Rigaku

Structural Failure Analysis

Wed., May 22, 10 am CDT

Presenter: Ted Huang | **Co-presenter:** Angela Criswell | **Host:** Viral Vaghela

- *You will be muted during the workshop*
- *You can ask questions using the Q&A tool.*
- *You should hear music if your sound is working*

Structural Failure Analysis

Wed., May 22, 10 am CDT

Presenter: Ted Huang | **Co-presenter:** Angela Criswell | **Host:** Viral Vaghela

We are starting now...

Rigaku

Presenter: **Ted Huang** | X-ray Imaging Application Scientist

Co-presenter: **Angela Criswell** | Director of X-ray Imaging

Host: **Tom Concolino** | X-Ray Diffraction and X-Ray Imaging Sales Manager
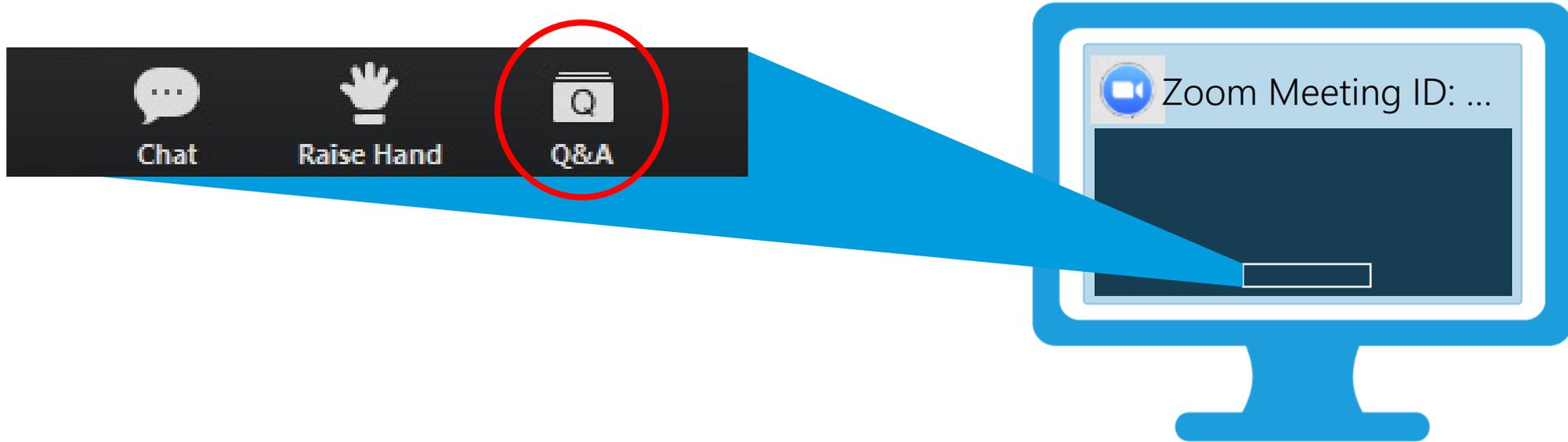
You can ask questions during the presentation.
Please use the Q&A to ask questions.

Recording will be available tomorrow.

Decoding Defects:
Failure Analysis
Using X-ray CT

Structural failure analysis

What is Structural Failure Analysis ?

You will learn

- What is structural failure

- What leads to structural failure

- What are signs of potential failure

- How X-ray CT helps you navigate

pixabay

Cost of structure failure

- Catastrophic disaster
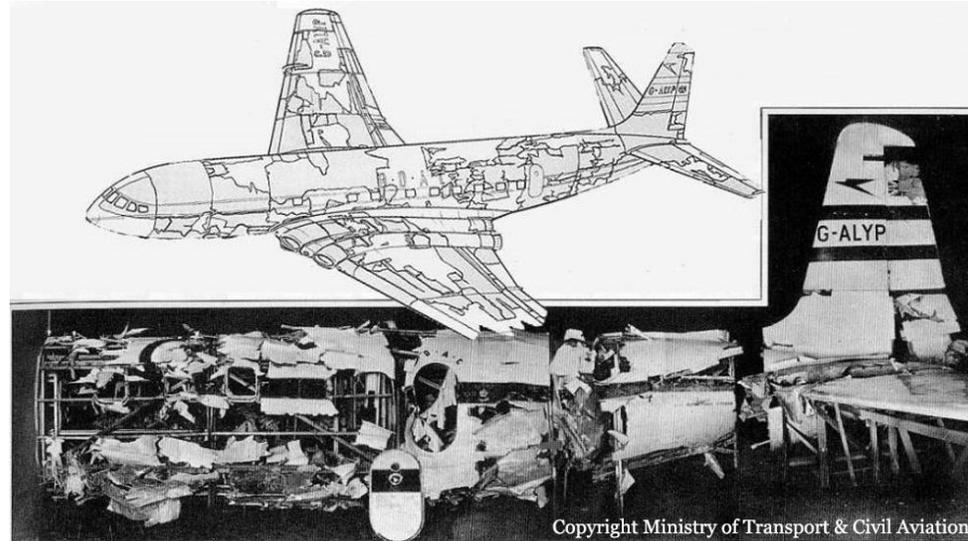
De Havilland DH-106 Comet 1

Cost of structure failure

- Catastrophic disaster

UK public buildings feared to be at risk of collapse as concrete crumbles

Ministers launch inquiry into use of reinforced autoclaved aerated concrete (RAAC)

The Guardian   [Article link](#)

Sydney apartment complex 'at threat of collapse' after 'serious defects' found in concrete, NSW Building Commission order says

By Millie Roberts and Penny Timms

Posted Wed 17 Jan 2024 at 12:15am, updated Wed 17 Jan 2024 at 5:21pm

[Article link](#)
abc news

pixabay

Cost of structure failure

- Failing product

Broken "neck"

CBS MORNINGS

Patients expected Profemur artificial hips to last. Then they snapped in half.

By Anna Werner, CBS News & Brett Kelman, KFF Health News
December 5, 2023 / 7:36 AM EST / CBS News

cbs news [Article link](#)

MONEYWATCH

Johnson & Johnson to pay $120 million to settle hip-implant claims

By Sarah Min
January 22, 2019 / 5:34 PM EST / MoneyWatch

cbs news

[Article link](#)

Cost of structure failure

- ## Failing product

pixabay

LISTS

6 Most Fragile Smartphones That Definitely Need Protection

Published on July 15, 2015 at 4:32 pm by **DEJAN KVRGIC** in Lists

| f Share | 🐦 Tweet | ✉ Email |

Page 1 of 6   **NEXT >>**

Insider
[Article link](#)

Don't drop it! Shocking repair prices for the iPhone X

Repairing a damaged iPhone X could set you back $549 - more than half the retail price of that phone.

nbc news

[Article link](#)

Polling Question #1

Microsoft Stock

What is Fracture ?

The separation or fragmentation of a structure into two or more parts, under the action of stresses.

— *Mechanical Behavior of Materials*
by Mer Meyers and Krishan Chawla

pixabay

Types of fracture

- Simple fracture

- Impact fracture

- Fatigue fracture

- Environment assisted fracture

Simple fracture

pixabay

pixabay

Force too strong for intended condition

Impact fracture

pixabay

pixabay

Concentrated force in short period of time

Fatigue fracture

Great **number of loading cycle**

Environment assisted fracture

Corrosion cracking
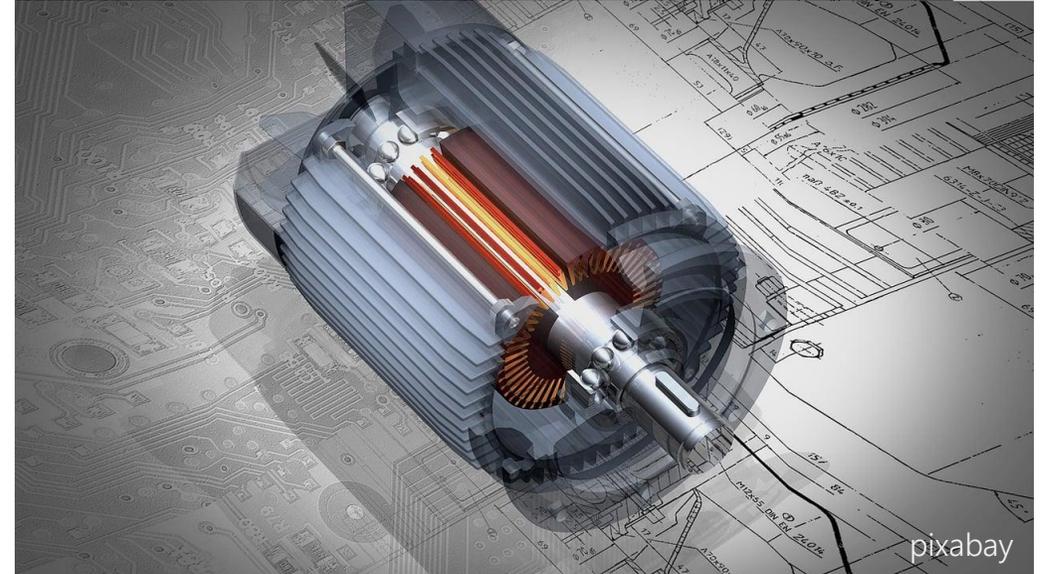
High temperature failure (Creep)

How does Fracture happen?

Process of fracture
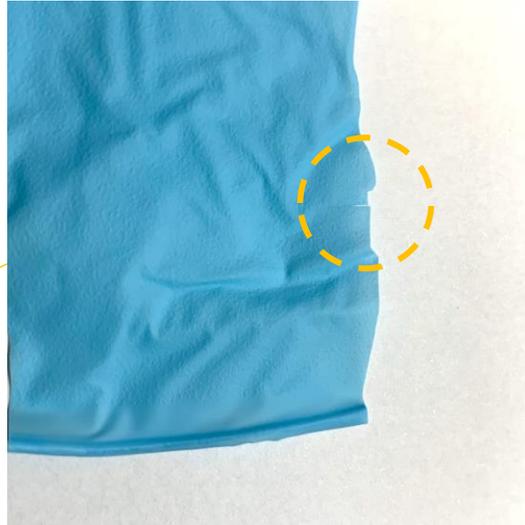
Process of fracture
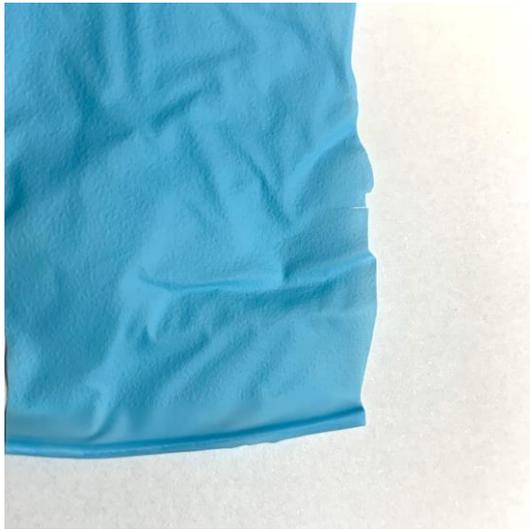
Damage accumulation

