CANFSA

Center for Advanced Non-Ferrous Structural Alloys

An Industry/University Cooperative Research Center

Project 32-L: Algorithmic Analyses of X-Radiography and Computed Tomography for Multiscale Structural Investigations of Metals

Semi-annual Fall Meeting

October 2021

- Student: C. Gus Becker (Mines)
- Faculty: Dr. Amy Clarke (Mines)
- Industrial Mentors: Dr. Michelle Espy (LANL, E-6)

COLORADO SCHOOL OF MINES   NSF   IOWA STATE UNIVERSITY

Project 32-L: Algorithmic Analyses of X-Radiography and Computed Tomography for Multiscale Structural Investigations of Metals

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- Student: C. Gus Becker (Mines)
- Advisor(s): Amy Clarke (Mines)

Project Duration
PhD: September 2017 to July 2022

- Problem: Industrial processes of metals such as casting and additive manufacturing can benefit from static/dynamic radiography, but user facilities have technique and access limitations.
- Objective: Analyze existing radiography and tomography data and establish cabinet-based x-ray capabilities at Mines for further experimentation.
- Benefit: Identify technique limitations for defect detection in AM metals and studies of solidification.

Recent Progress

- Lead a publication comparing in situ x-radiography of Al-Ag solidification to postmortem SEM EDS showing proof-of-concept method of monitoring concentrations in situ
- Improved APS AM simulator automated interface identification to work better without cropping to region of melt pool
- Identified method in literature for difficult segmentations combining intensity, edge, and shape information (to be applied to mock HE)

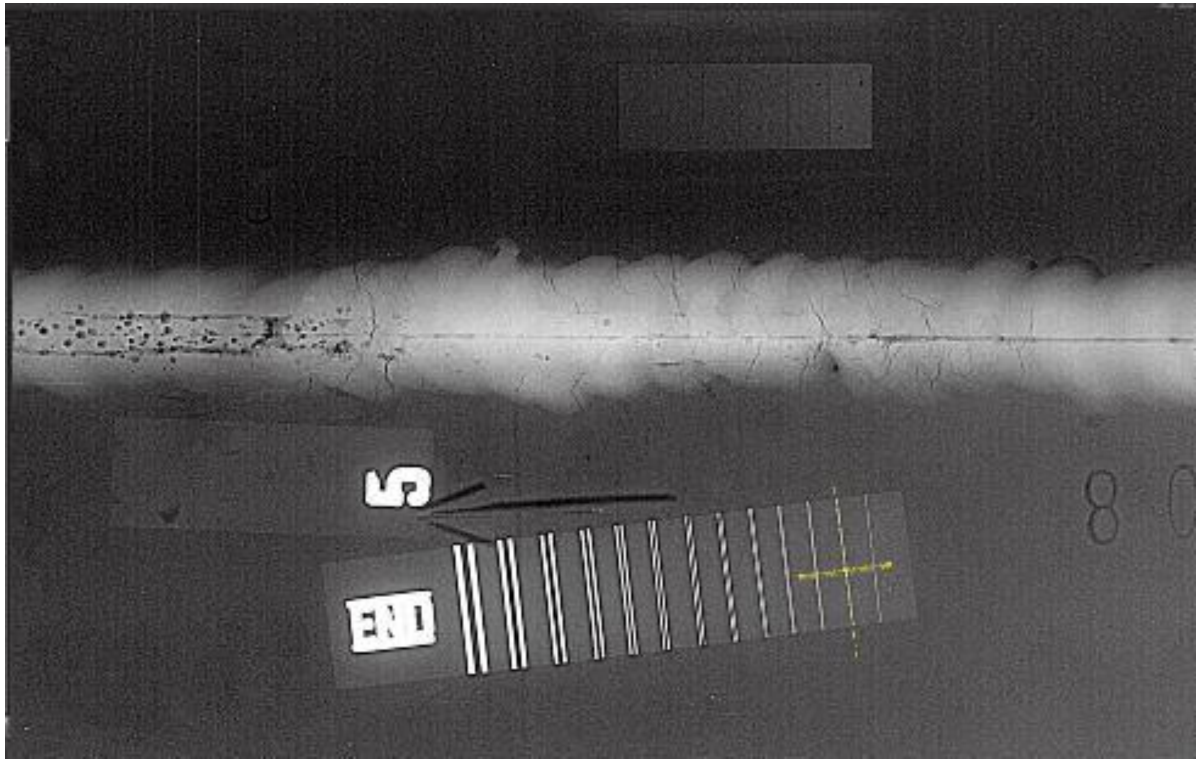
Metrics

Description	% Complete	Status
1. Establishment of cabinet-based high-energy microfocus x-ray capabilities at Mines	95%	●
2. Al-Ag x-radiography and EDS comparison	100%	●
3. Automation of AM simulator interface identification	90%	●
4. Segmentation of mock HE (adapt to Jupyter Notebooks, apply new method, quantify methodology, 2D to 3D)	25%	●
5. Neural network approach to AM simulator interface identification	5%	●

