SAND2016-9956C

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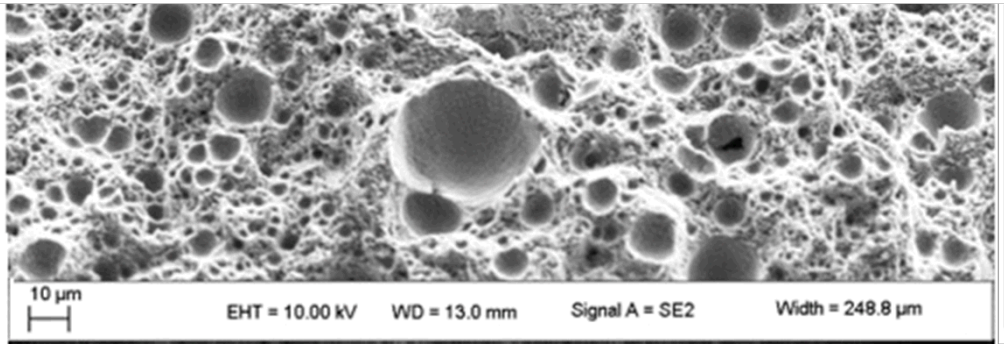

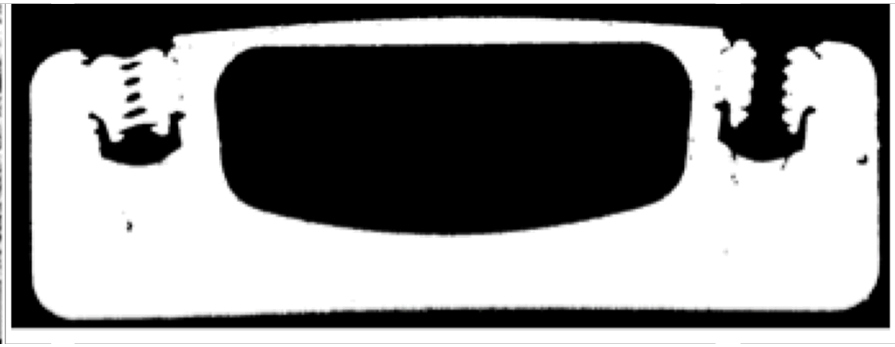

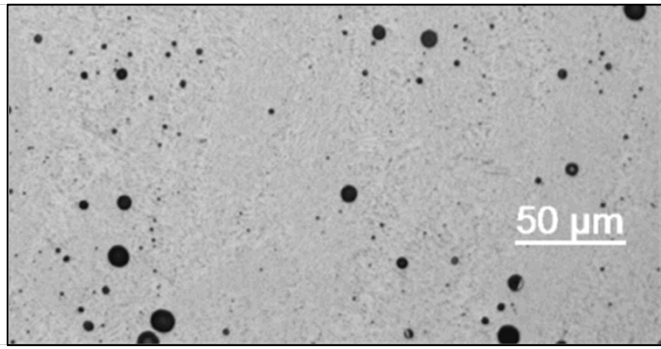

Identification of critical defects in powder bed additively manufactured metals

Lisa Deibler, Jay Carroll, Jeff Rodelas

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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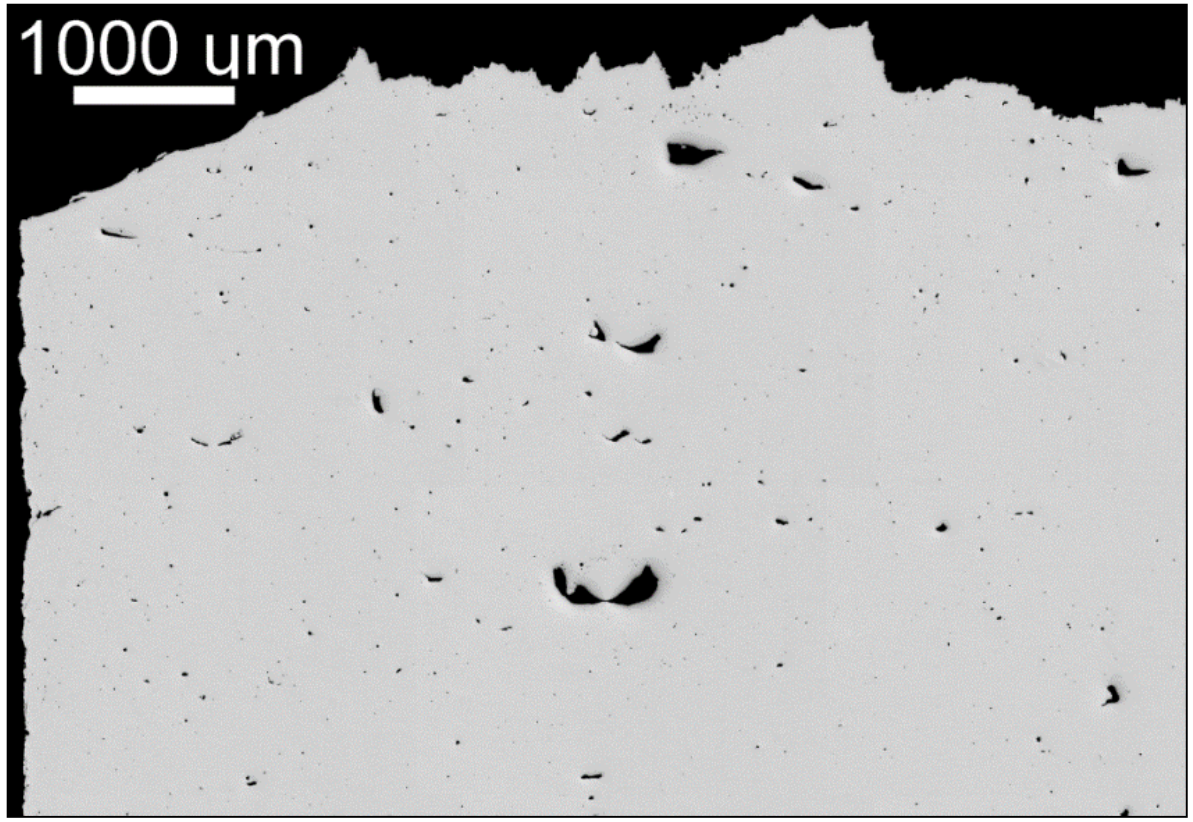
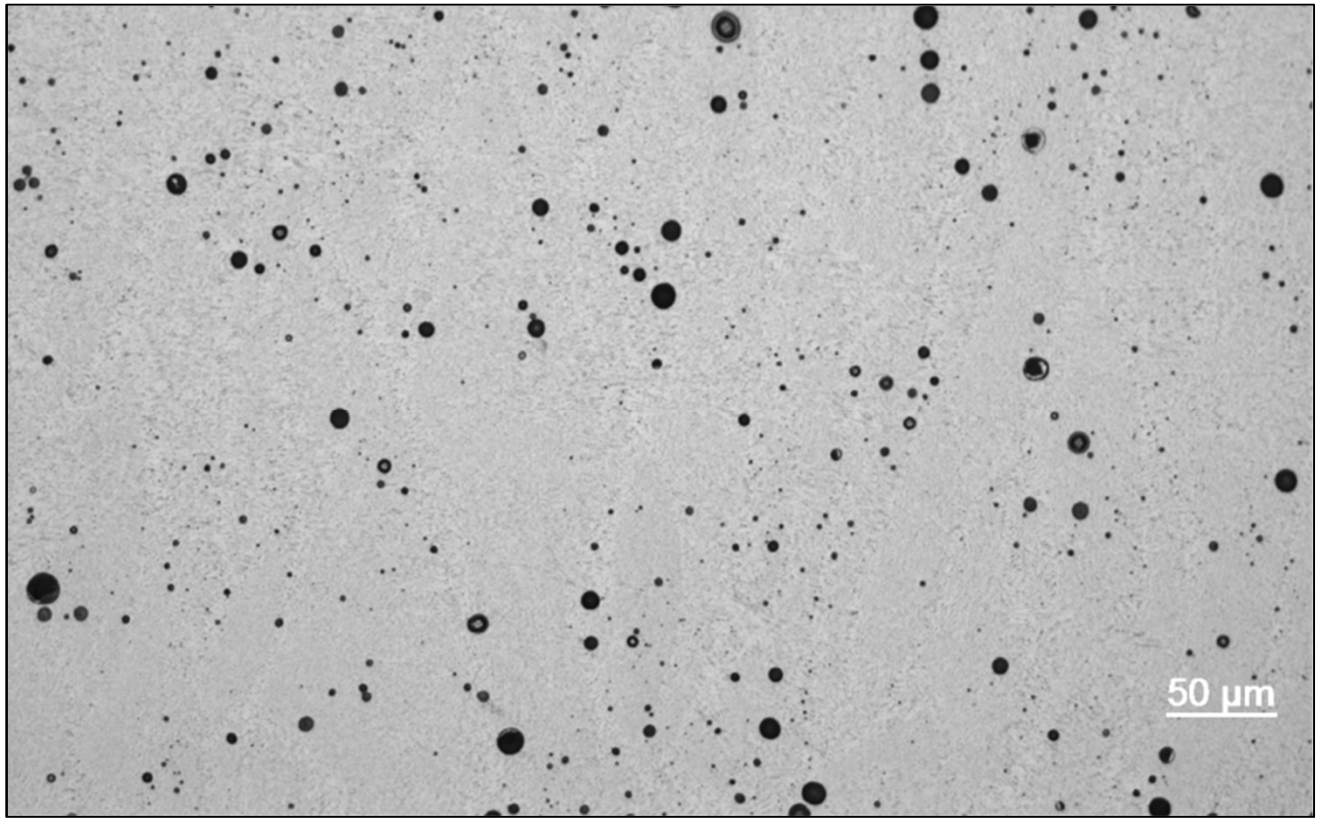
Background