Nucleation of more
cracks / voids

Growth of
cracks / voids

Rupture
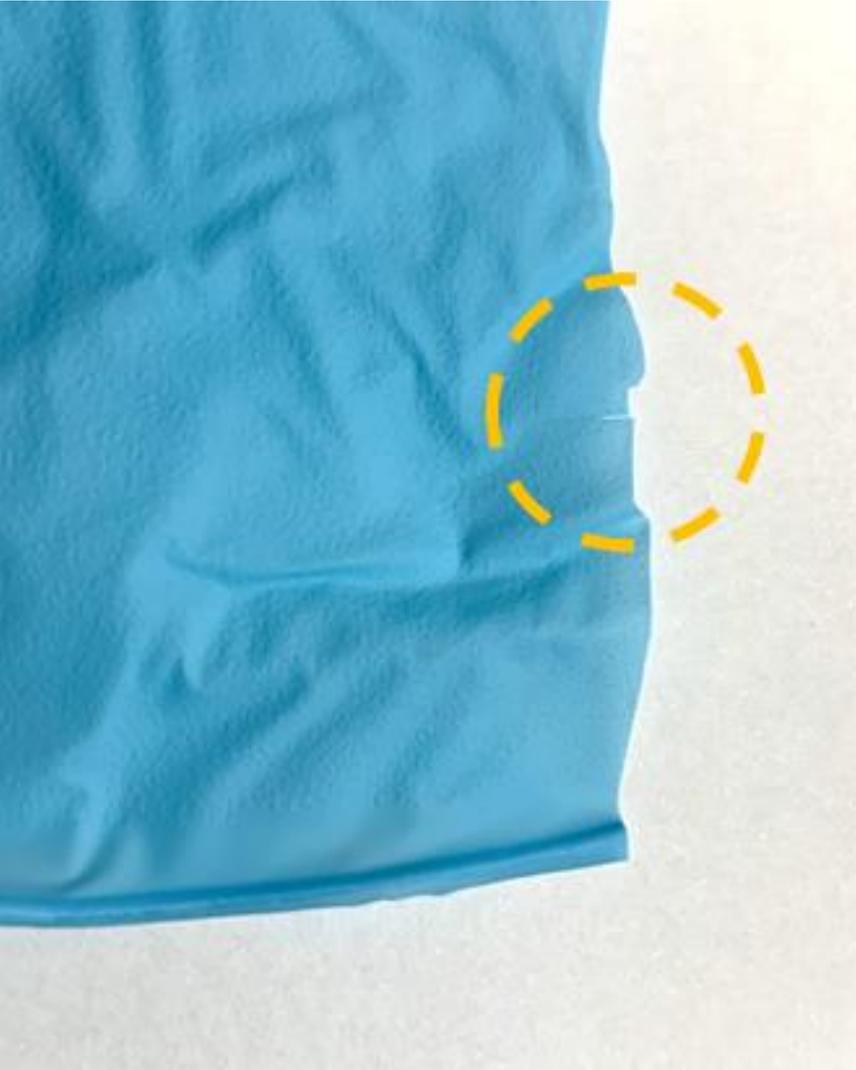
Damage accumulation

- Field inspection (Surface level)
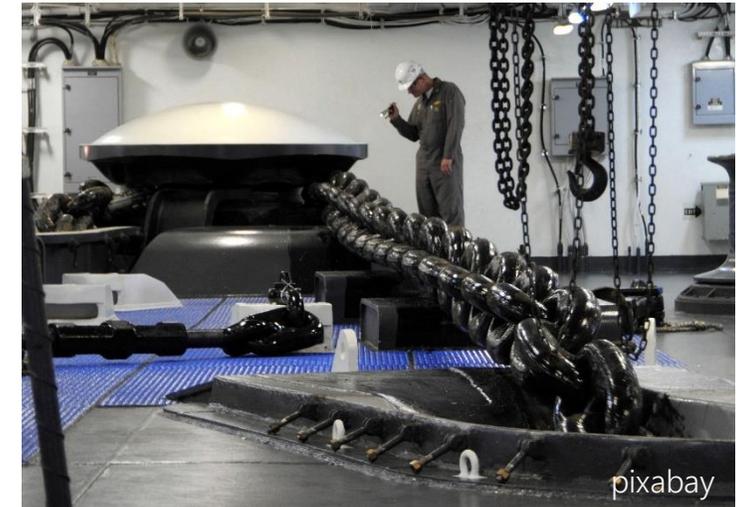
pixabay

pixabay

Nucleation of more cracks or voids

- Field inspection (Internal structure)

- Quality assurance

- R&D

U.S. Department of Transportation
© High Steel.

pixabay

Growth/coalescence of cracks or voids

- Mining, drilling
- Academic research

pixabay

pixabay

Rupture

- Post-mortem analysis

- Quality assurance

- R&D

- Everyone

Polling Question #2

Microsoft Stock

How to spot **Fracture** potential?

Microsoft stock
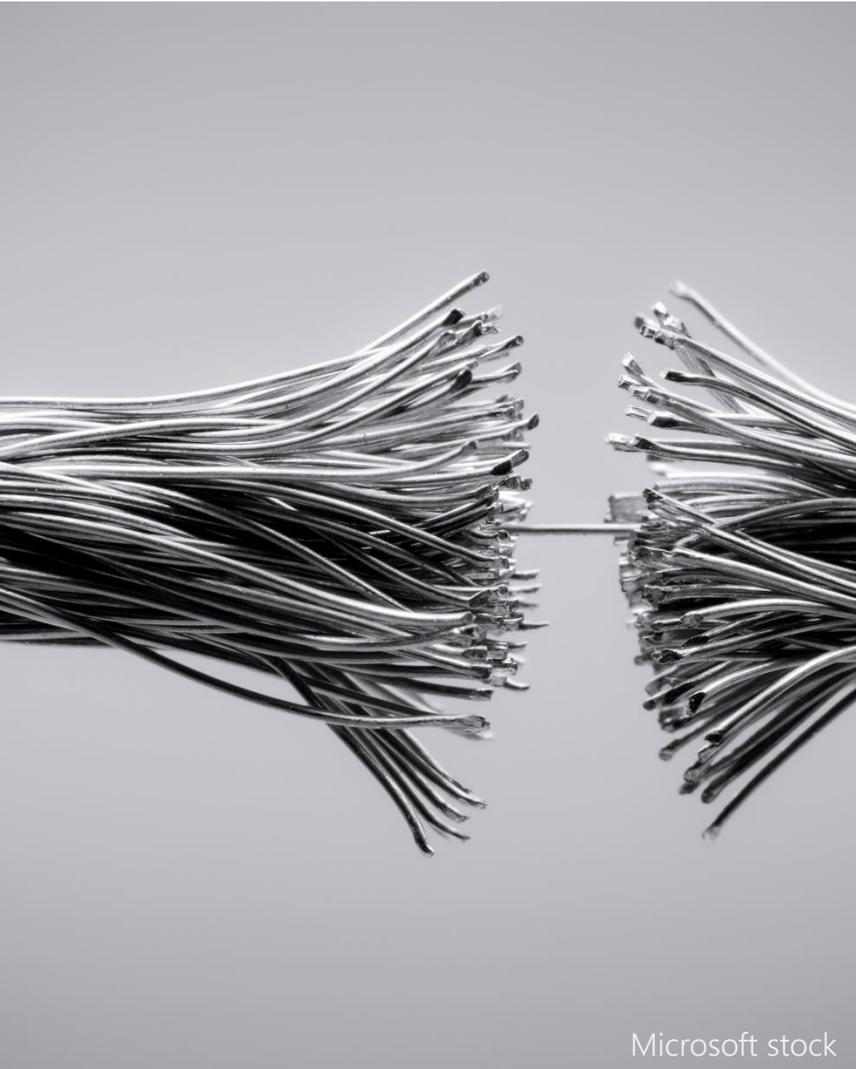
Structural weak points

- Sharp angle
- Cracks
- Pores/voids
- Others

Sharp Angle

Sharp angle

Stress ←σ   σ→ Stress
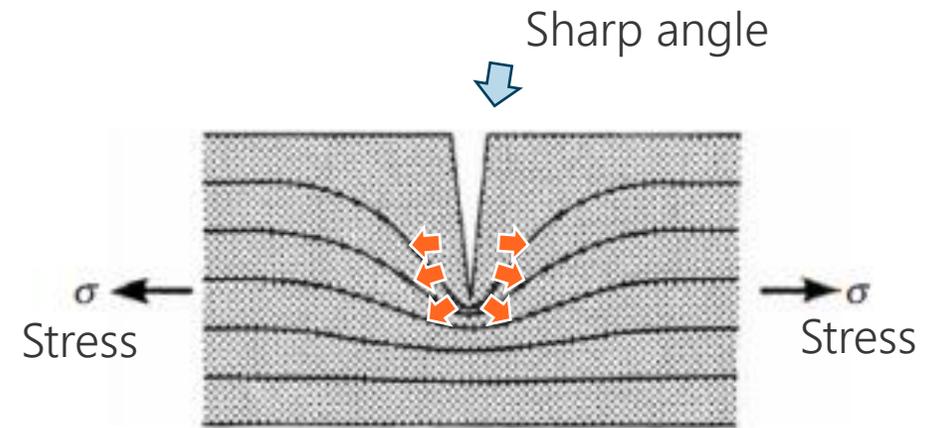
*Mechanical Behavior of Materials, 2nd edition, Mer Meyers and Krishan Chawla

Cracks

$$\sigma_{max}$$

$$\sigma_{max} = \sigma\left(1 + 2\frac{a}{b}\right)$$
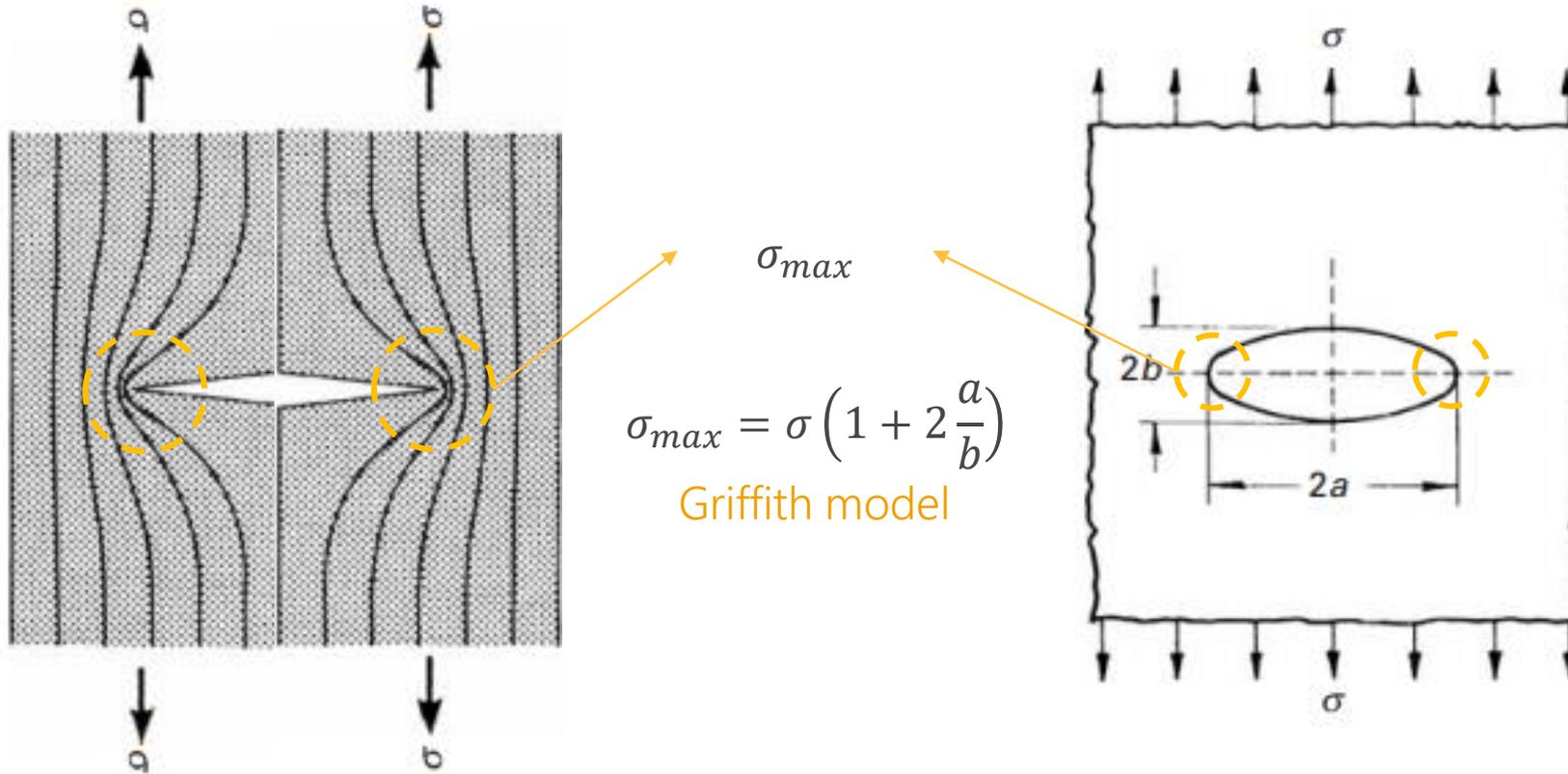
Griffith model