Industrial Relevance

- Identify defects in additively manufactured (AM) builds by non-destructive imaging
  - Qualification and certification
  - Technique limitations

- Weld inspection
  - Safe and stable welds
  - Failure points, inclusions, porosity



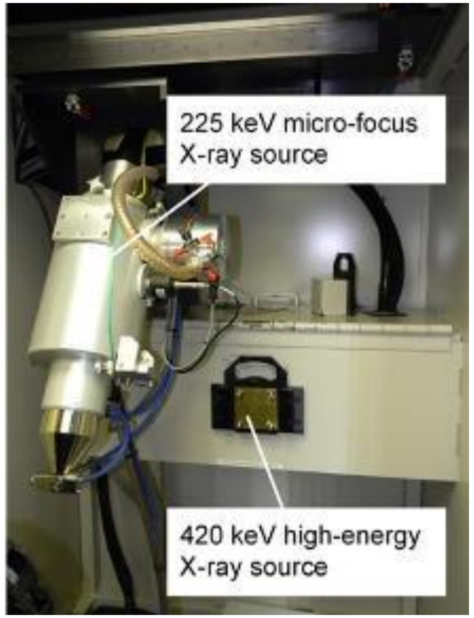
http://solutionsinimaging.com/industrial-applications/weld-inspection/

Industrial Relevance

- In situ x-ray imaging of dynamic materials processes to inform model development

- Establishment of x-radiography and computed tomography (CT) cabinet at Mines
  - Support ongoing projects
  - Allow for consideration of a wider range of projects from industry
  - Accommodates custom/flexible experimental platforms (solidification, deformation, etc.)