- We find two types of voids in these parts: Lack of fusion and gas porosity

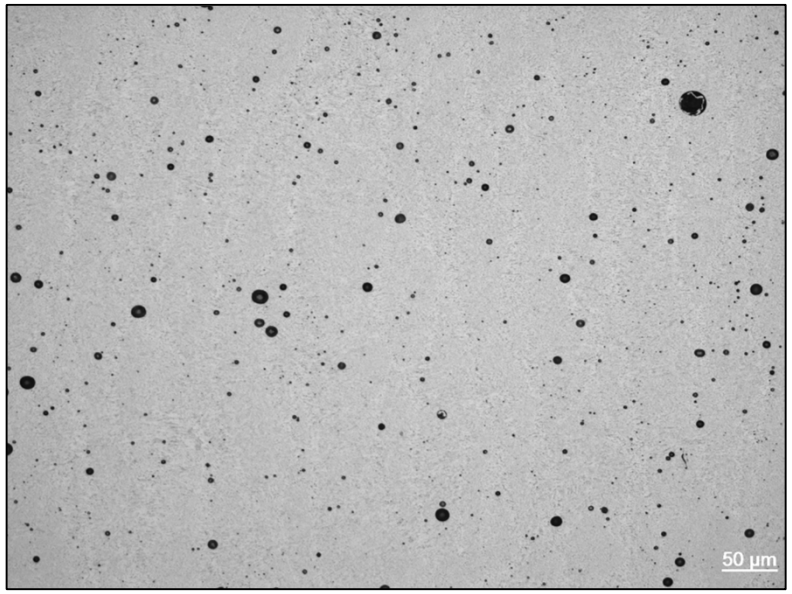


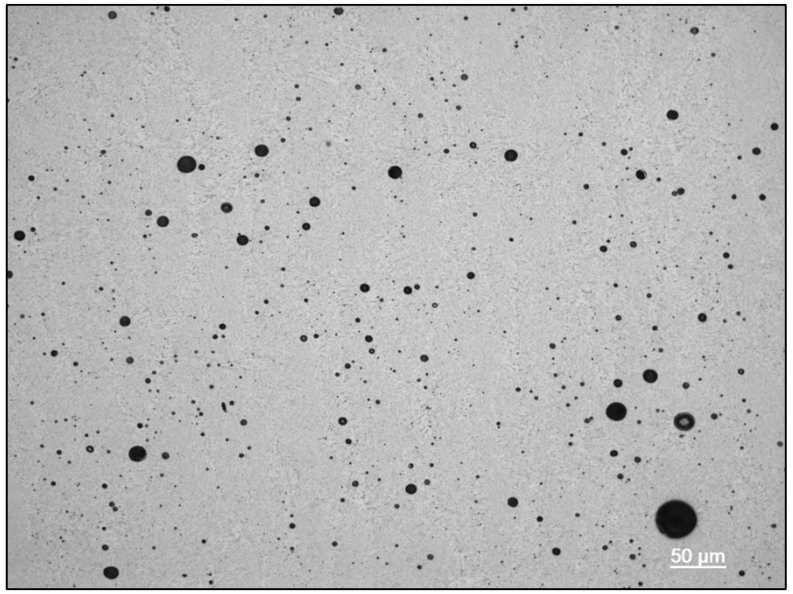


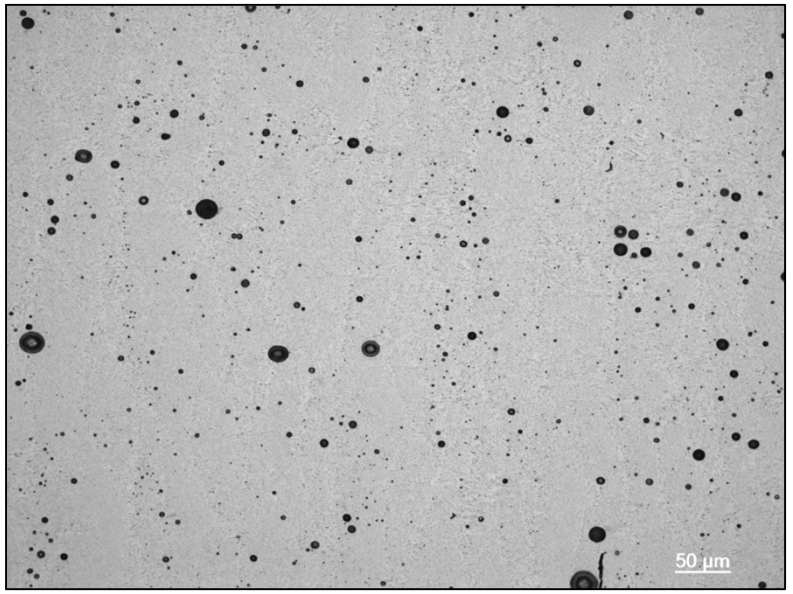
- Porosity in Al10SiMg AM parts has a big effect on mechanical properties.

Metallographic porosity characterization

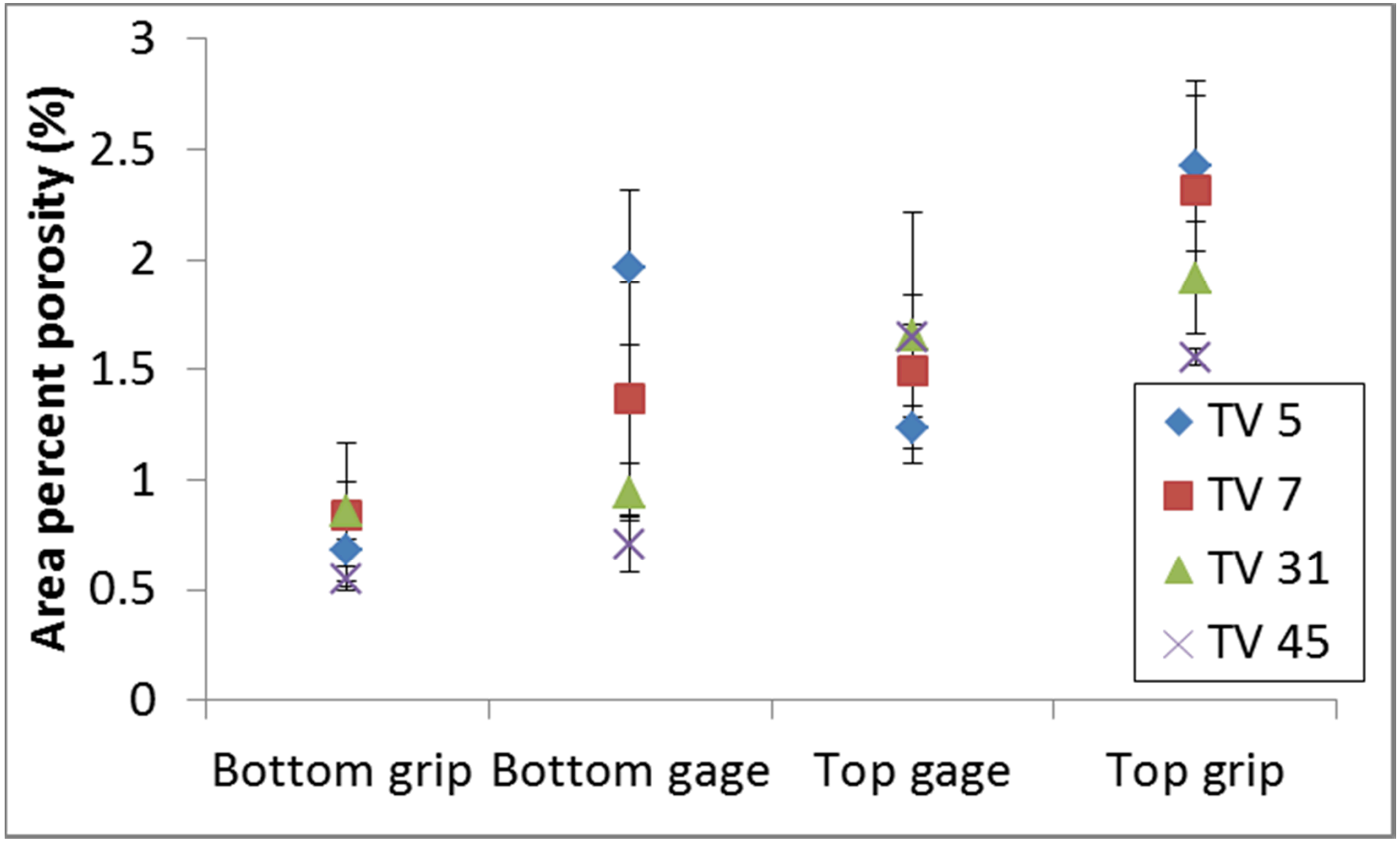
- Technique requirements
  - Sample prep
  - Image selection – random, statistically significant
  - Unbiased image analysis
  - Pore size is complicated. Area percent is easier