*Mechanical Behavior of Materials, 2nd edition, Mer Meyers and Krishan Chawla

Pores / voids
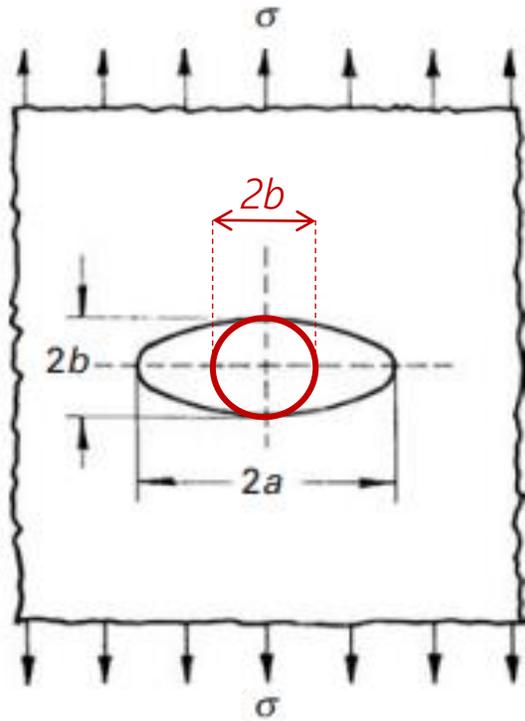
Griffith model

$$\sigma_{max} = \sigma\left(1 + 2\frac{a}{b}\right)$$

$$\sigma_{max} = 3\sigma$$

BAG • TEAR AT PERFORATION •
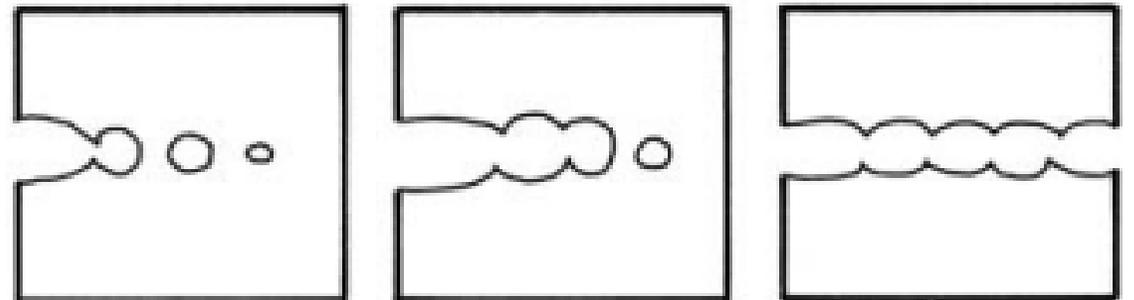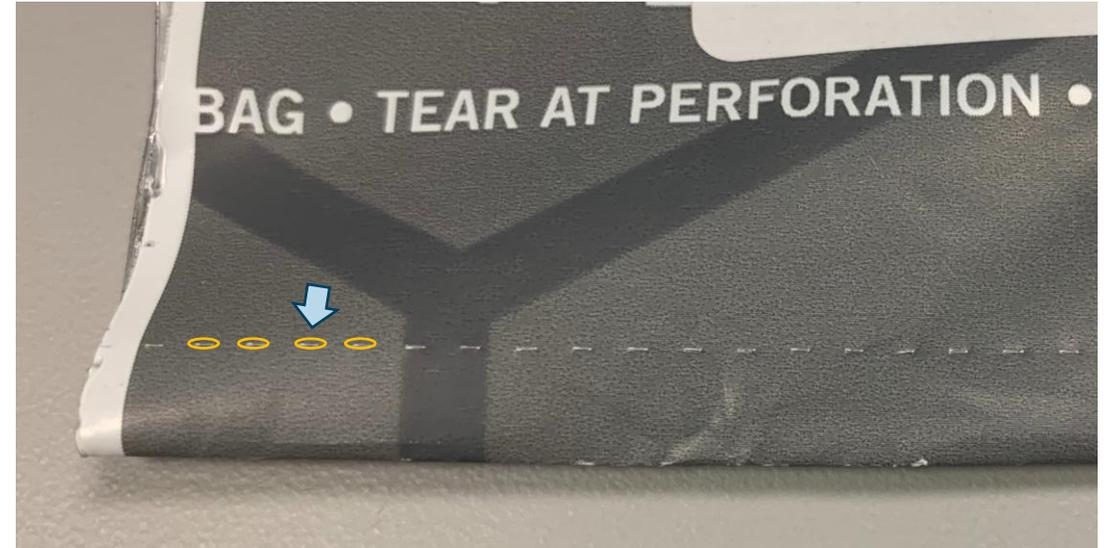
*Mechanical Behavior of Materials, 2nd edition, Mer Meyers and Krishan Chawla

Others

- ## Structure specific flaws
  - ### Inclusion/fiber mismatch

- ## Reduction of load area
  - ### Necking/manufacturing error

- ## Environment specific flaws

Random fiber failure

Necking
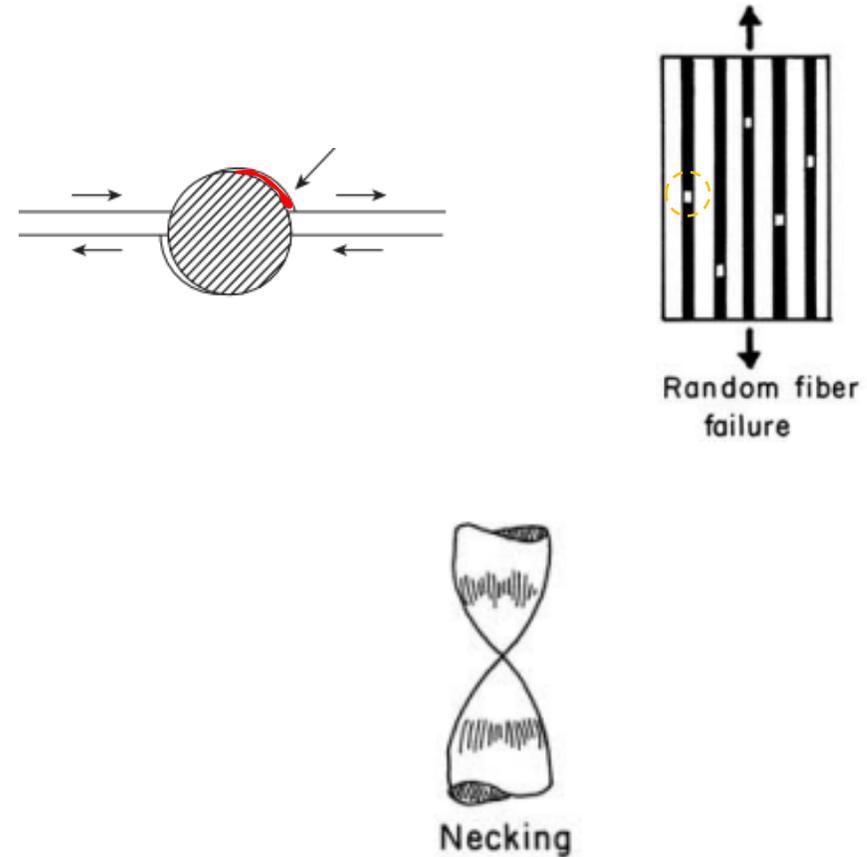
*Mechanical Behavior of Materials, 2nd edition, Mer Meyers and Krishan Chawla

Structural failure analysis methods

![Worker inspecting machined metal parts](Microsoft stock)

Structural failure analysis methods

- Material standard testing

- Simulation

- Actual product inspection
  - Microscopy (Optical, SEM)
  - Ultrasonic flaw detection
  - X-ray radiography
  - X-ray CT

Tools for structural failure analysis
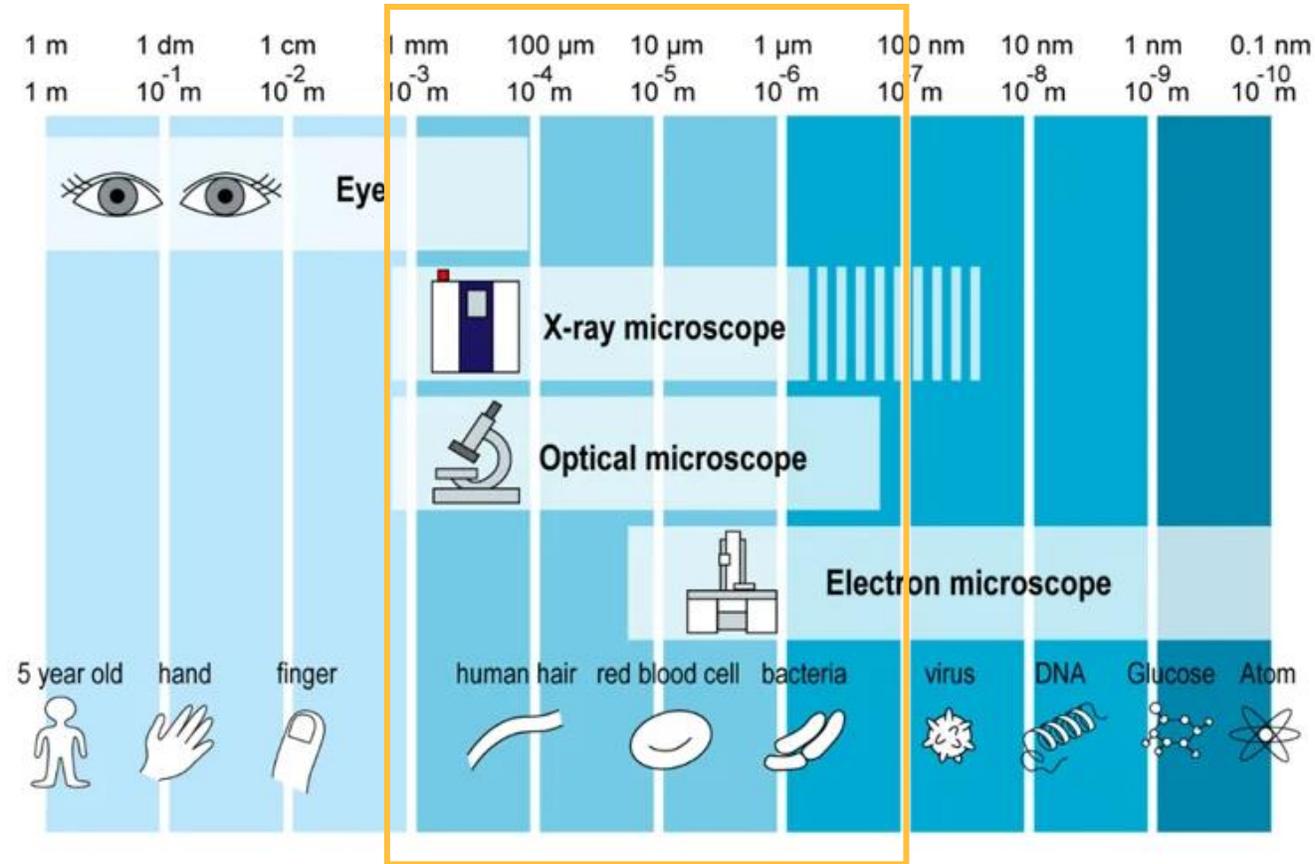
Size range of structural defects