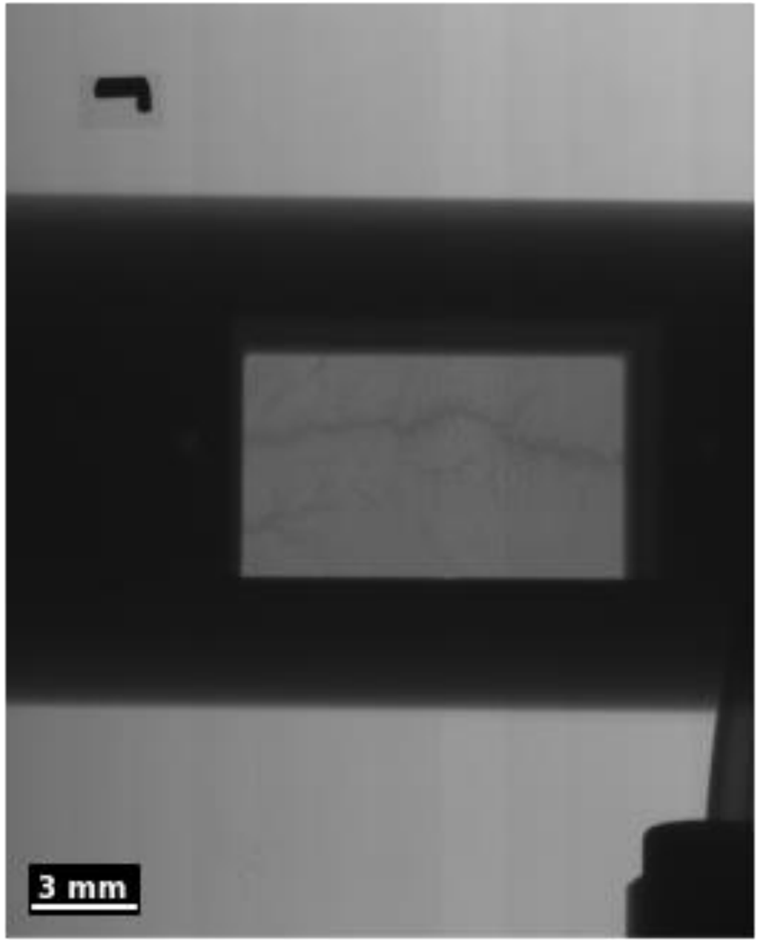
Cabinet Timeline

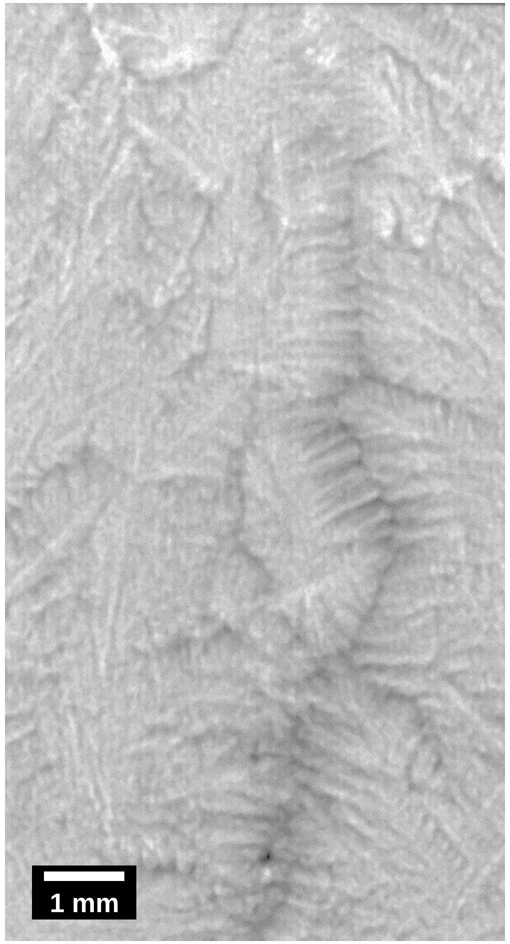


Process Donation Internally (LANL)	Ship to White Rock, NM	Ship to Santa Clara, CA for Refurbishing	Prepare Lab Space for System	Install New Microfocus System	Ship to Mines	Installation and Training
Complete	Complete	Complete	Moving Utilities	Refurbishing Complete	Complete	October 2021

Analyzing Al-Ag Solidification

- Developing reproducible processing methods
- Pulling quantitative information from images
  - Experimental details
  - Technique details
- Understanding solidification structures will help inform model development for dynamic processes (casting, AM, etc.)