Metallographic porosity results



X-ray microcomputed tomography characterization

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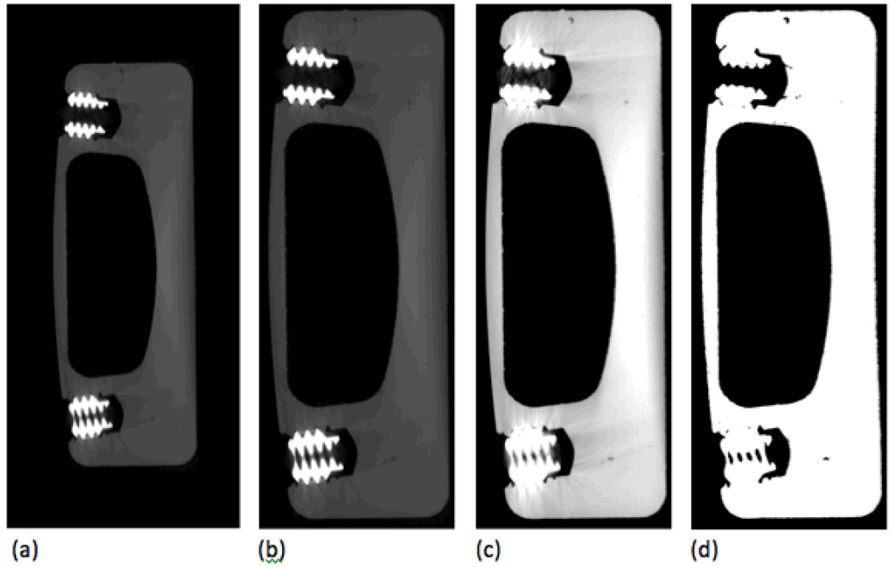
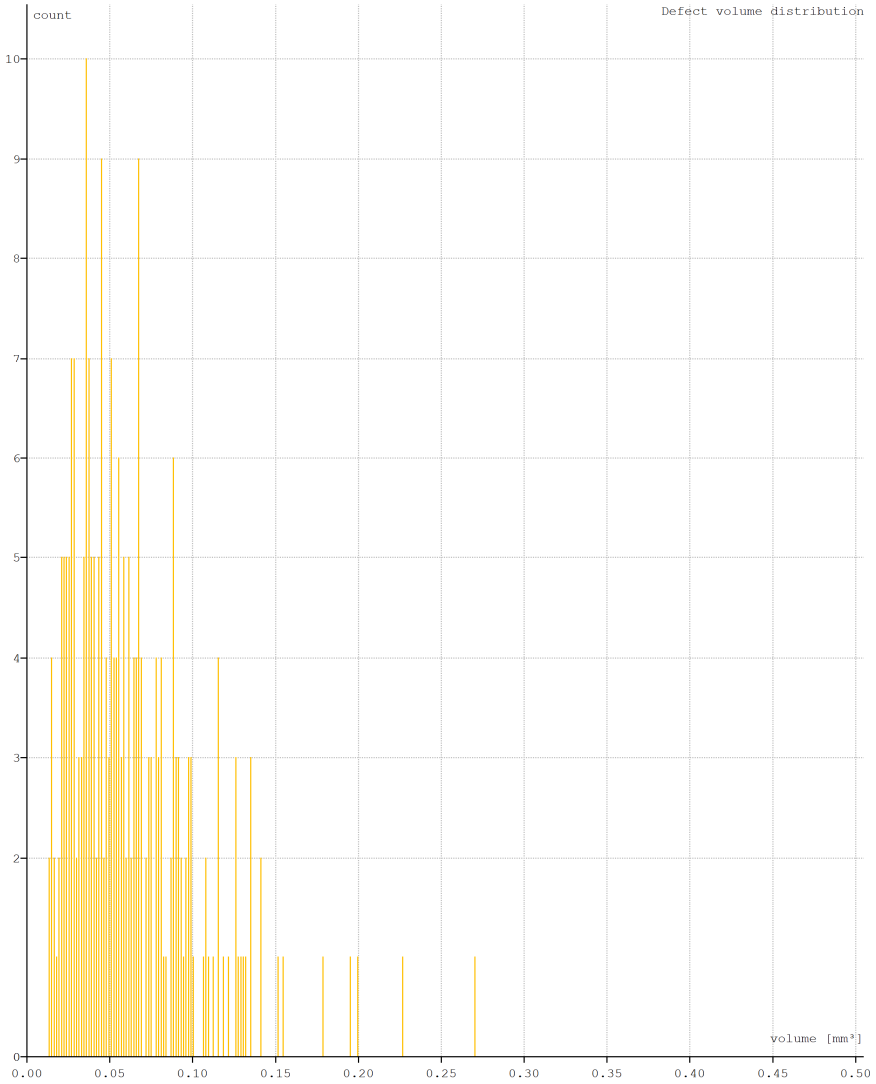
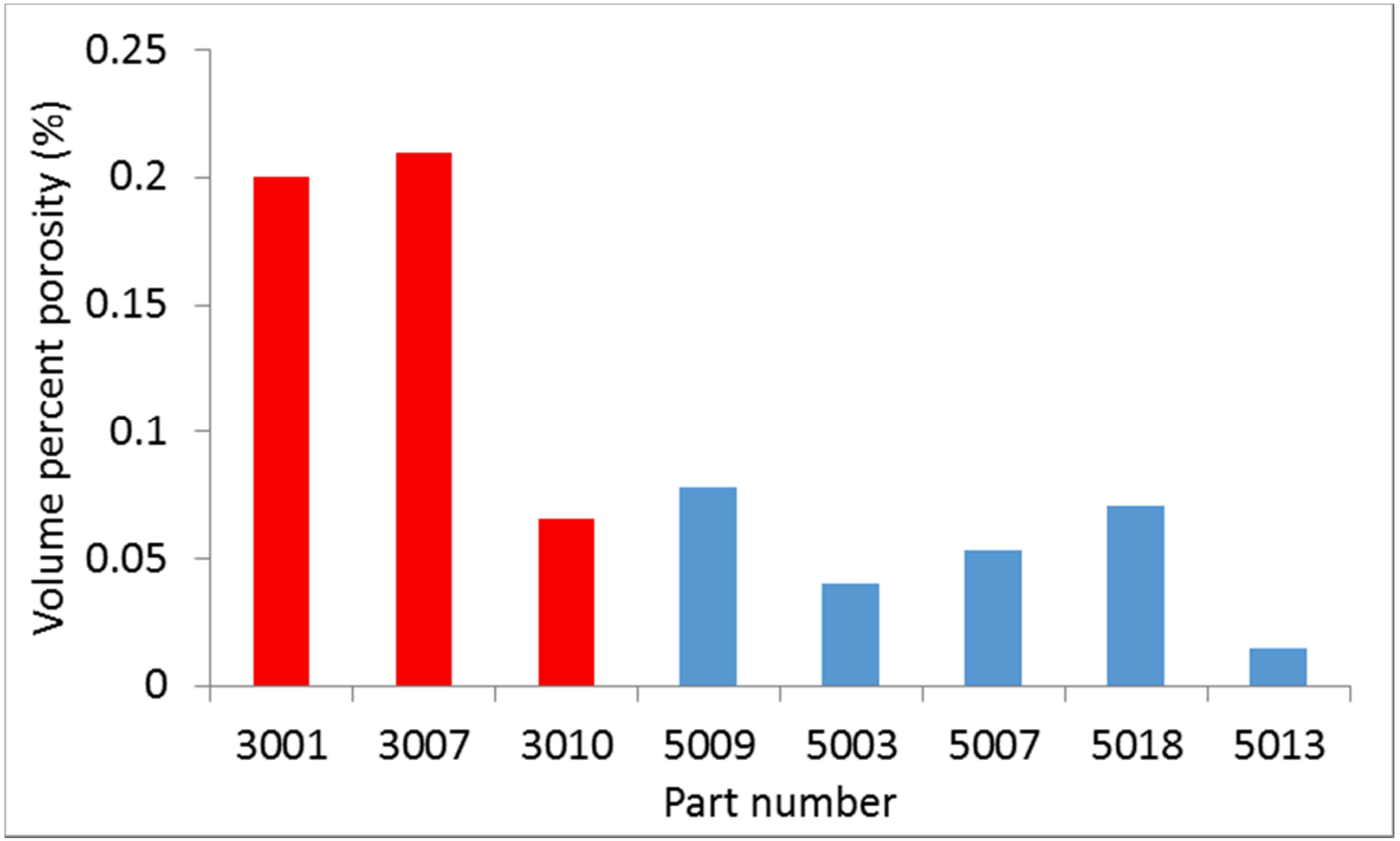
- Technique requirements
  - Amenable sample – X-rays have to be able to penetrate
    - Lack of artifact causing other materials/geometry.
  - Results can be difficult to interpret/quantify
  - Resolution can be an issue, and there's a resolution/speed tradeoff.



North Star Imaging, Inc. X50 XViewCT Cabinet System
YXLON Demountable Microfocus Tube (10-225kV)