Why choose X-ray CT?
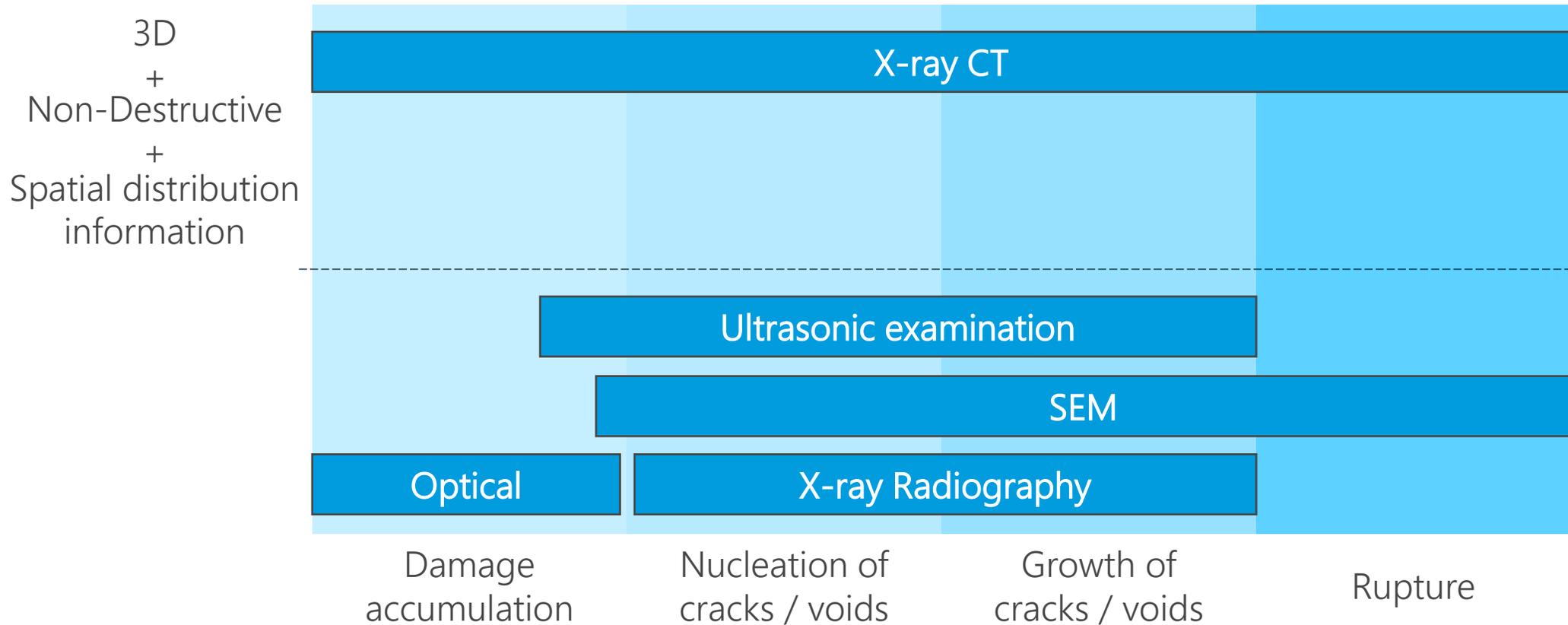
Structural information from X-ray CT
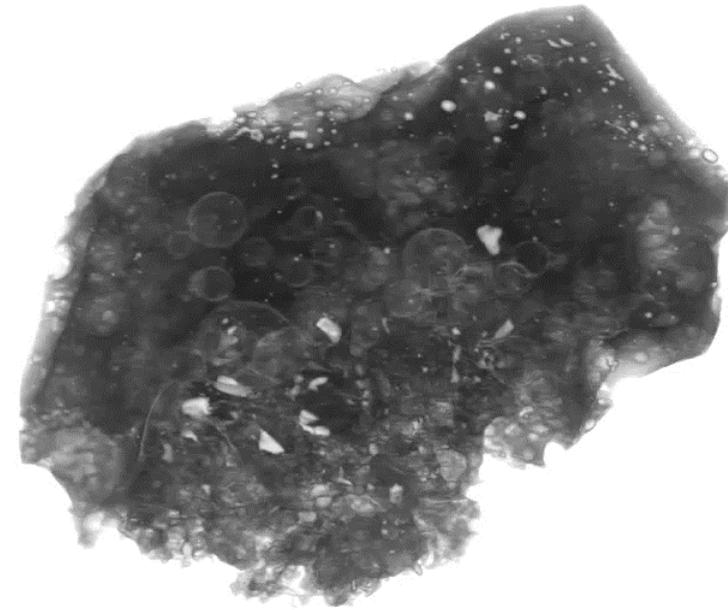
Sea of tranquility

Agglutinate

200μm

100μm

Advanced microstructural and compositional analysis of a lunar agglutinate from the Apollo 11 mission
TJ Huang, E Ganju, H Torbatisarraf, MS Thompson, N Chawla, *Meteoritics & Planetary Science (2024)*

Structural information from X-ray CT

2D CT slice

100 µm

SEM

Al Mg Ca Fe Na
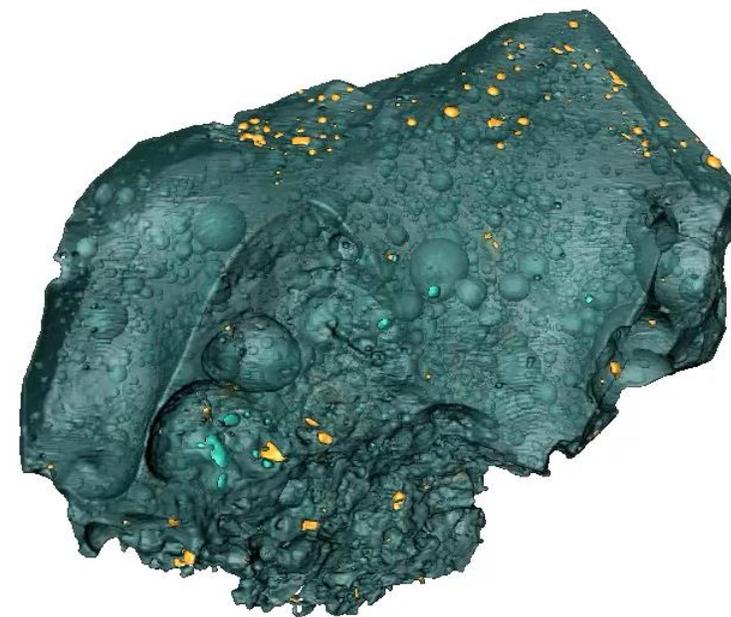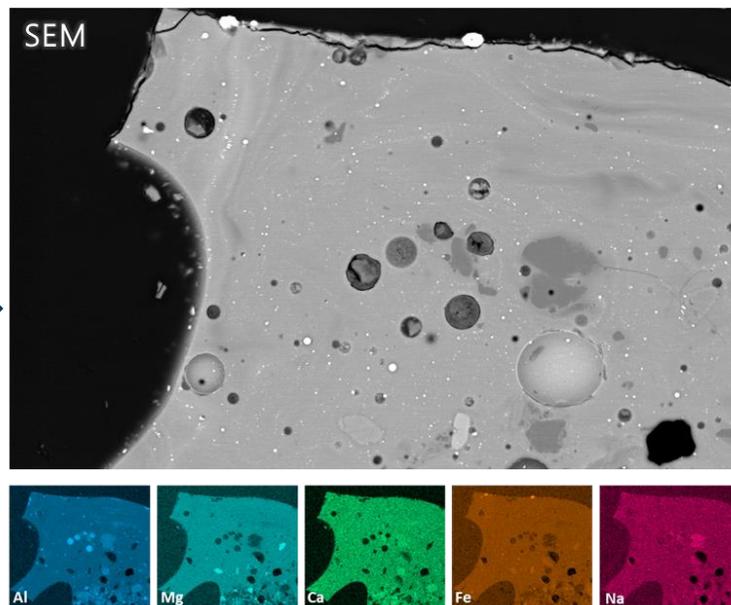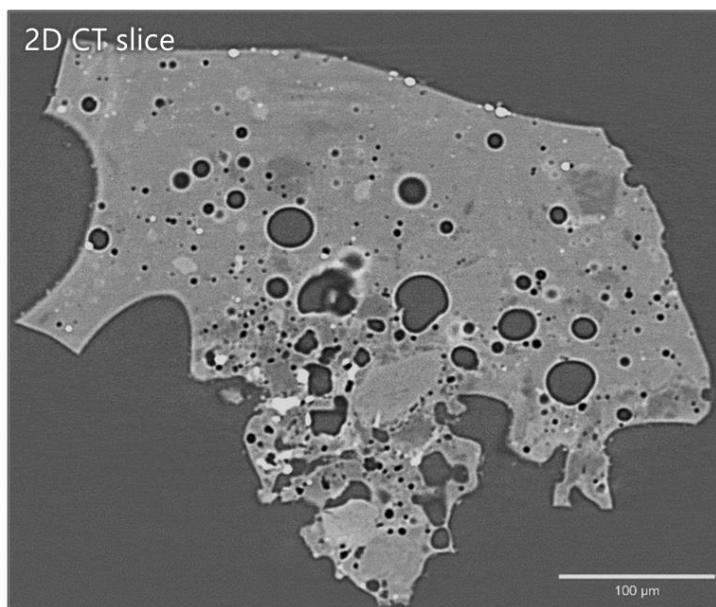
Correlate info from SEM back to 3D CT scan

100µm

Advanced microstructural and compositional analysis of a lunar agglutinate from the Apollo 11 mission
TJ Huang, E Ganju, H Torbatisarraf, MS Thompson, N Chawla, *Meteoritics & Planetary Science (2024)*