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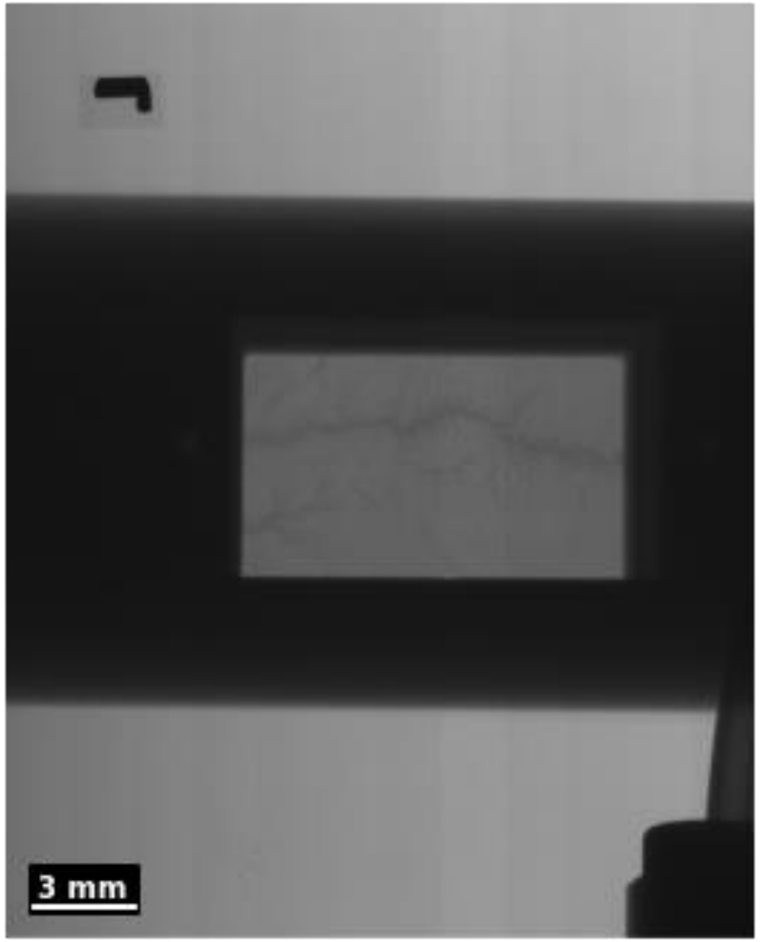
