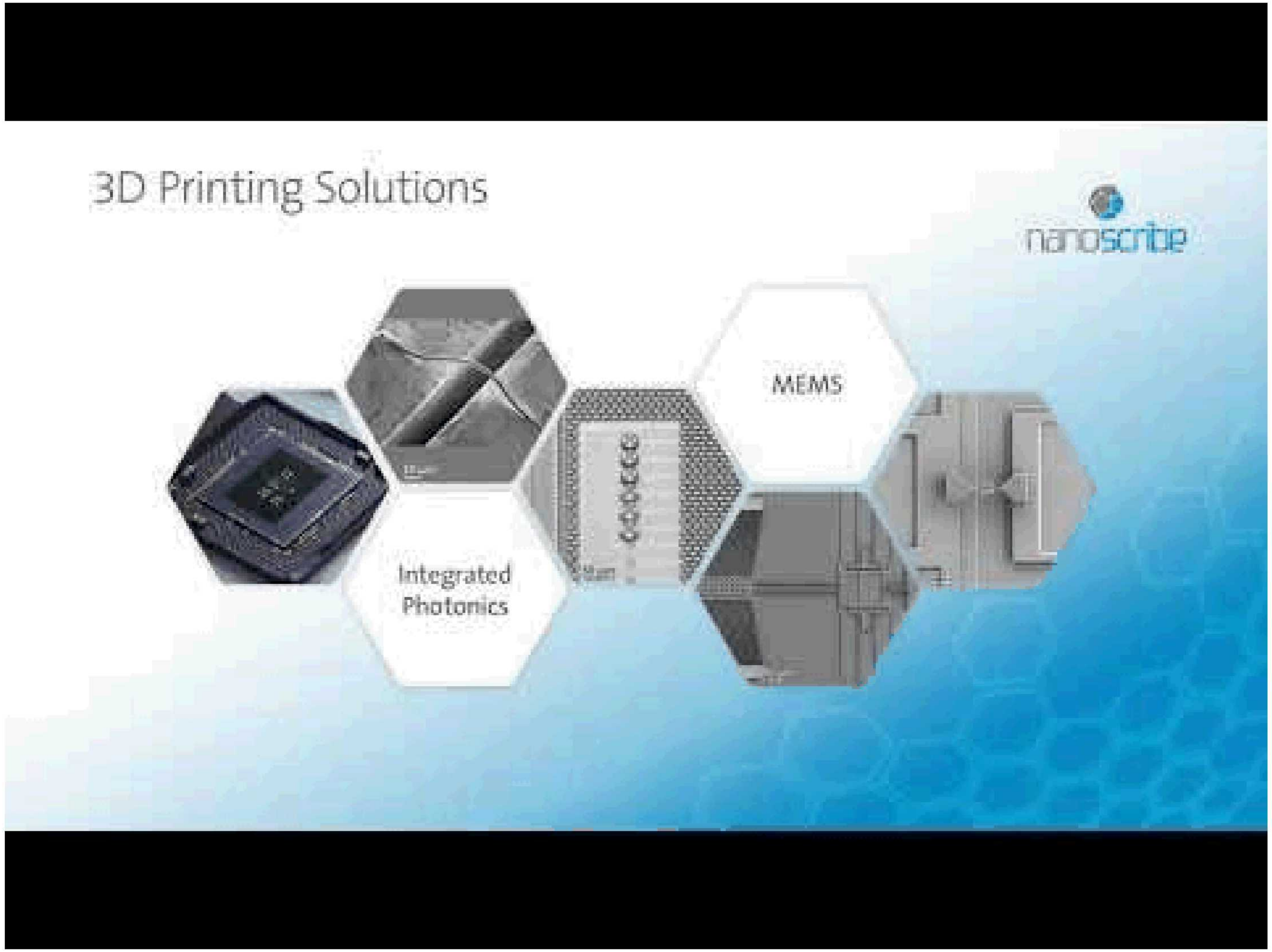
BAAM (Big Area Additive Manufacturing)