X-ray µCT data

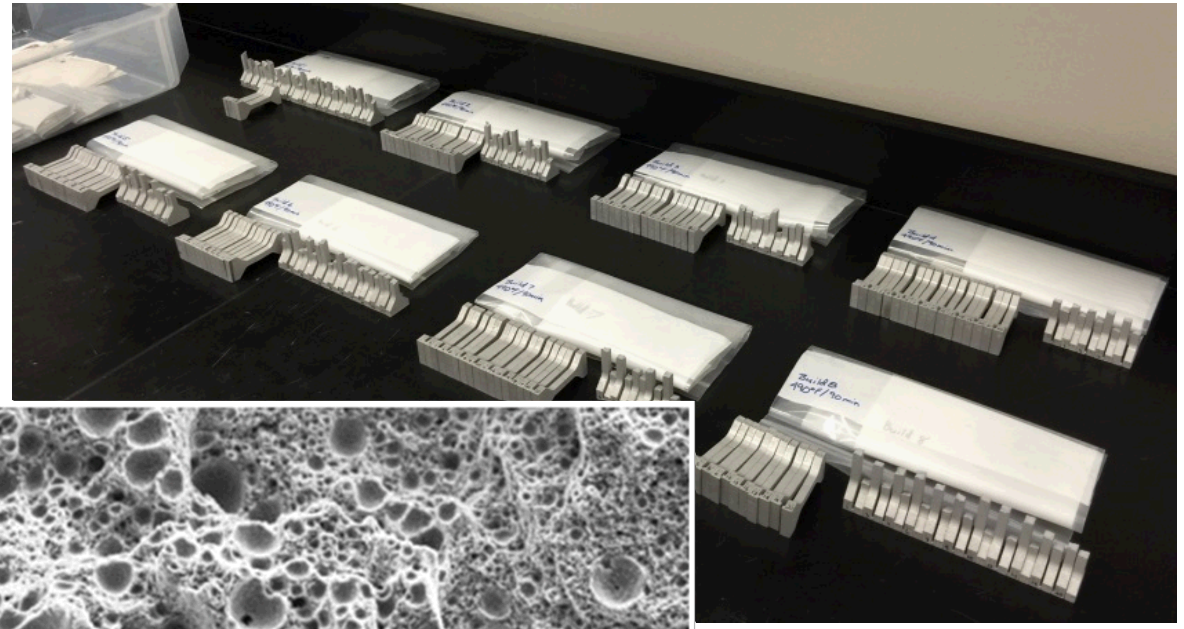


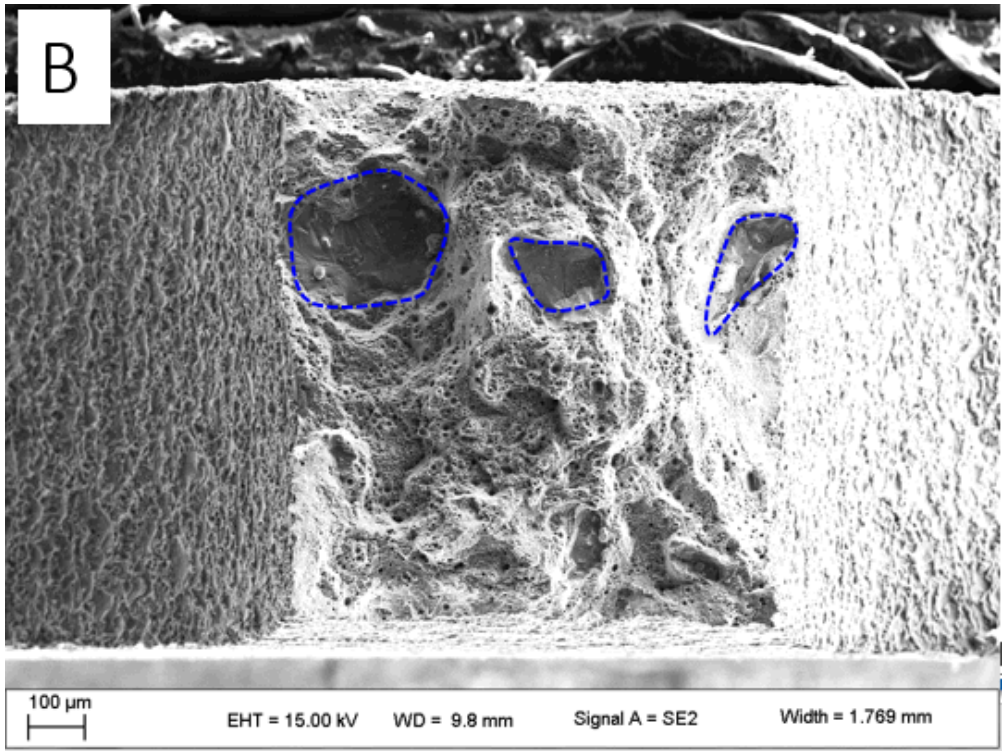


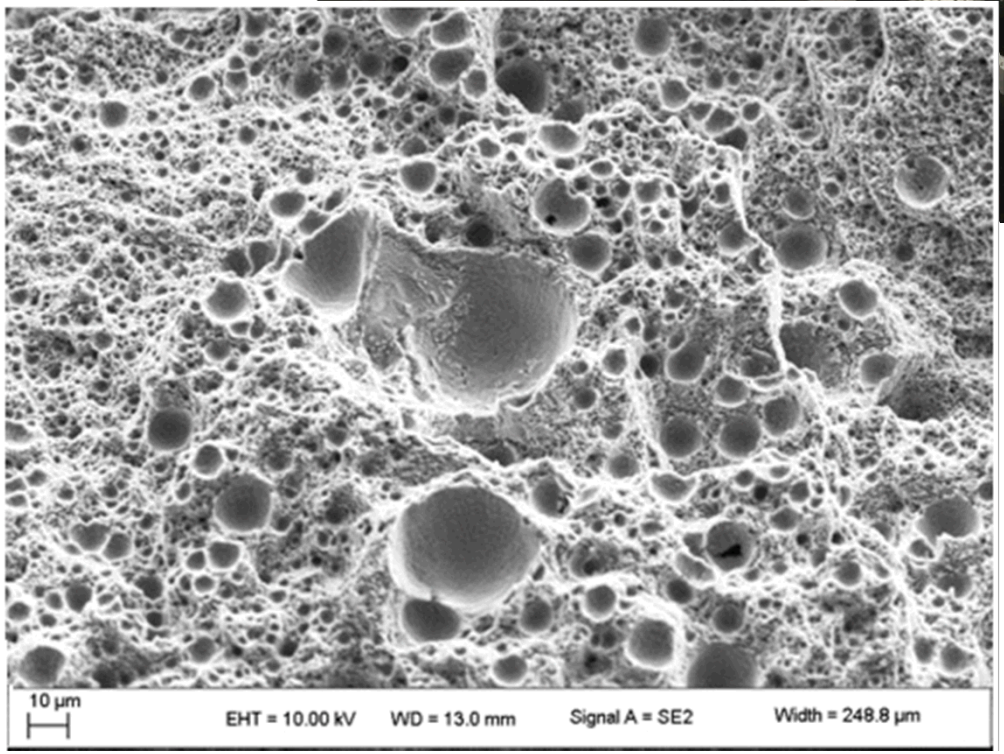
Stuart Lloyd-Smith (NSC), Jonathon Madison

Fracture surface characterization

- Technique requirements
  - Fractured sample
  - High magnification image of fracture surface
  - Magnification effect on data
  - Human/manual selection of porosity

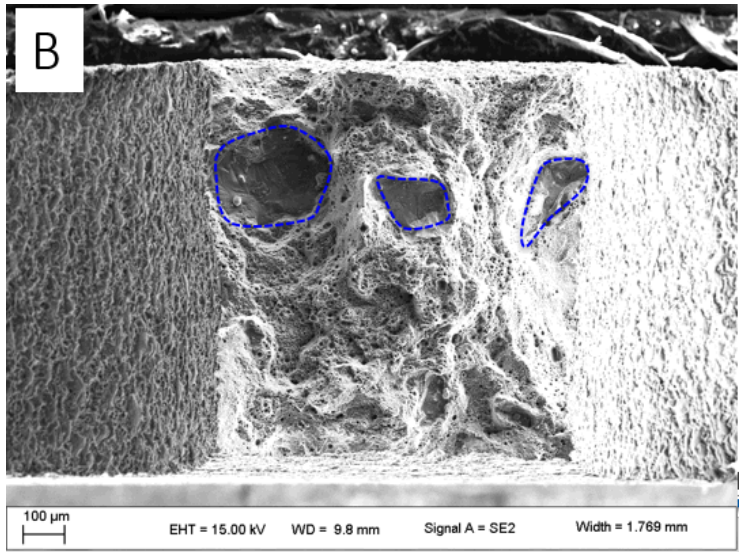


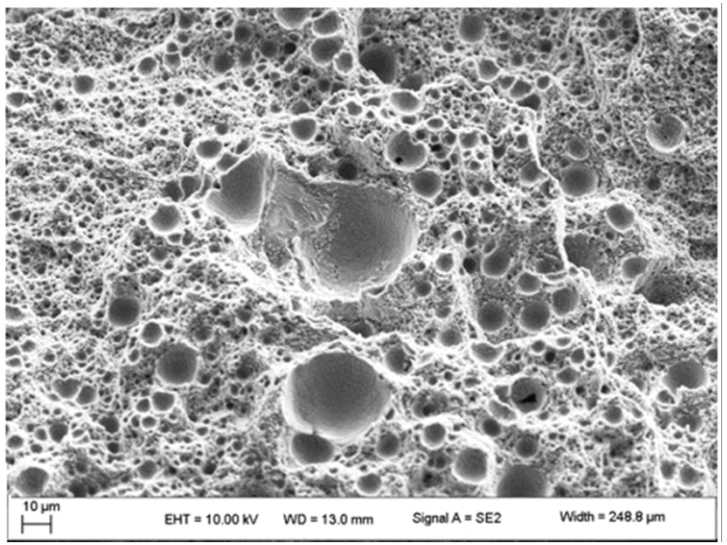


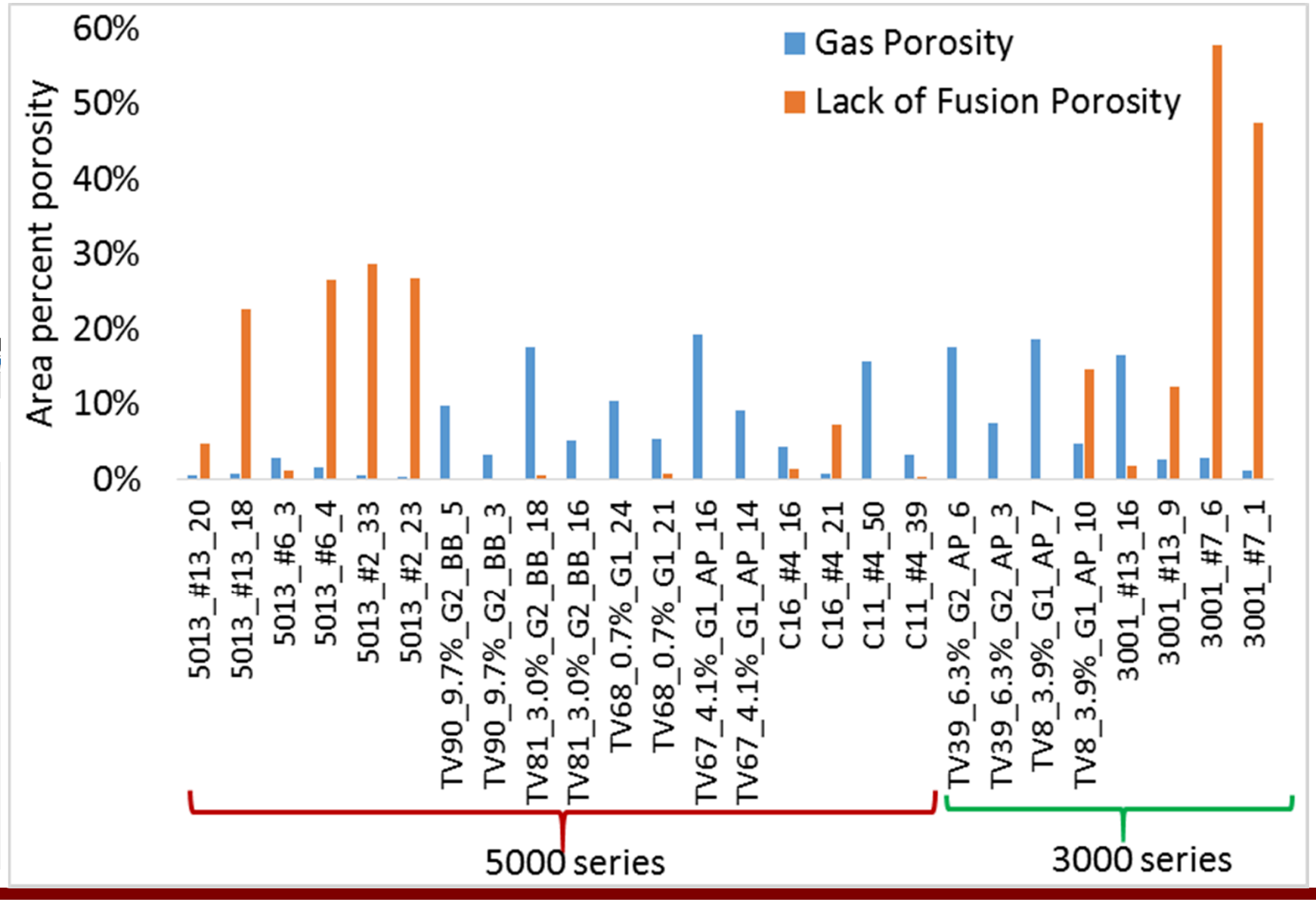


D.F. Susan, T.B. Crenshaw, and J.S. Gearhart, *Journal of Materials Engineering and Performance* 24(8), pp. 2917-2924, June 2016.