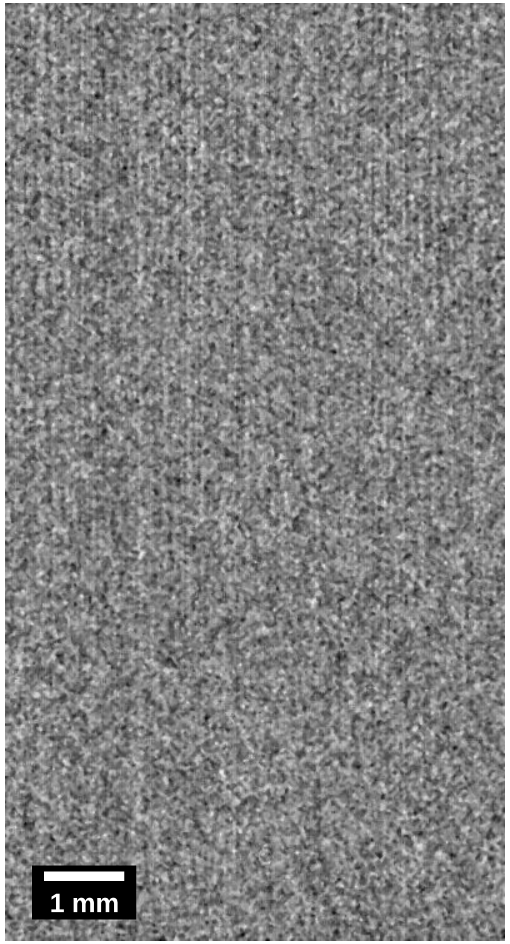