BAAM (Big Area Additive Manufacturing) Overview
https://youtu.be/cyX-v83_5Zg

3D Printing Houses

GIANT 3D Printers Make Ten Houses in Only a Day!
https://youtu.be/k74rb7xl3aY

3D Print Nano Structures

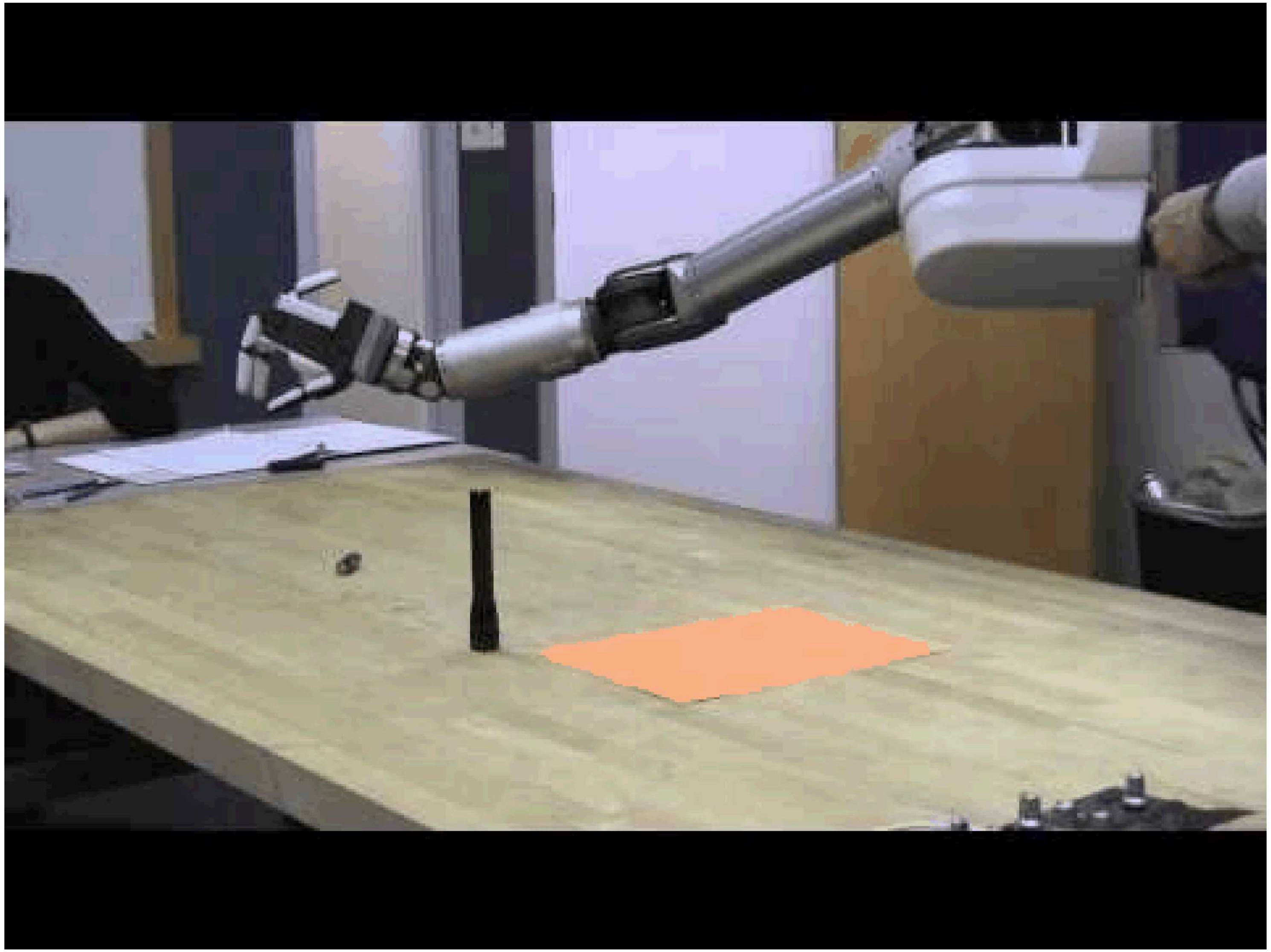


Submicron Additive Manufacturing: Integrated Systems
https://youtu.be/ZHY8kS3CZ7g

Integrated Circuits

Voxel8: The Worlds First 3D Electronics Printer
https://youtu.be/zbm2SSql8V8

Robotic Hand



Sandia Robotic Hand
https://youtu.be/gDFBbCmlKHg