Fracture surface porosity results

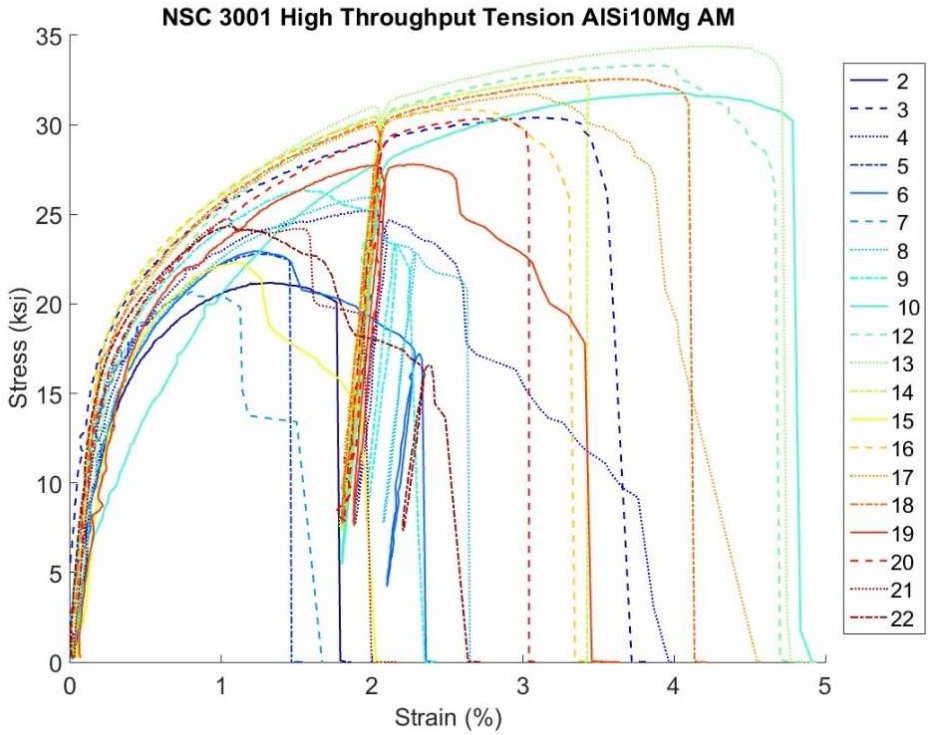


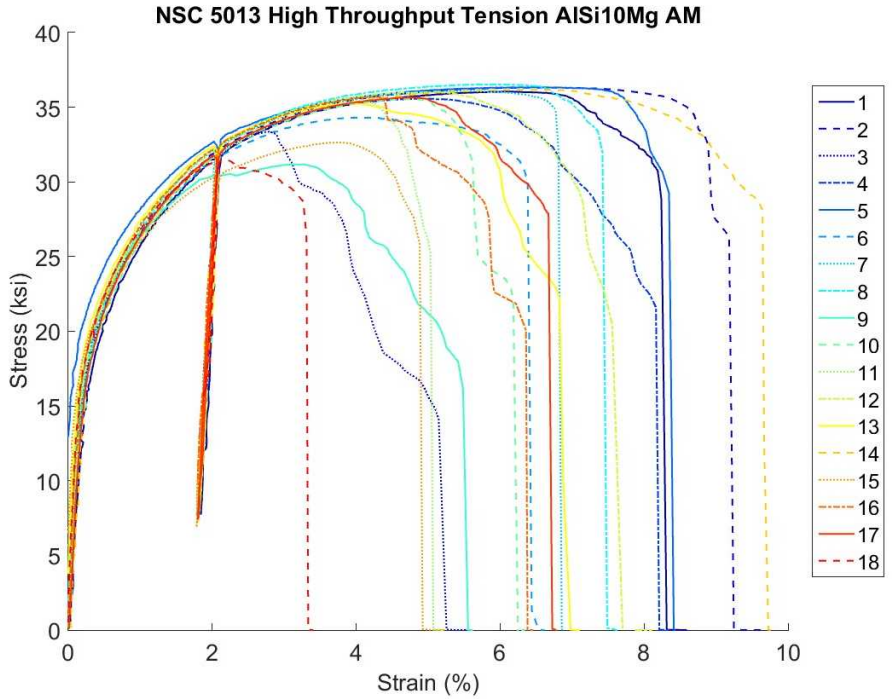


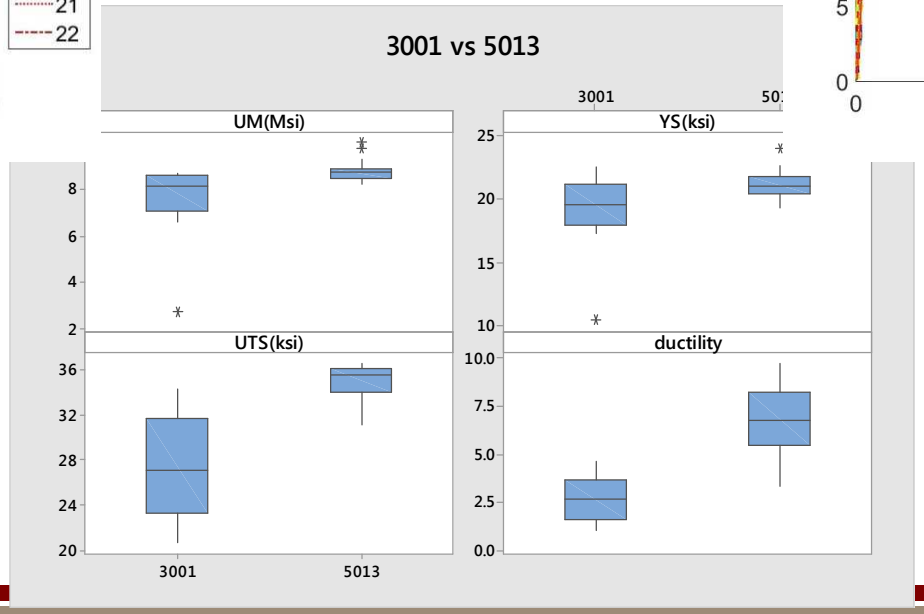


Chris Finfrock, Bonnie McKenzie, Jeff Rodelas

Tensile testing of high throughput bars





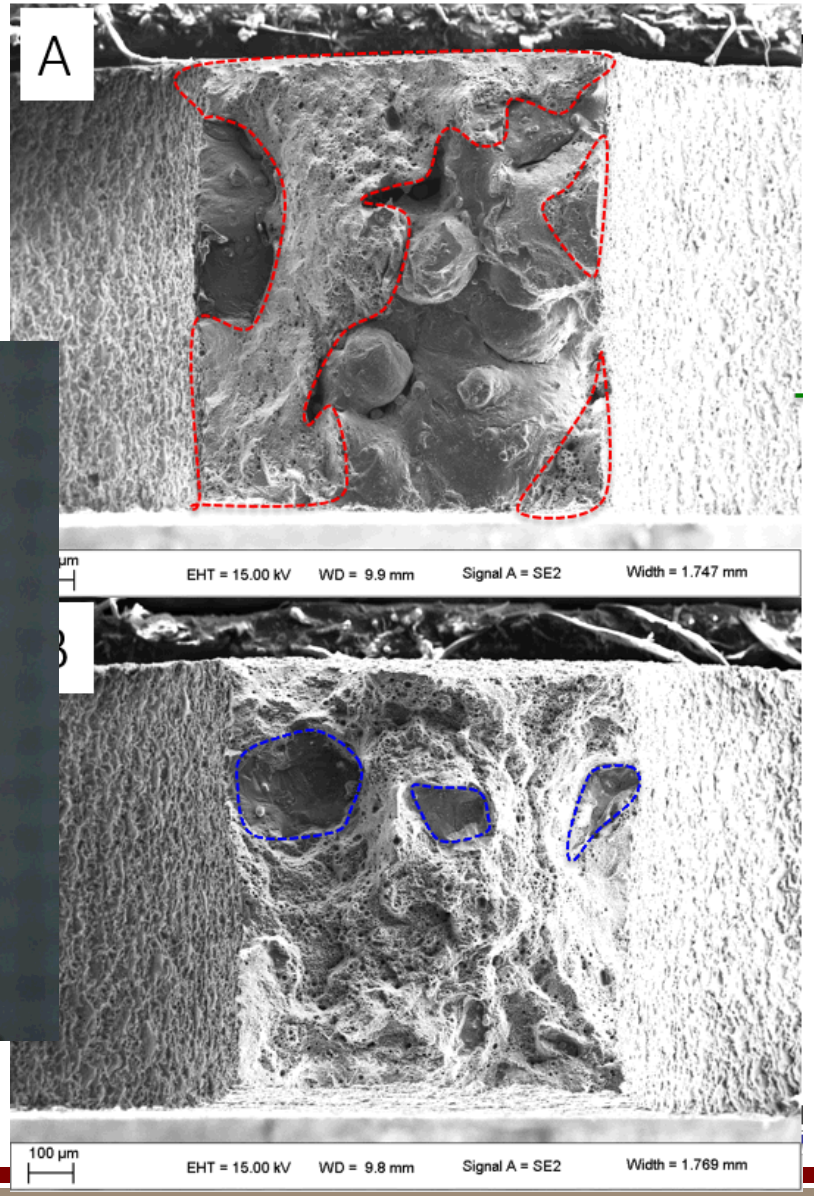


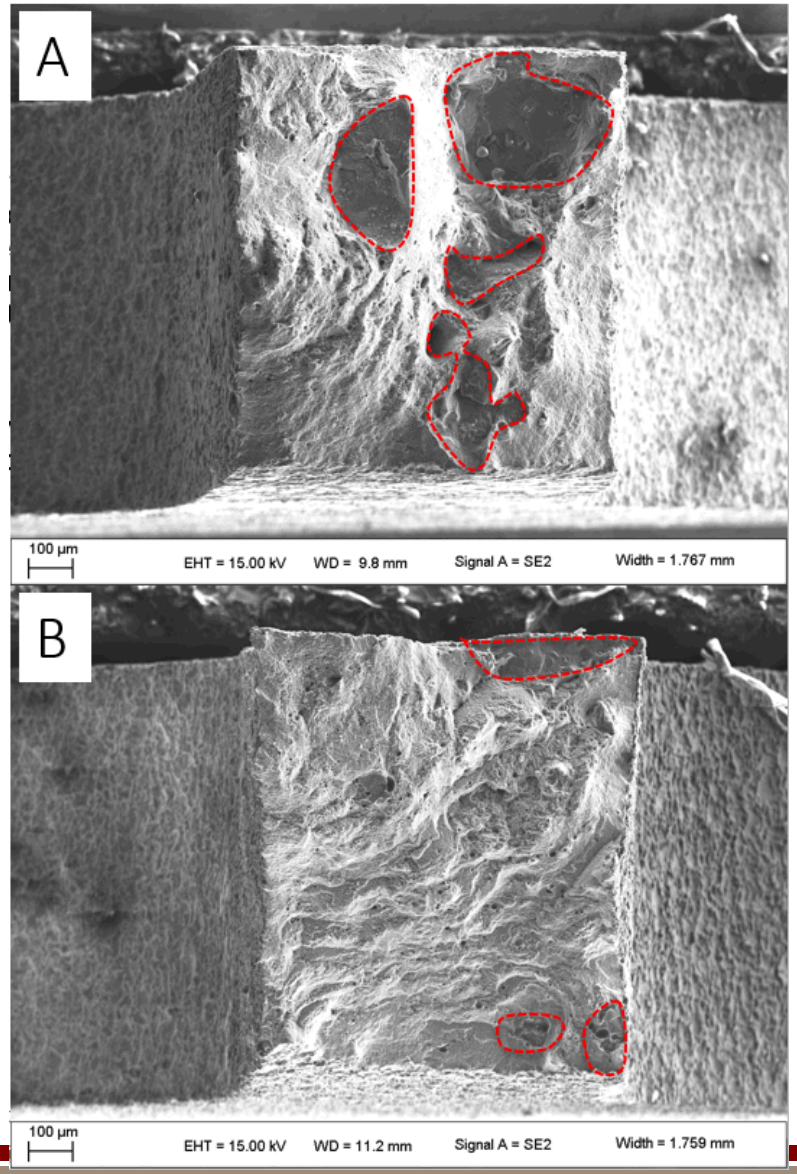
Brad Salzbrenner, Jay Carroll, Daniel Campbell

Fractography of high throughput tensile bars

Sandia National Laboratories

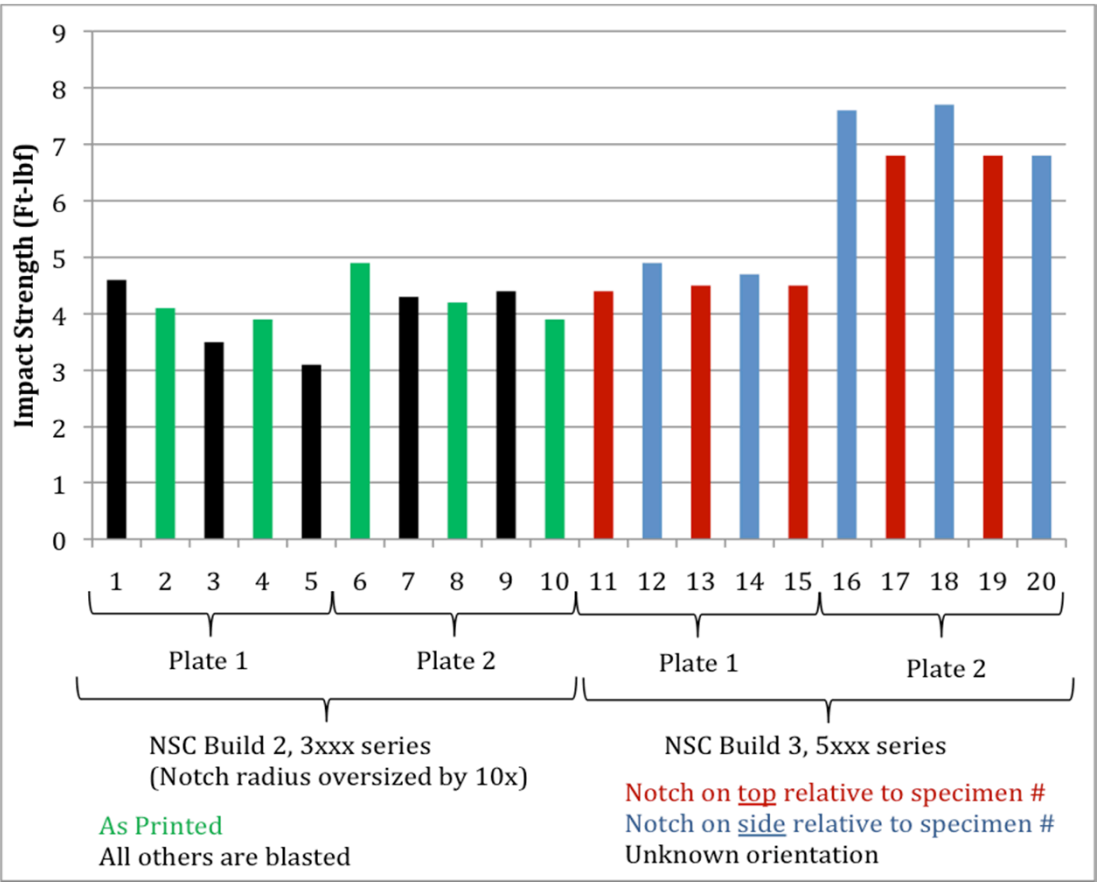
Lack-of-fusion porosity in 3000 series part with high throughput samples removed