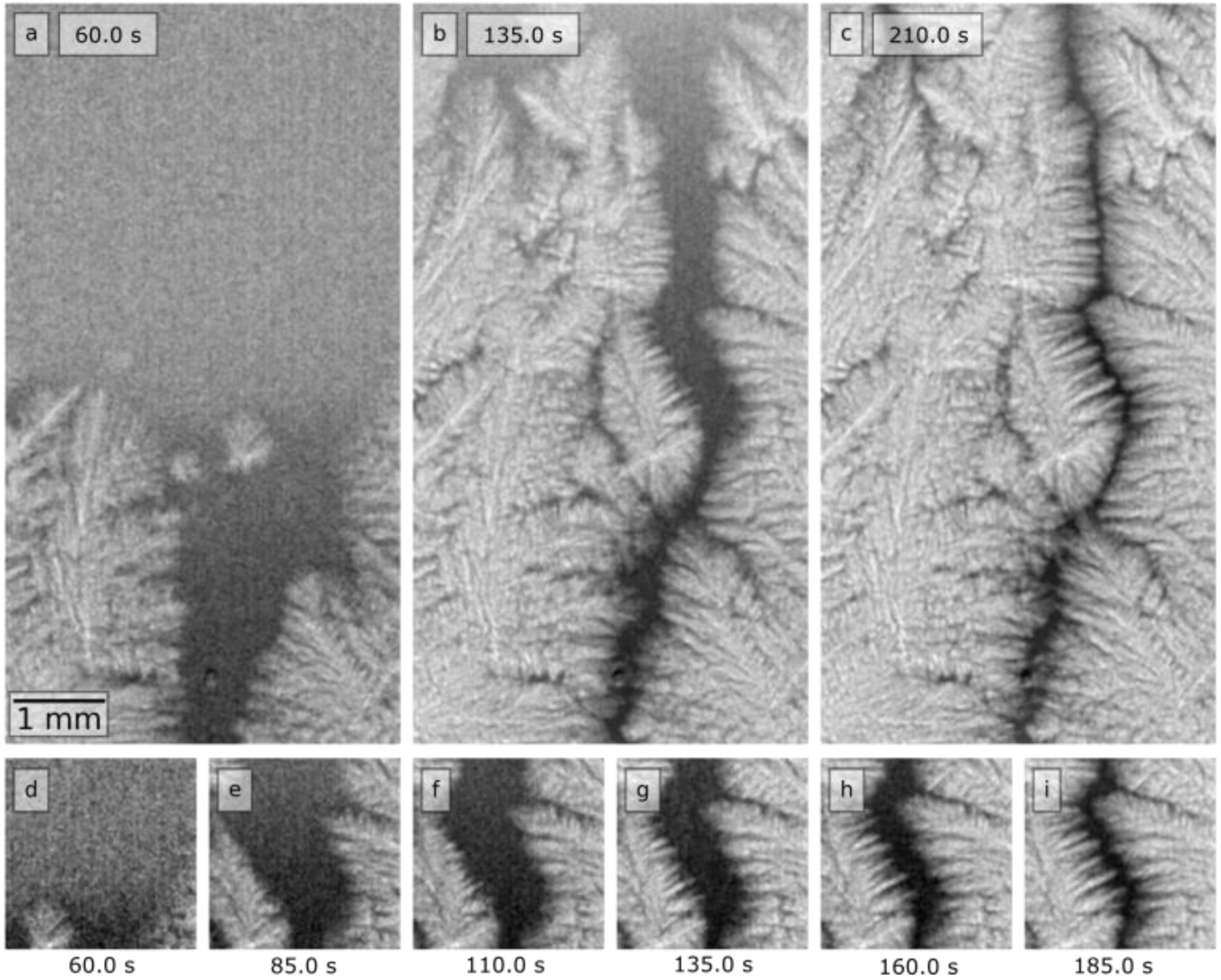
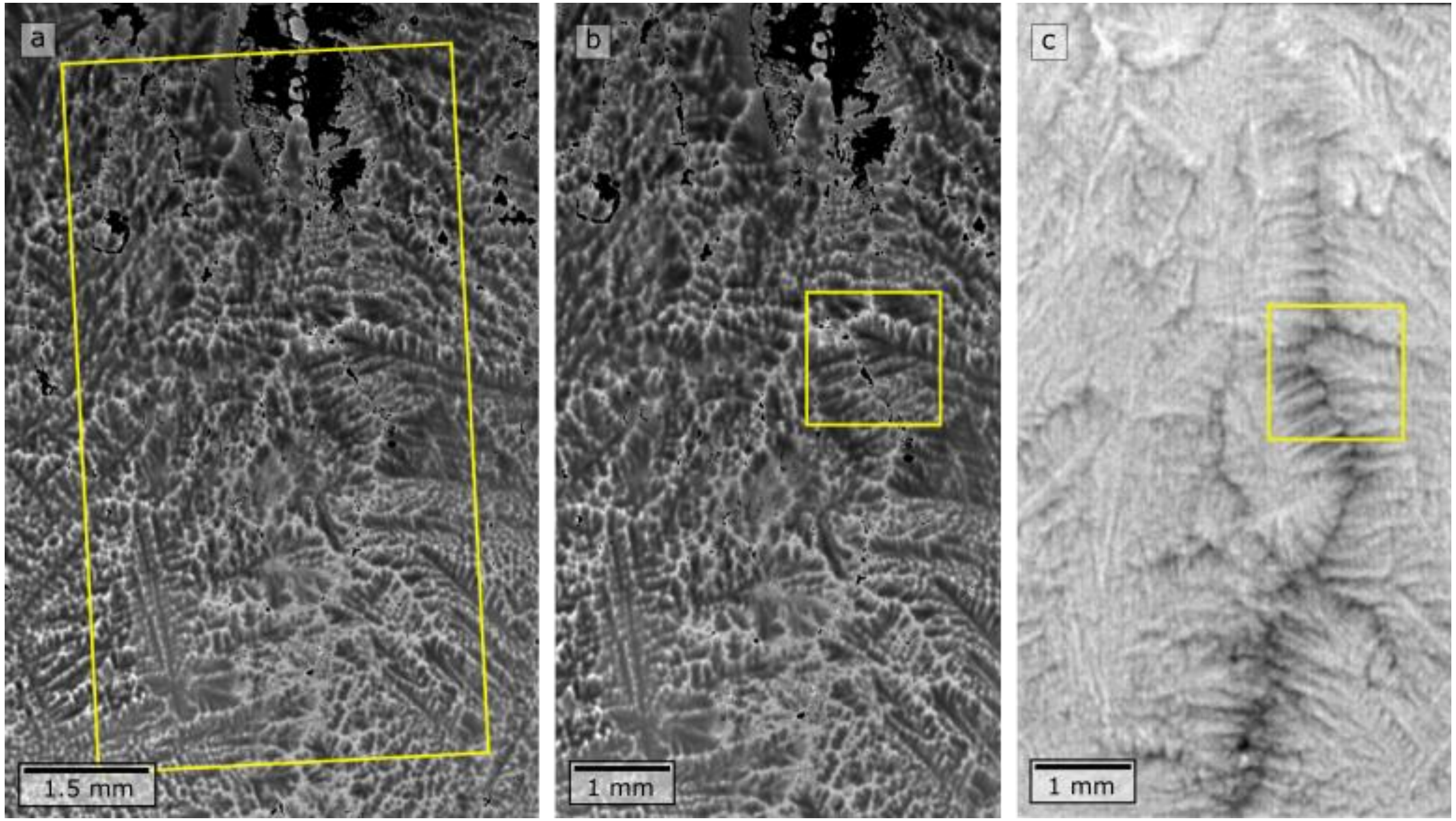