Structural failure analysis X-ray CT examples

Analysis example- 3D printed structure

CT Lab HX130

Cone beam X-ray source
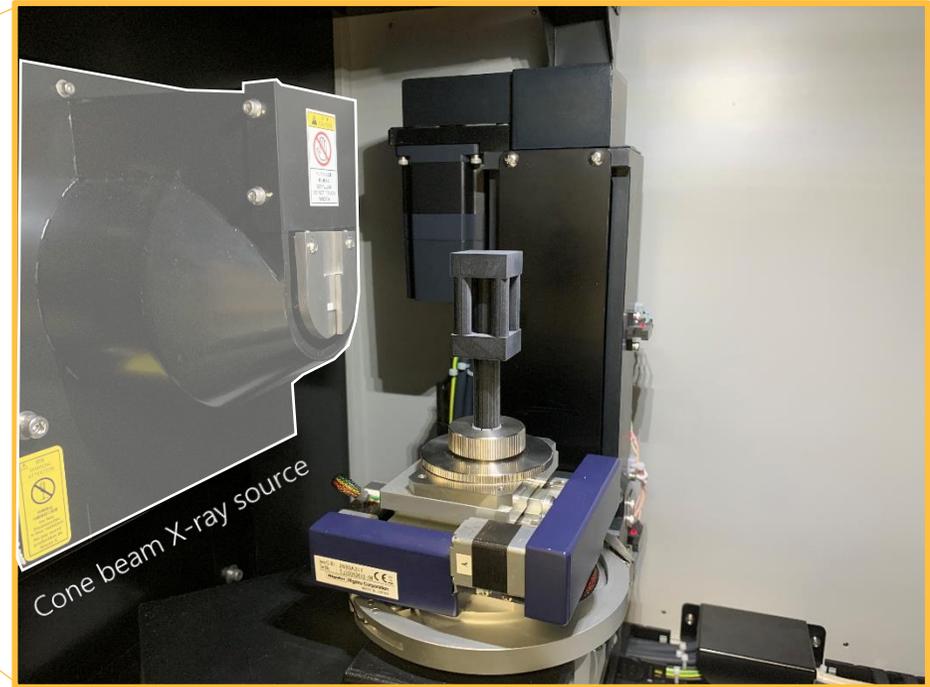
Analysis example- 3D printed structure
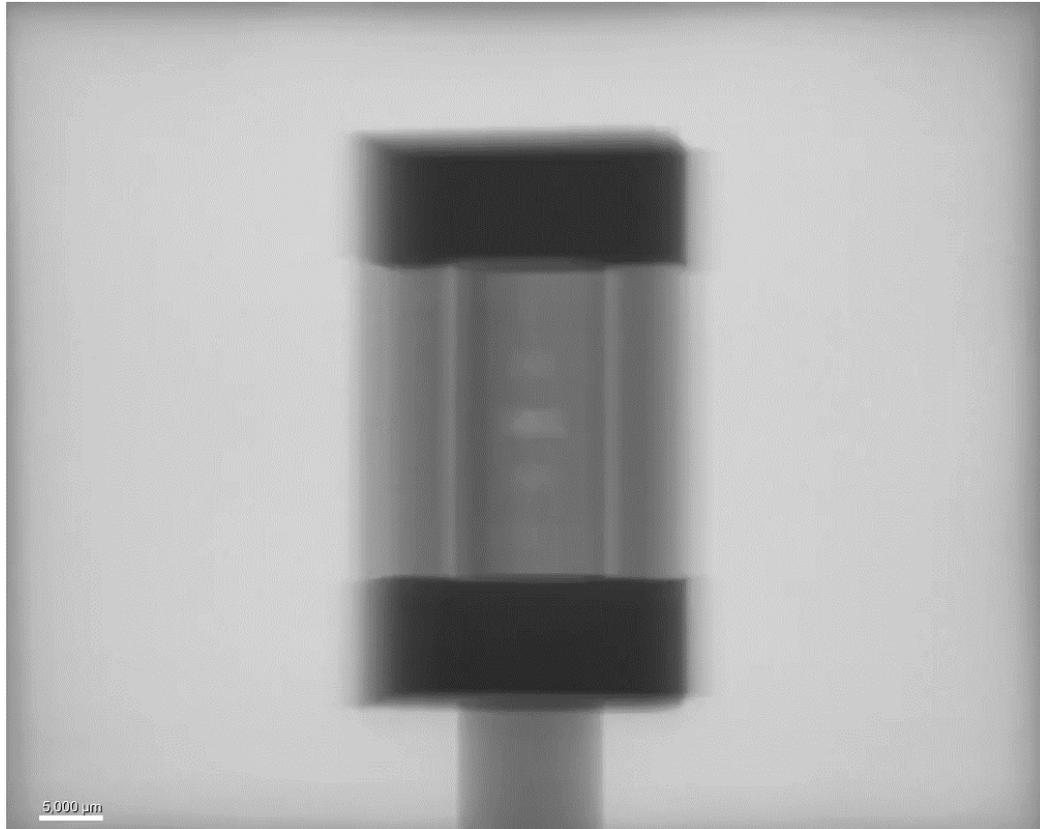
2D Radiograph
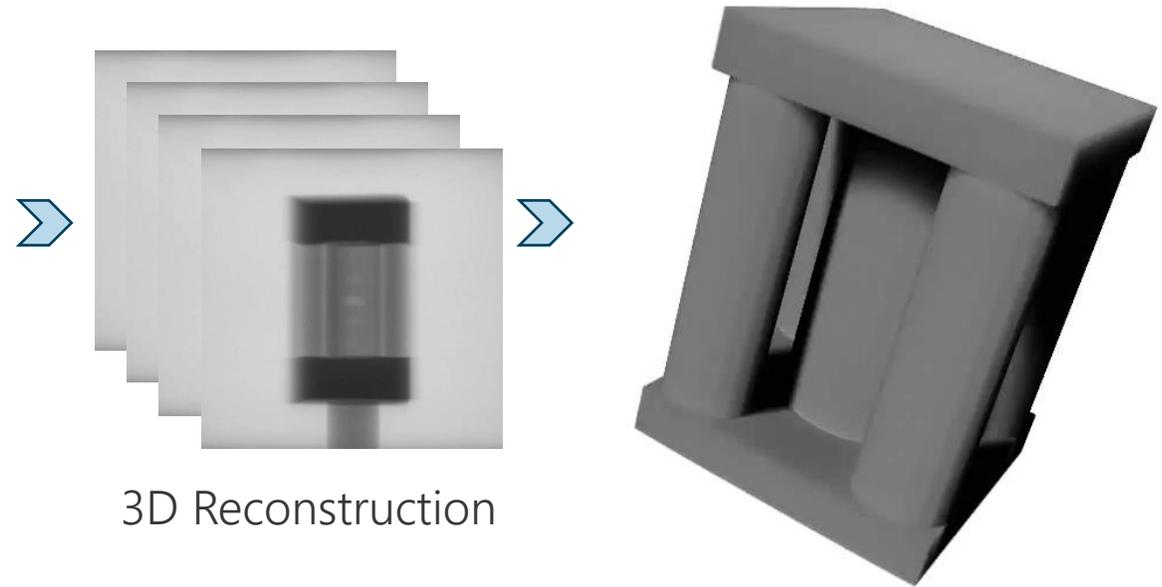
3D Reconstruction

Analysis example- 3D printed structure

2,500 µm

Wax
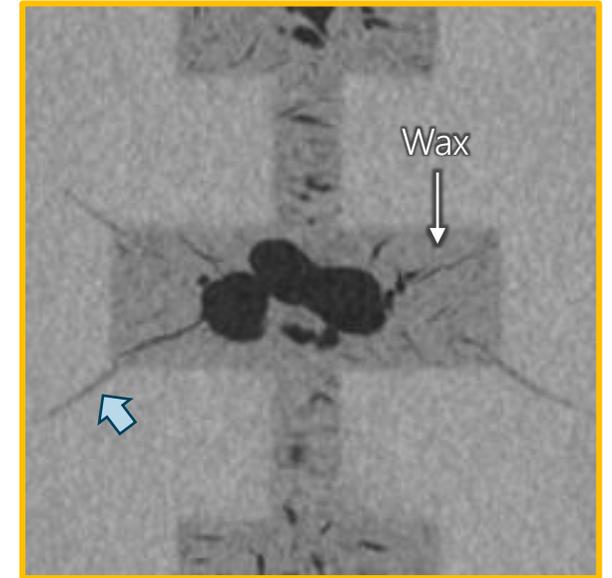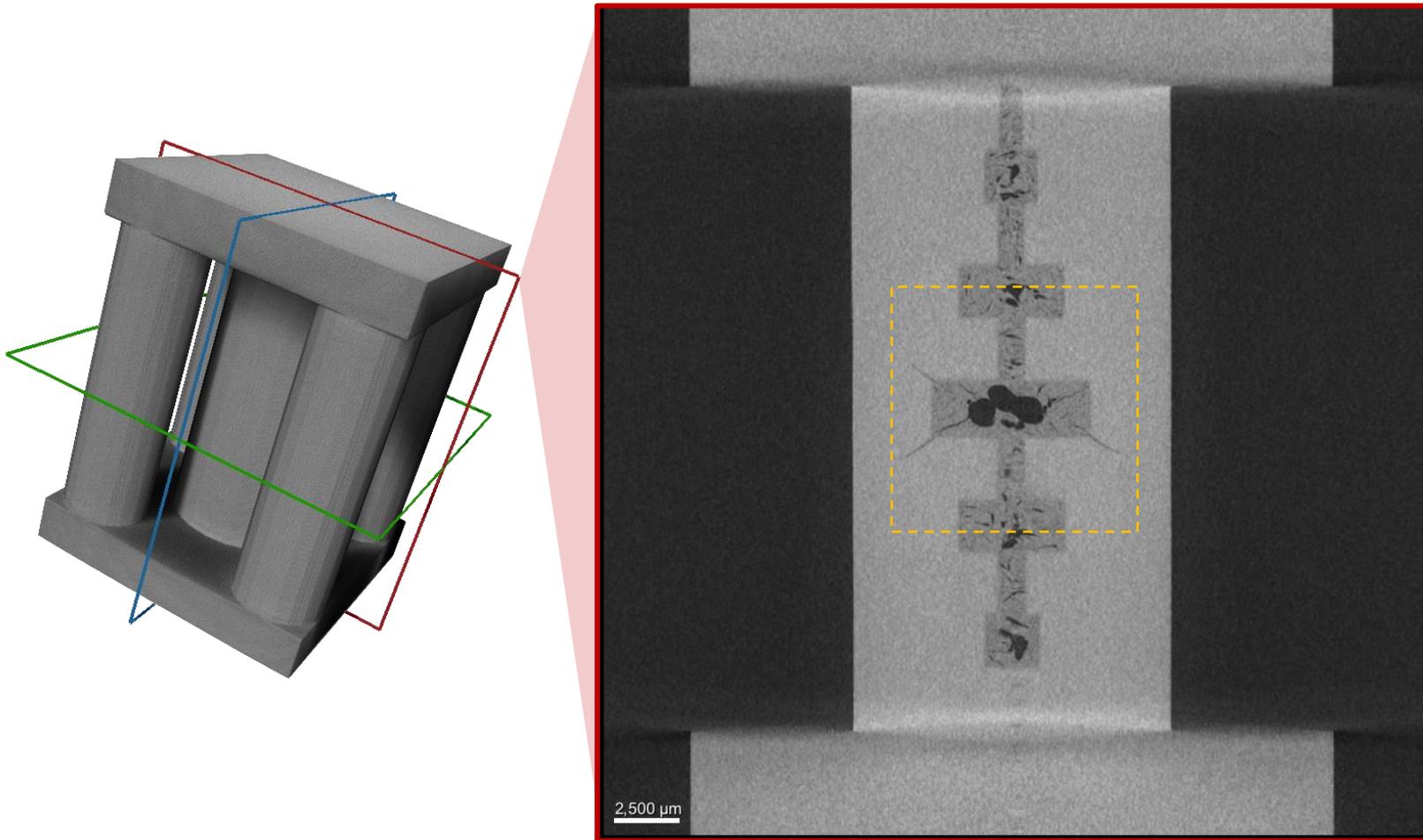
Crack growth into printed material