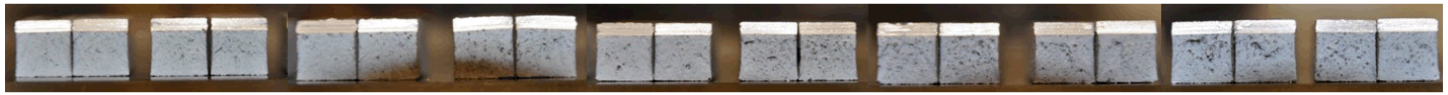


Brad Salzbrenner, Jay Carroll, Bonnie McKenzie, Jeff Rodelas, Joe Romero

Charpy impact strength comparison

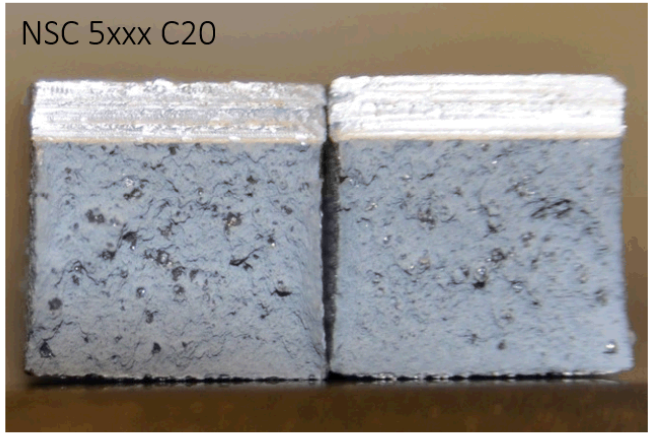


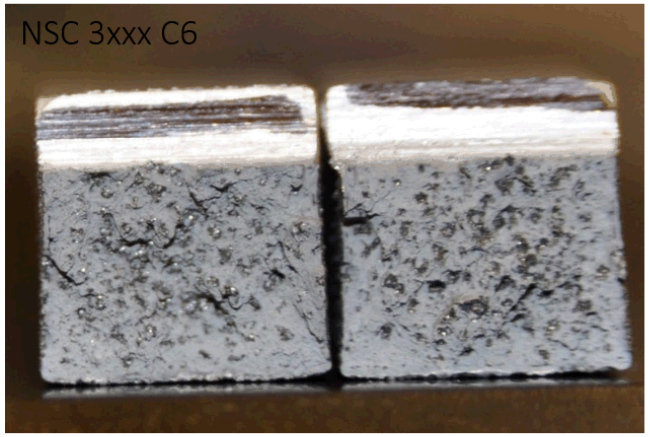
NSC, 5xxx series



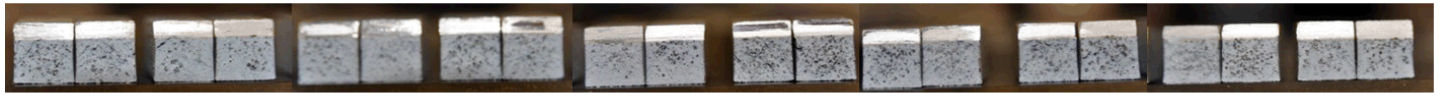
C11 C12 C13 C14 C15 C16 C17 C18 C19 C20

Group 1 Group 2





NSC, 3xxx series



1 2 3 4 5 6 7 8 9 10

Charpy impact sample fractography

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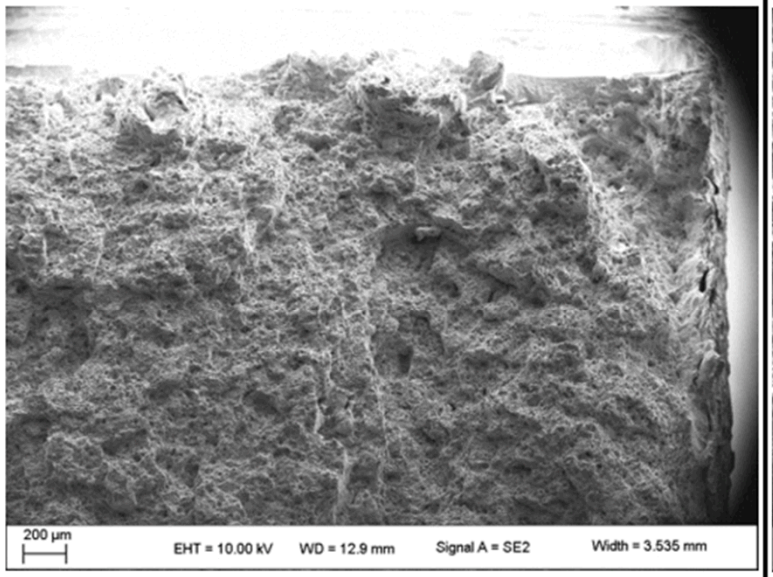