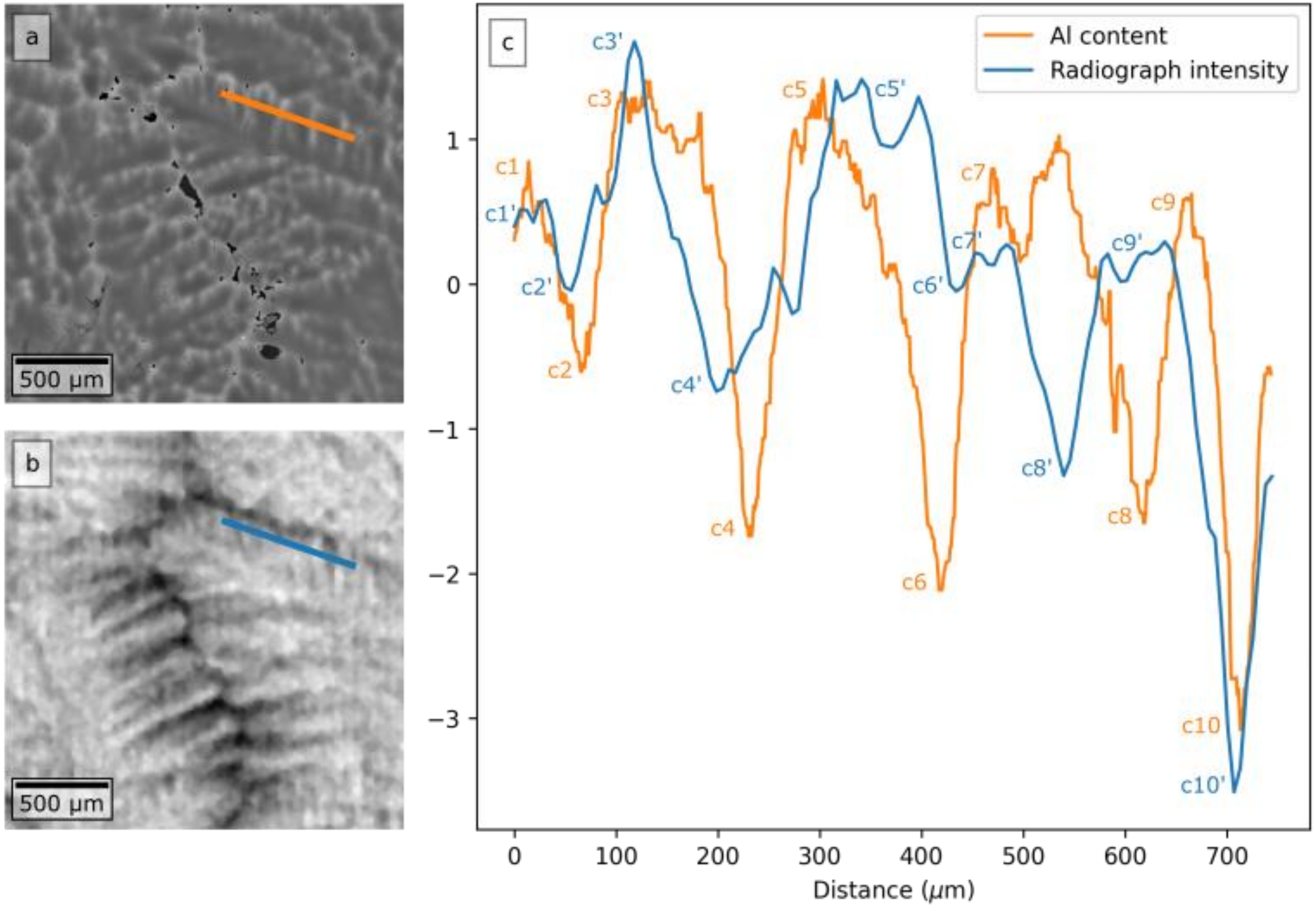
Analyzing Al-Ag Solidification



Analyzing Al-Ag Solidification

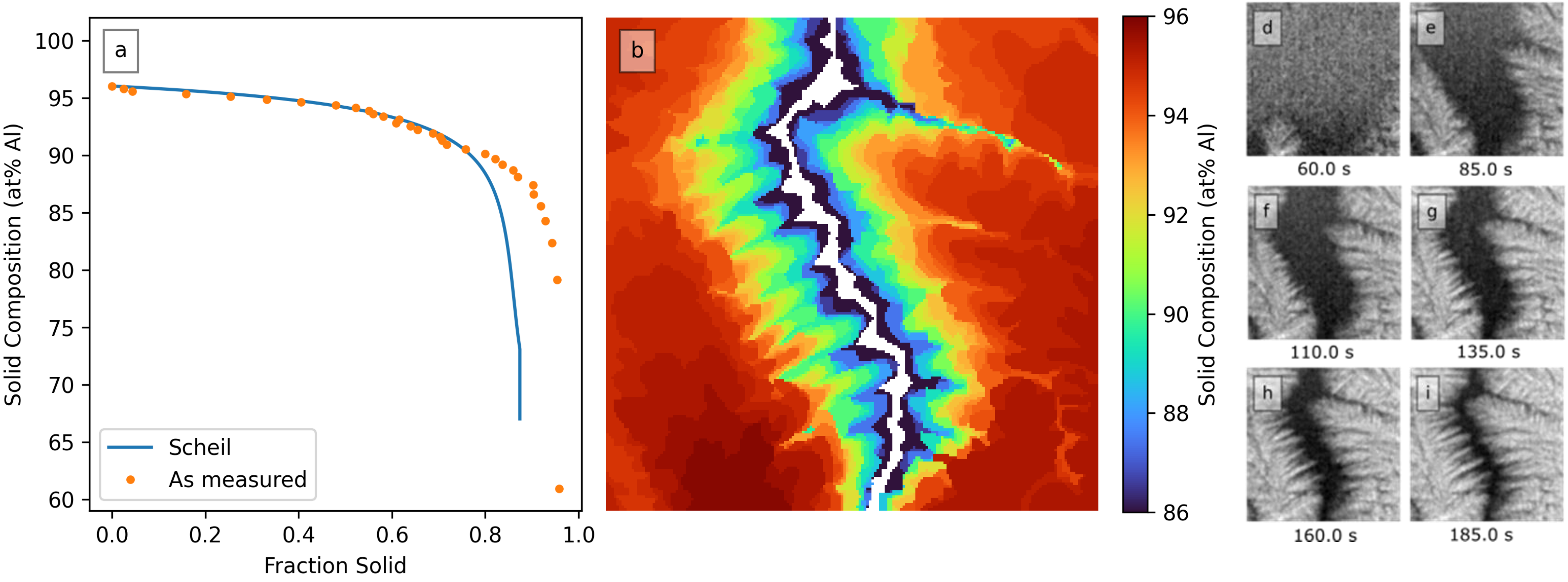


Comparing EDS to Radiography



[1] C. G. Becker et al. JOM. (2021). https://doi.org/10.1007/S11837-021-04884-8.