Analysis example- 3D Printed Structure

- 3D visualization
- Quantification

Grayscale histogram
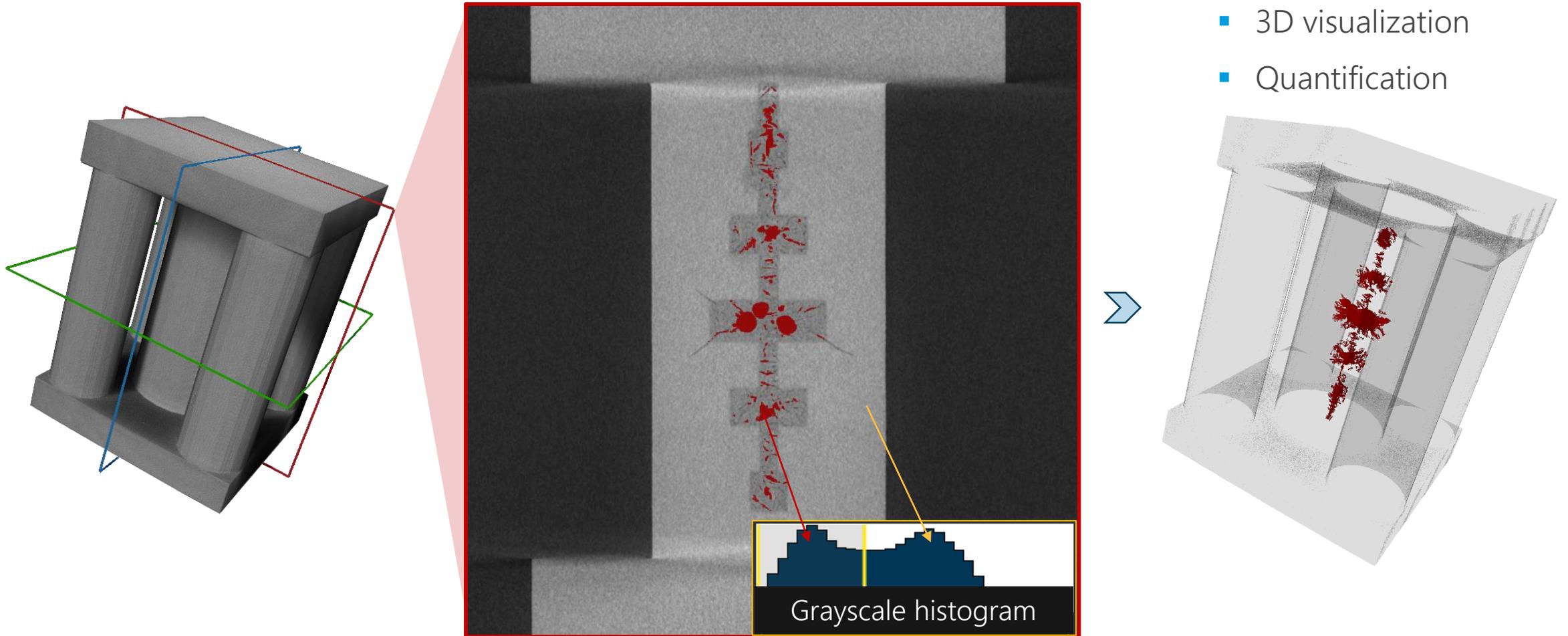
Analysis example- 3D printed structure
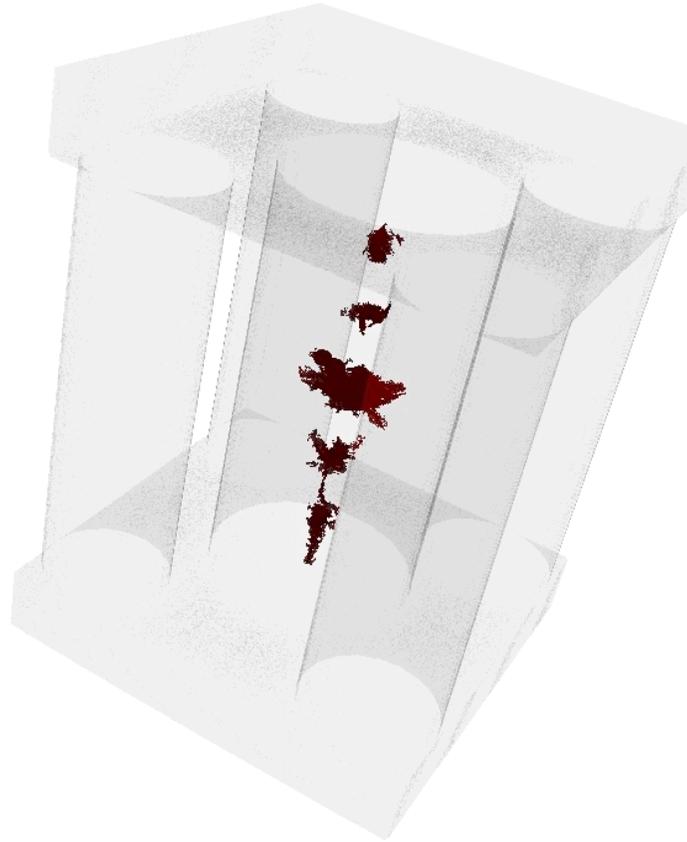
$$\sigma_{max} = \sigma \left(1 + 2 \frac{a}{b} \right)$$

Griffith model

$$\frac{a}{b}$$

Aspect Ratio

Larger voids

Small pores

Inversed Aspect Ratio

0.59
0.52
0.46
0.39
0.32
0.26
0.19
0.12
0.06

Analysis example- 3D printed structure

Nominal model: Deviation [mm]
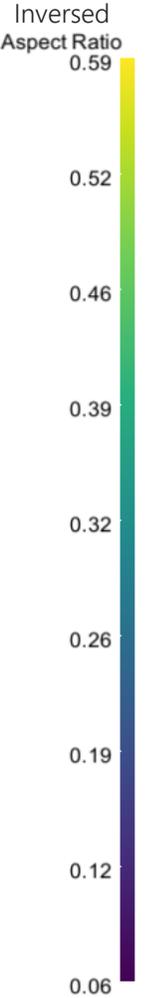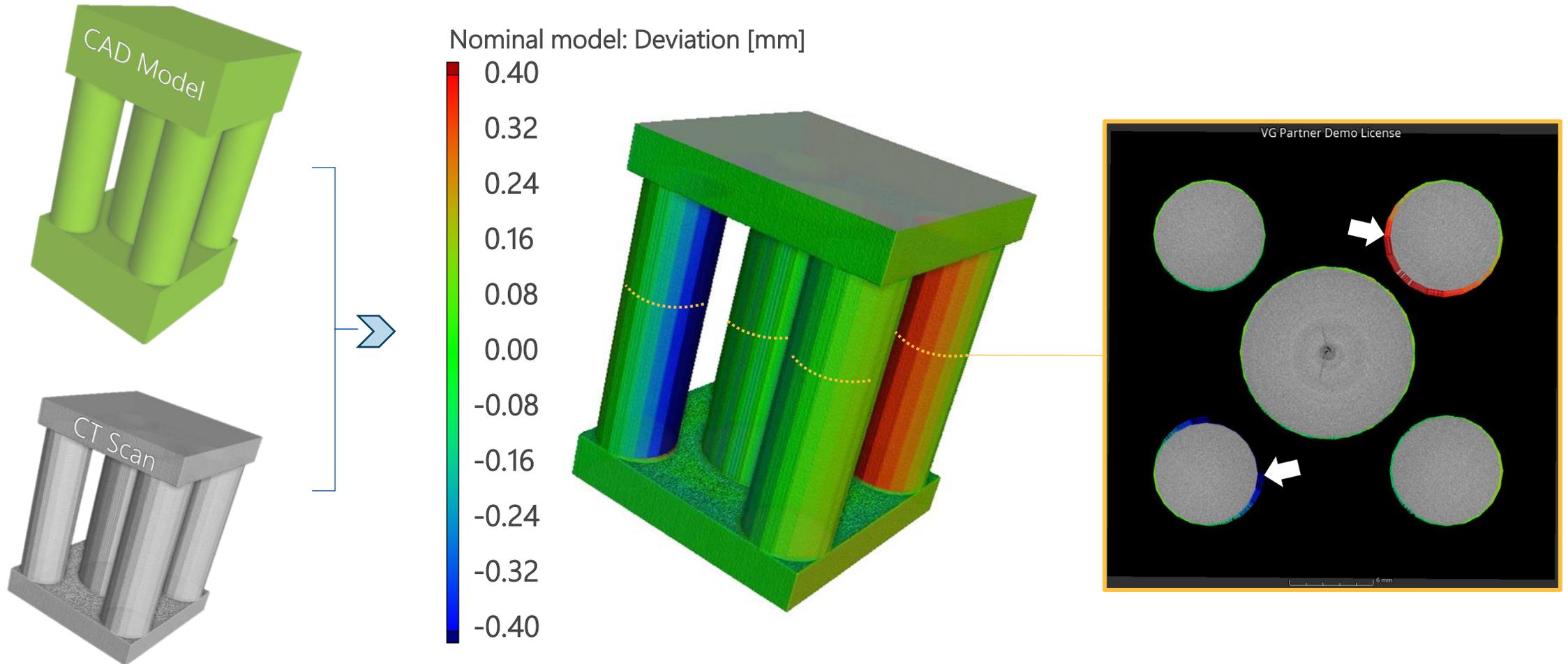
Analysis example- CFRP
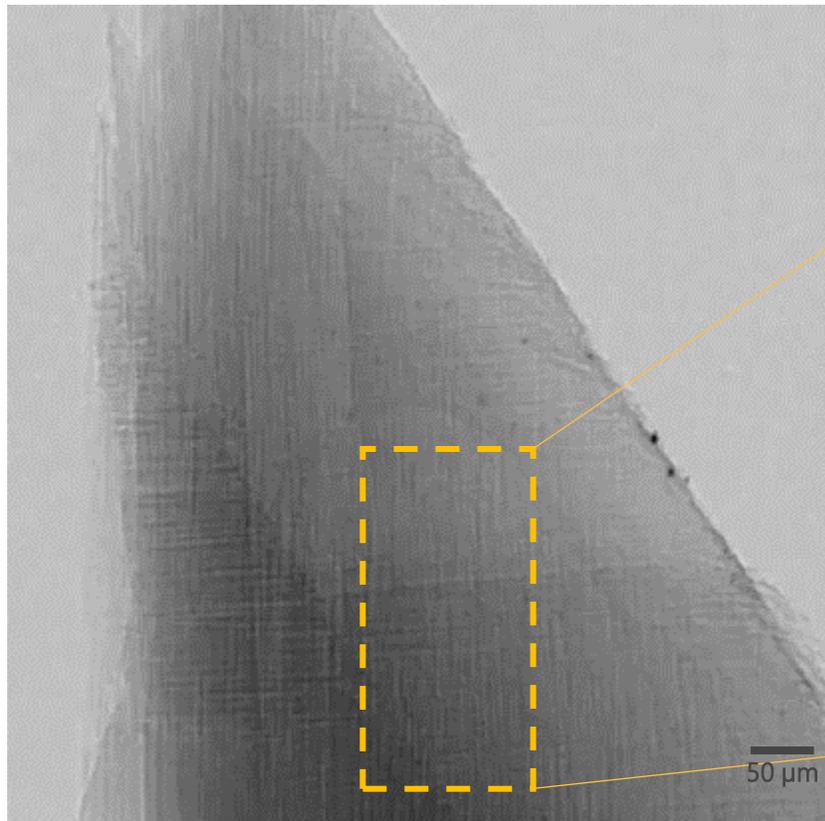
2D Radiograph
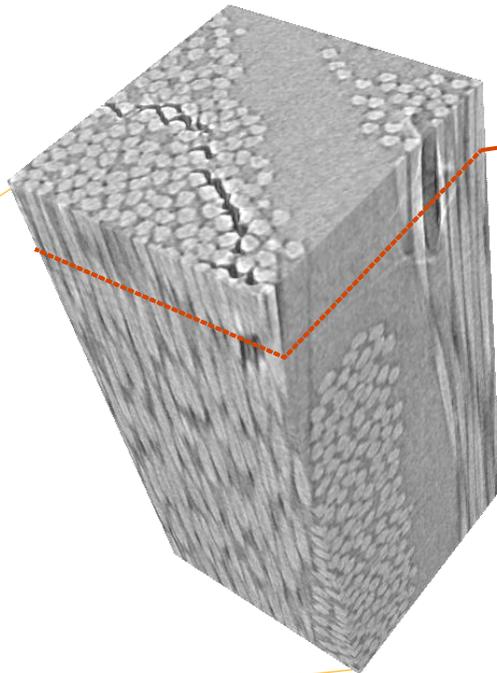
3D Scan
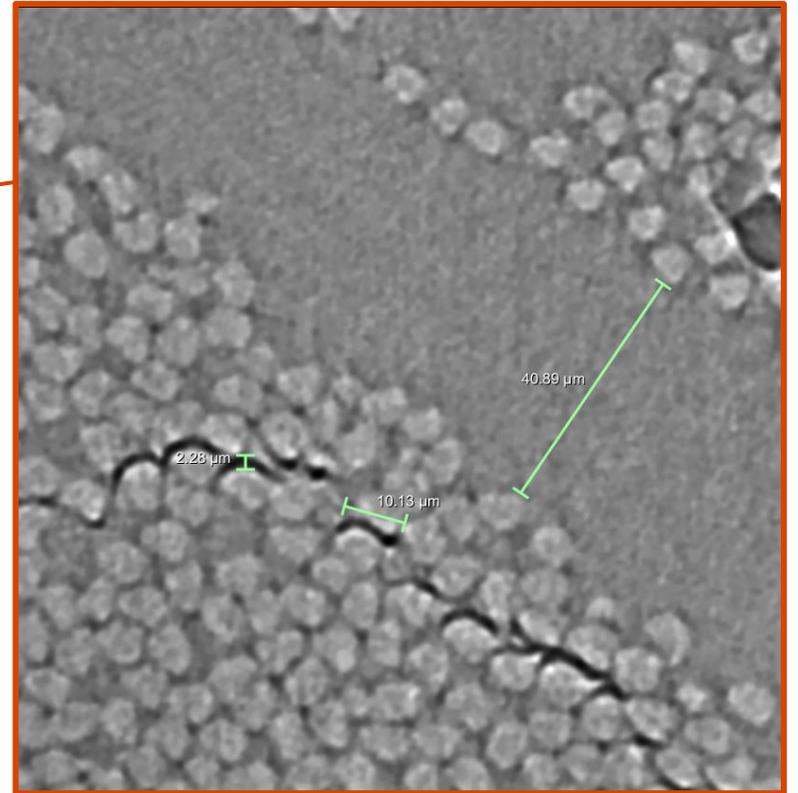
2D Cross section