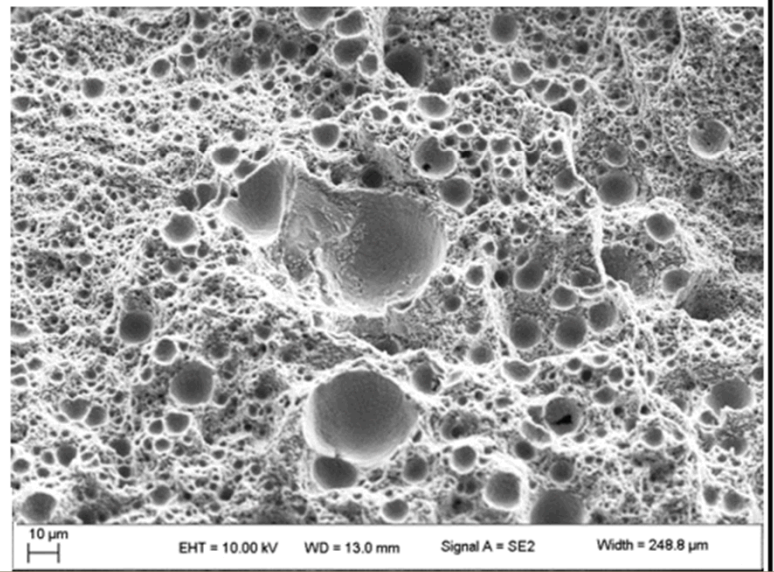
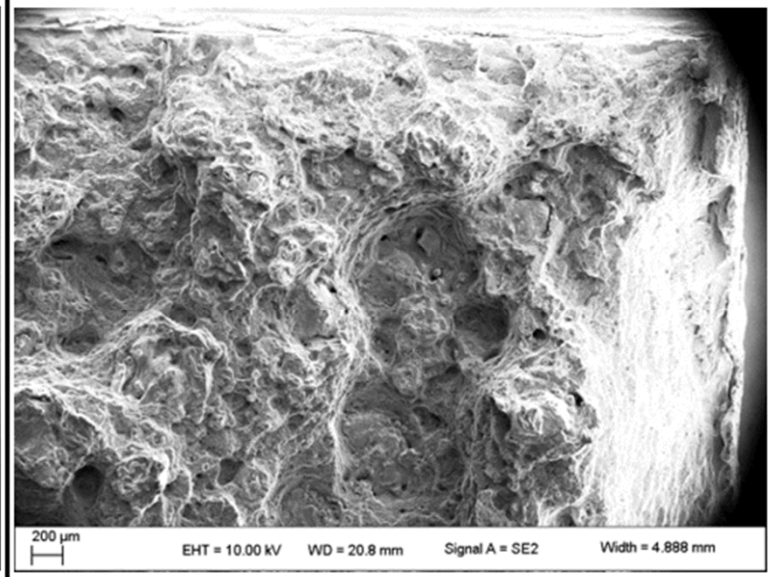
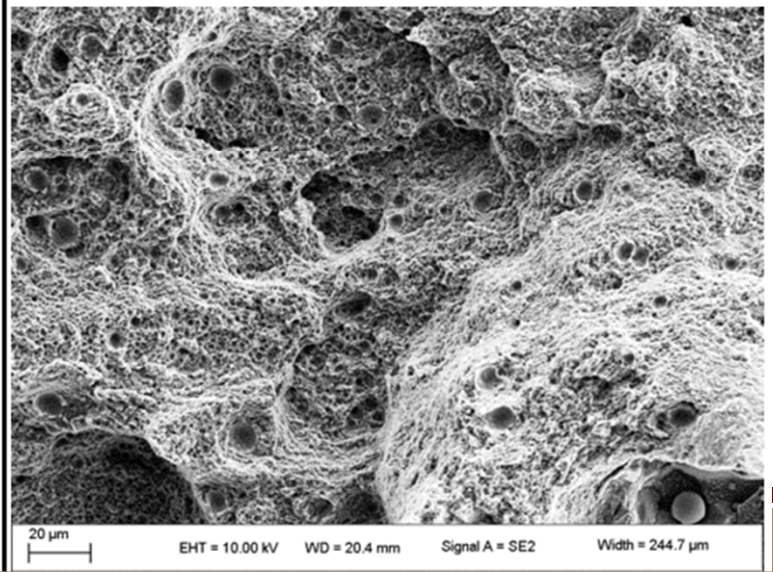
A **5000 series plate 1: Sample C11: Low impact toughness (4.4 ft-lb)**





B **5000 series plate 2: Sample C16: High impact toughness (7.6 ft-lb)**





Methods of porosity characterization

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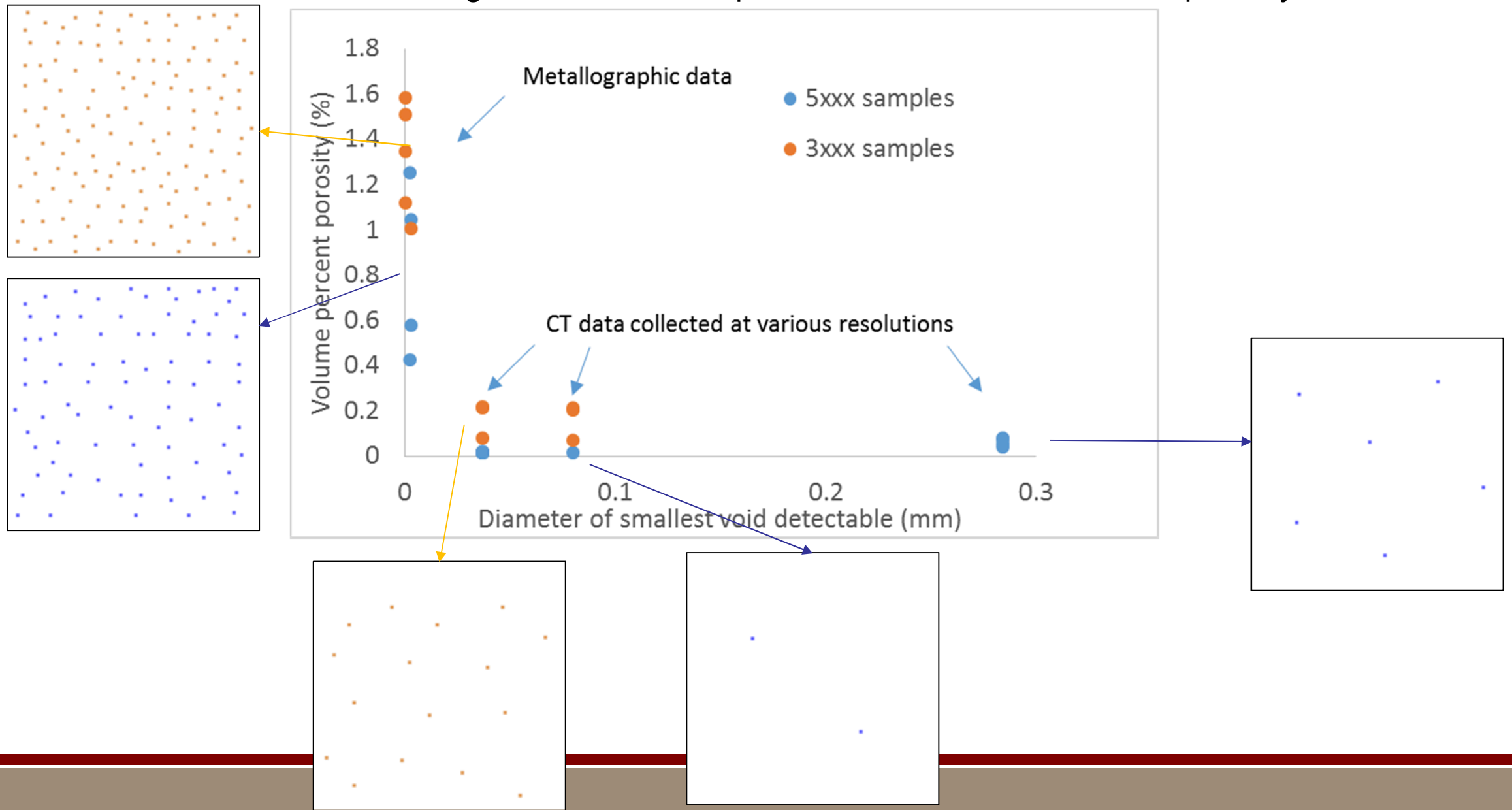
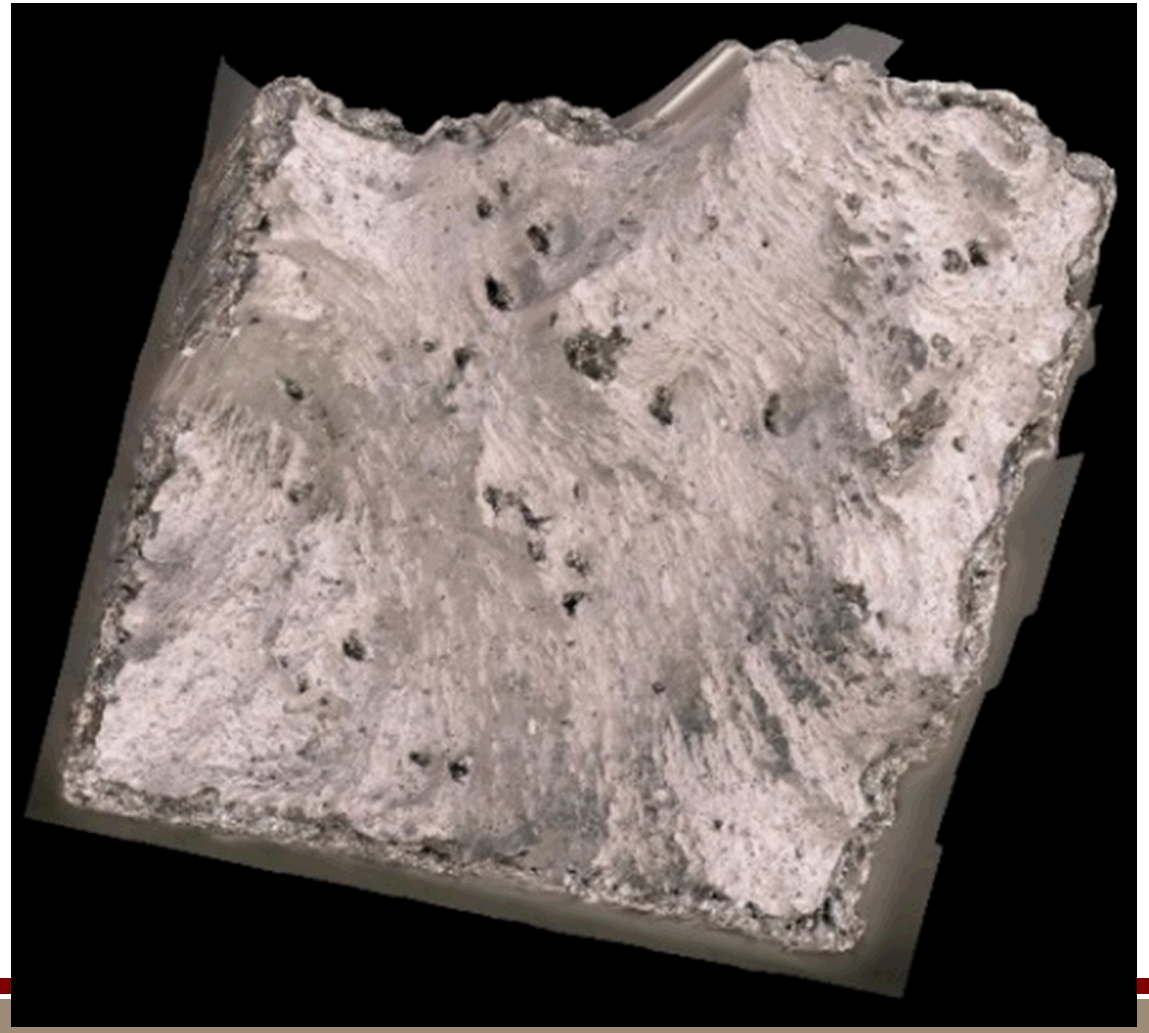
Images show the examples of the measured amount of porosity