Analysis example- CFRP

Training data input

Classes and labels			
Name	Count	Label
Polymer	81,247	1
Fiber	71,587	2
Crack	962	3
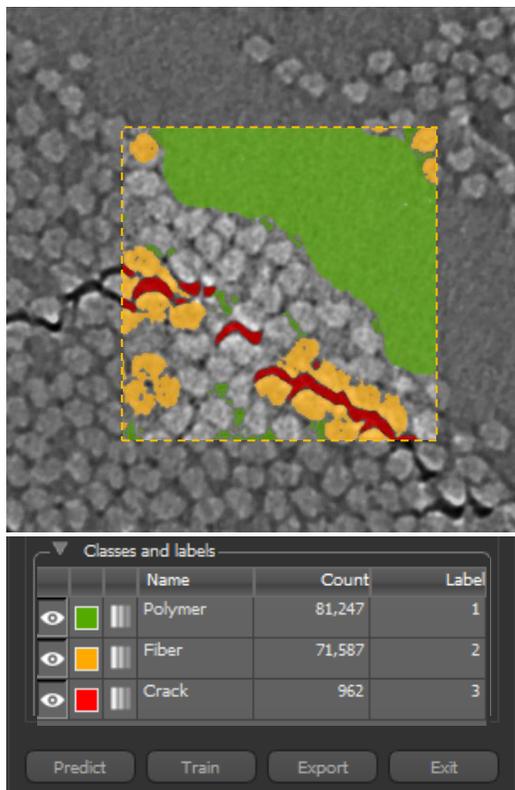
Predict   Train   Export   Exit
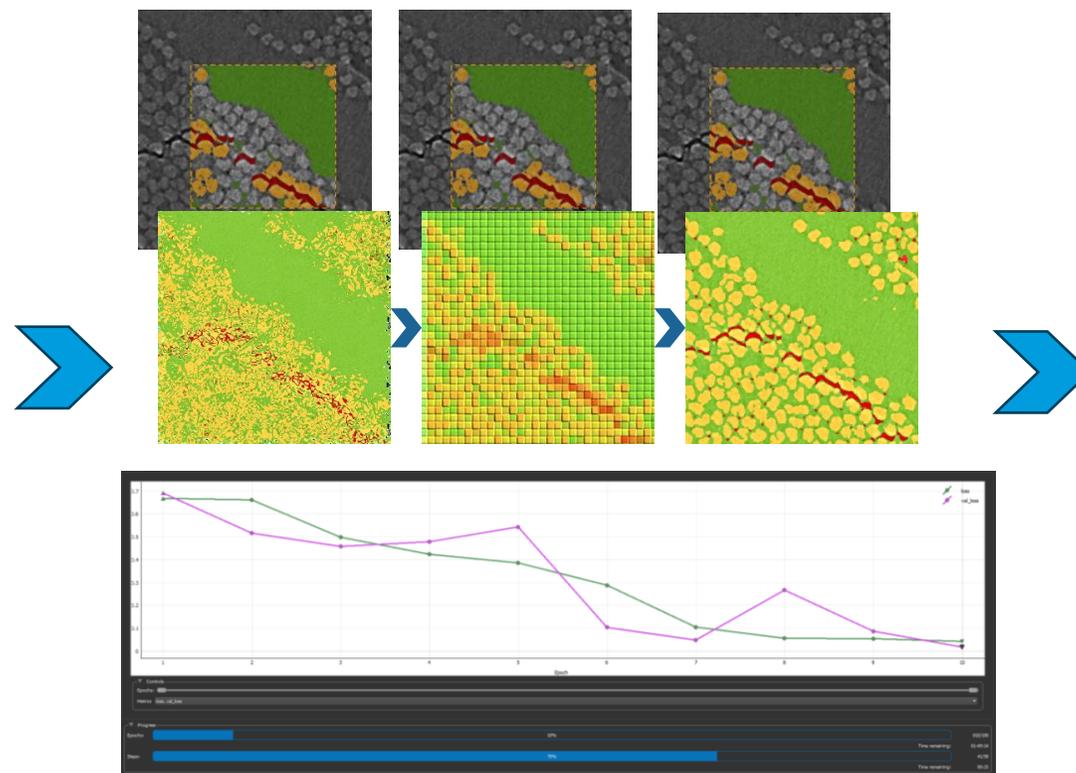
Deep learning
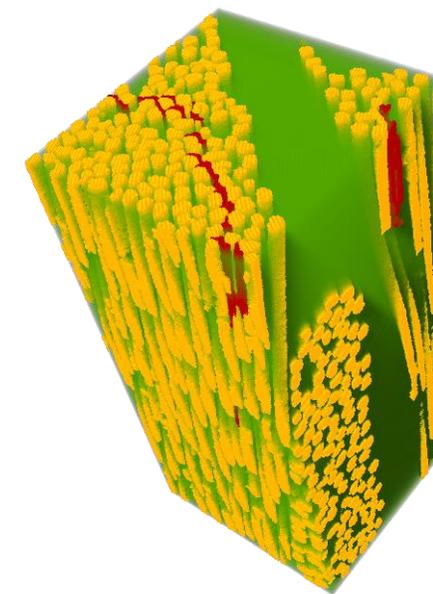
3D segmented Data

Analysis example- CFRP

$$\sigma_{max} = \sigma\left(1 + 2\frac{a}{b}\right)$$

Griffith model

Cracks

Polymer

Fibers

Fiber - Volume (µm³)
10000.00
8812.50
7625.00
6437.50
5250.00
4062.50
2875.00
1687.50
500.00
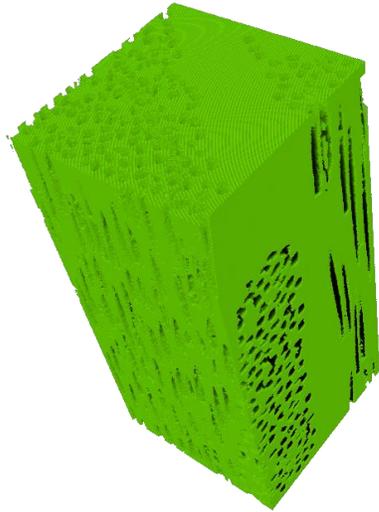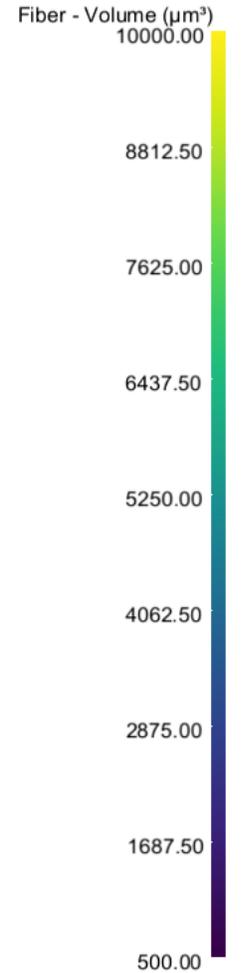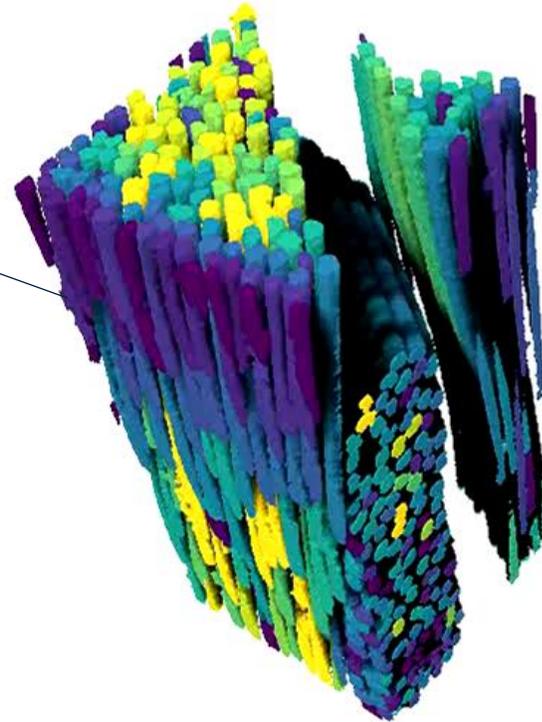
Analysis example- Super alloy 3D print
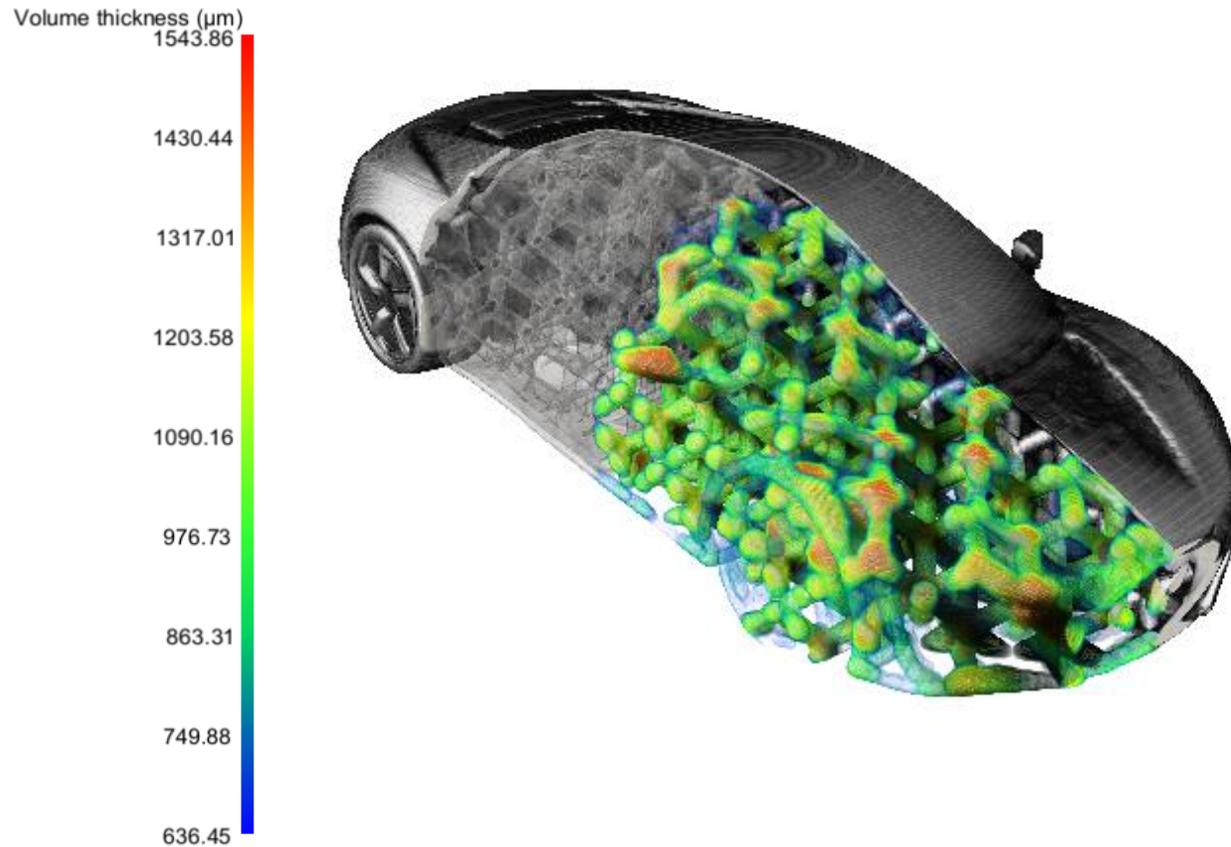
- Simulation
- Load distribution

Analysis example- Super alloy 3D print

Max. principal stress [MPa]

Top loading force

High tension areas
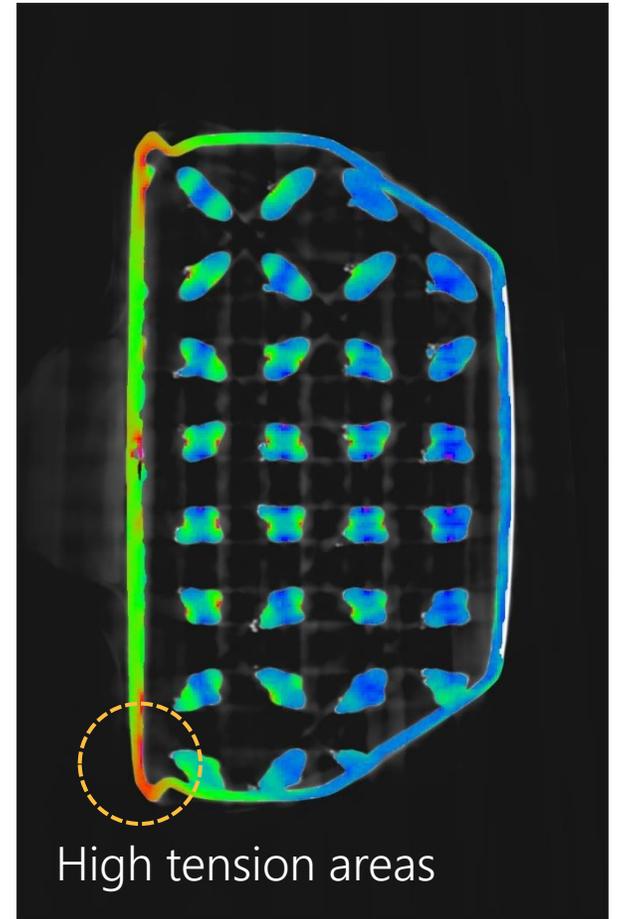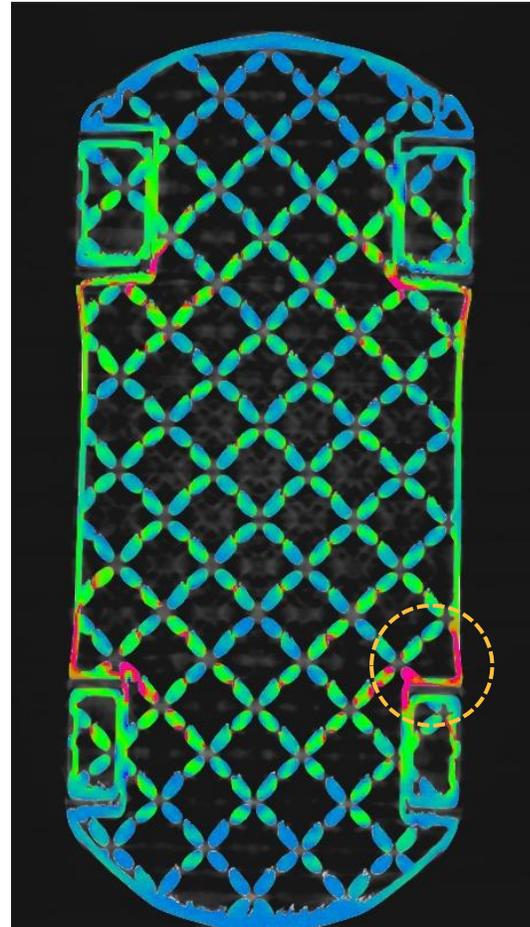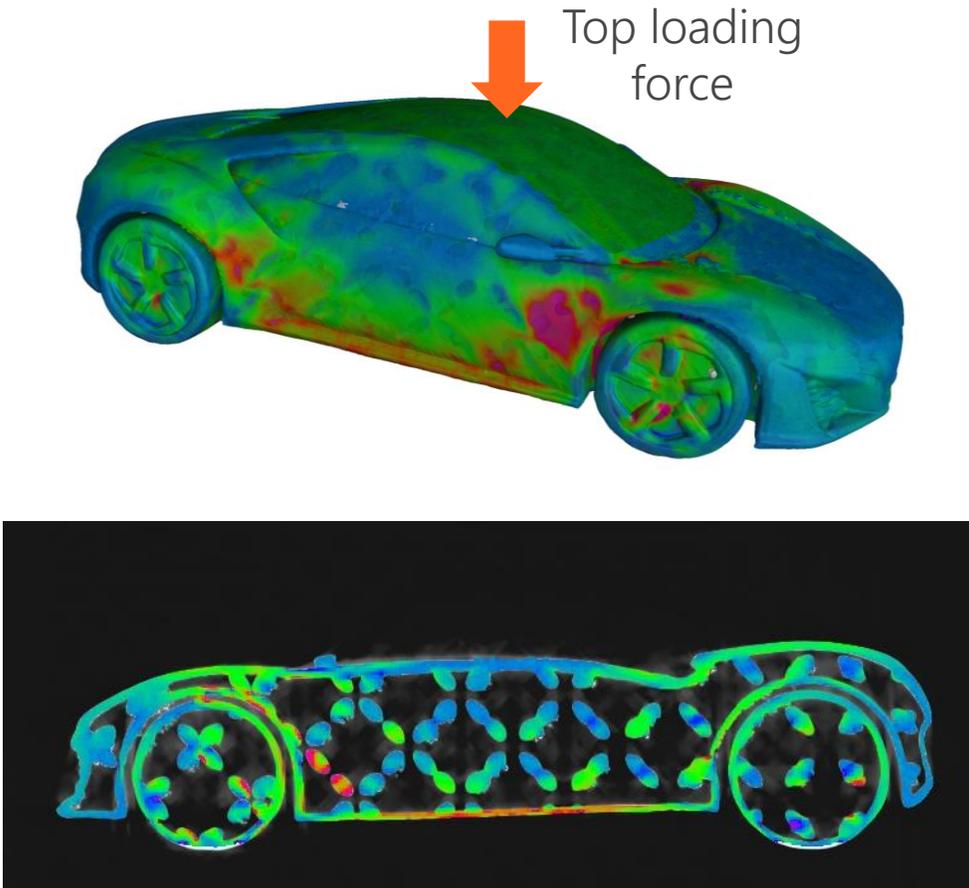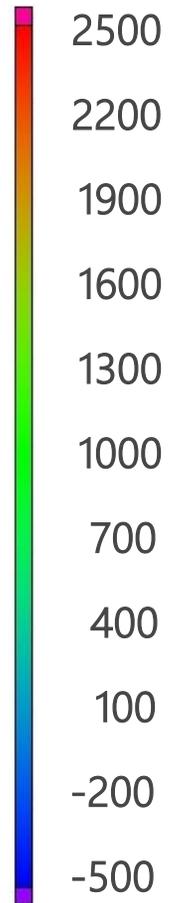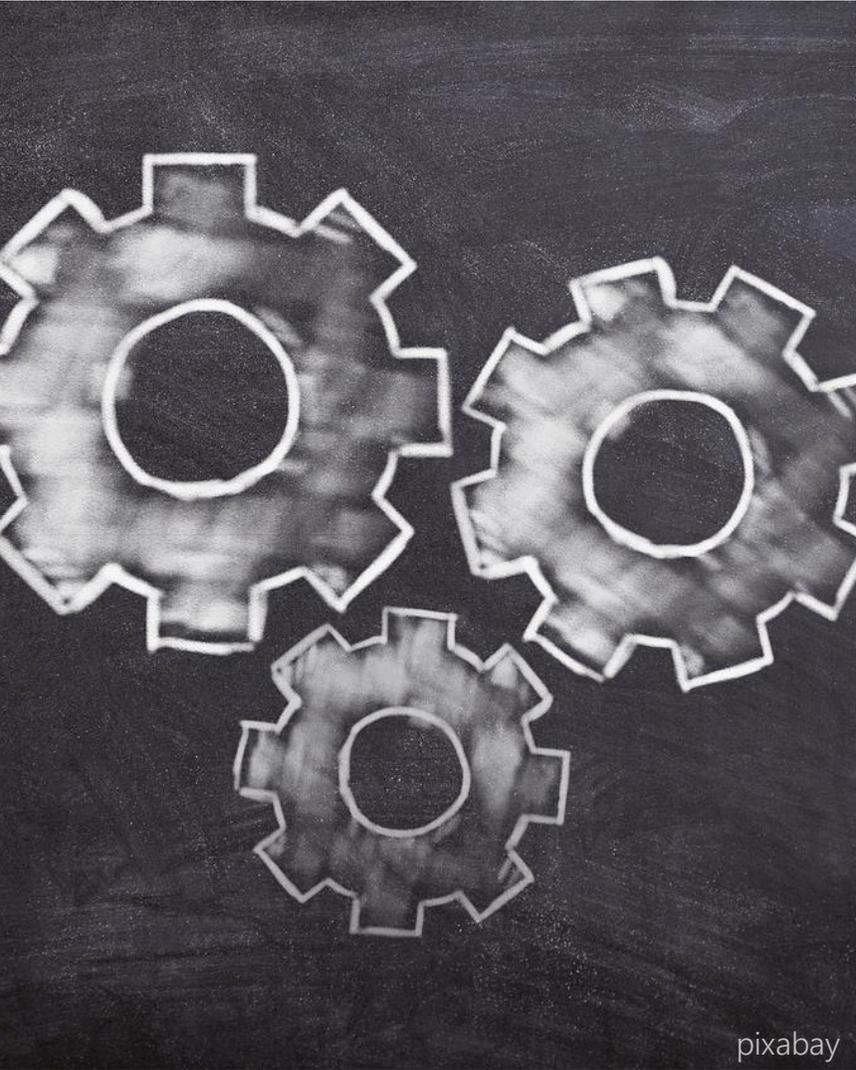
You have learned

- What is structural failure

- What leads to structural failure

- What are signs of potential failure

- How X-ray CT helps you navigate

pixabay

Q & A Session

Functional Failure Analysis

Wed., June 9, 10 am CDT

Presenter: Angela Criswell | **Co-presenter:** Ted Huang | **Host:** Viral Vaghela

- *Registration page link in the chat*