Future plans for fractographic pore analysis

- "High throughput" optical fractographic analysis. In addition to what has already been tested:
  - 400 small high throughput tensile bars
  - 192 large high throughput tensile bars
  - 64 Charpy samples
- Correlation of porosity with tensile test results.
  - Statistical analysis



Conclusions

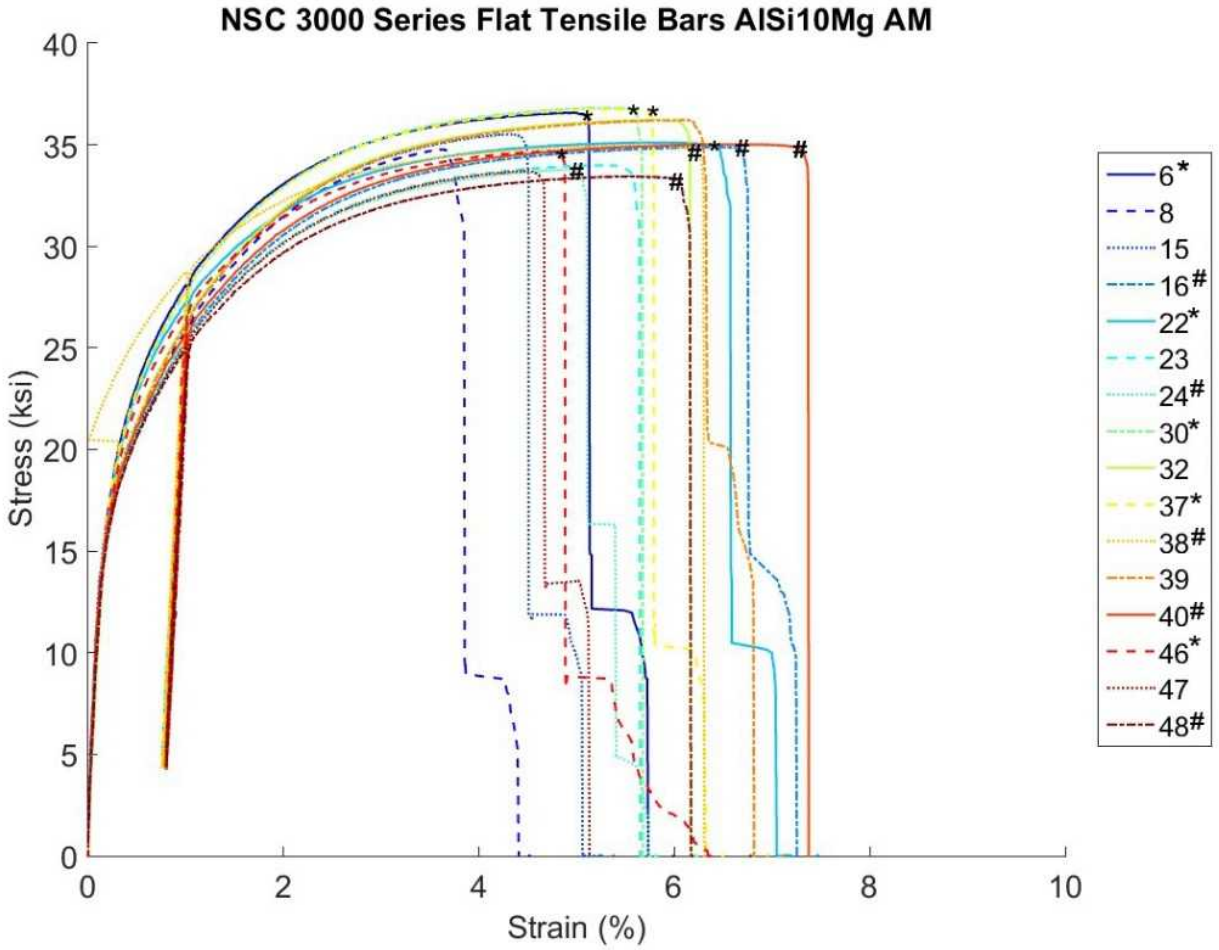
- Various methods of porosity determination have their own advantages and disadvantages.
- We are still working to determine the level necessary for useful correlation with mechanical properties.

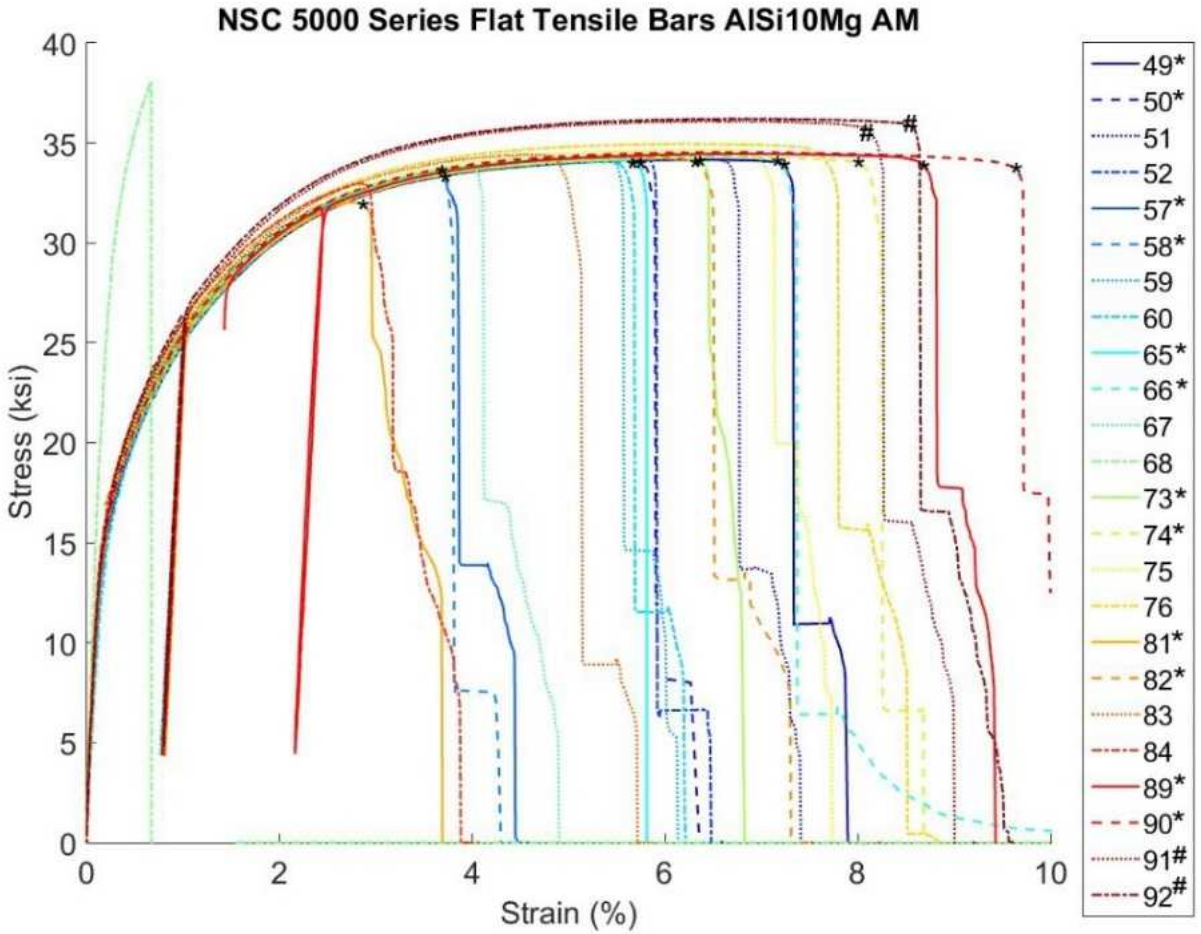
Tensile testing

Both printed samples and samples cut from parts were tested. There are various benefits of each geometry:

- Size effect
- Determination of tails of distributions
- Efficiency of testing
- Sample area determination
- Representative cooling rates/build height

Tensile testing of flat tensile bars





Fractography of lowest strain flat tensile bars