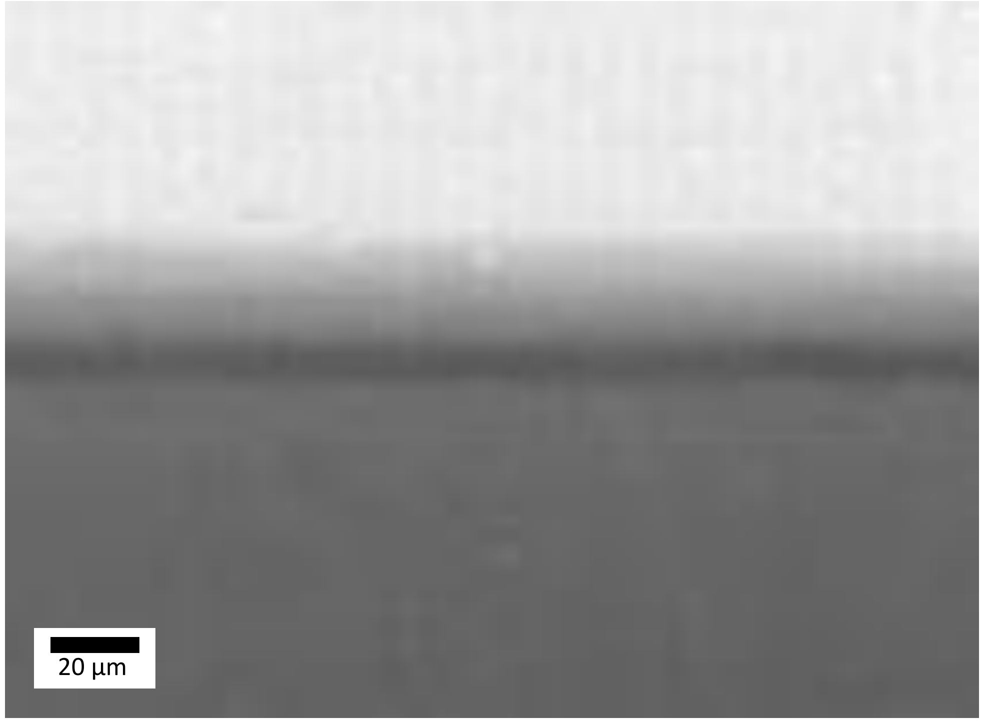
Scheil Simulation Data



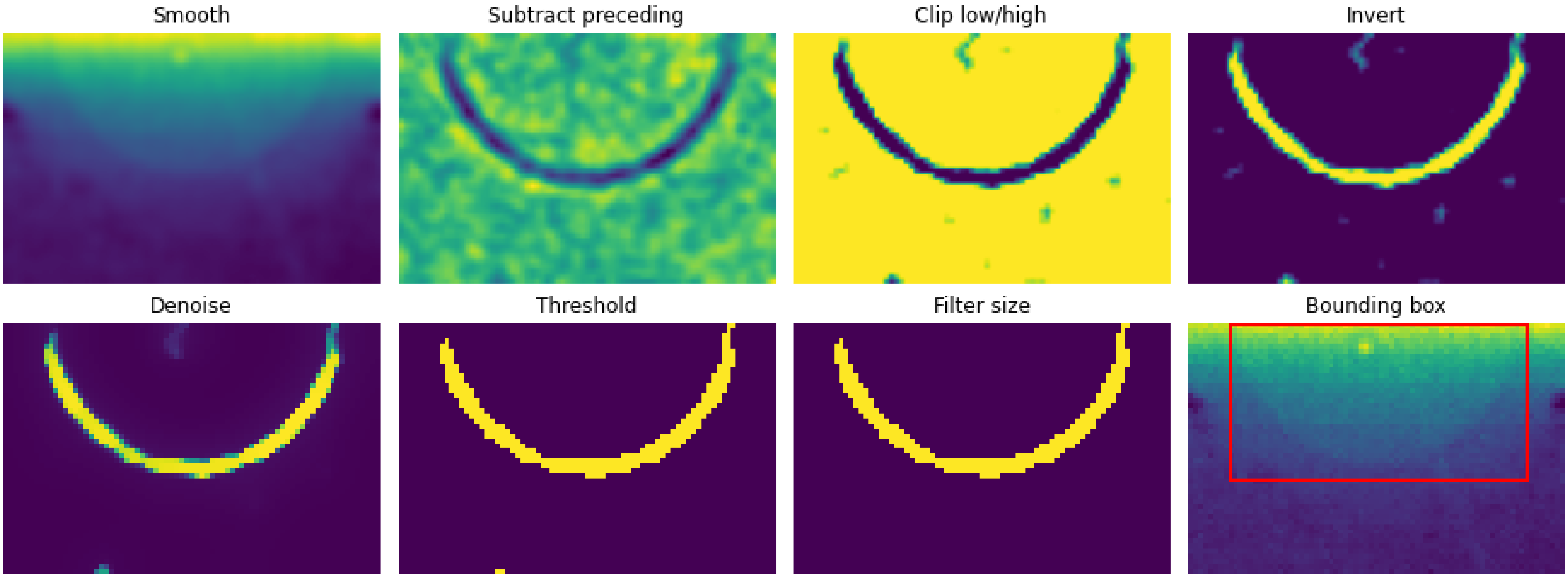
[1] C. G. Becker et al. JOM. (2021). https://doi.org/10.1007/S11837-021-04884-8.

APS AM Simulator: Solidification Velocity

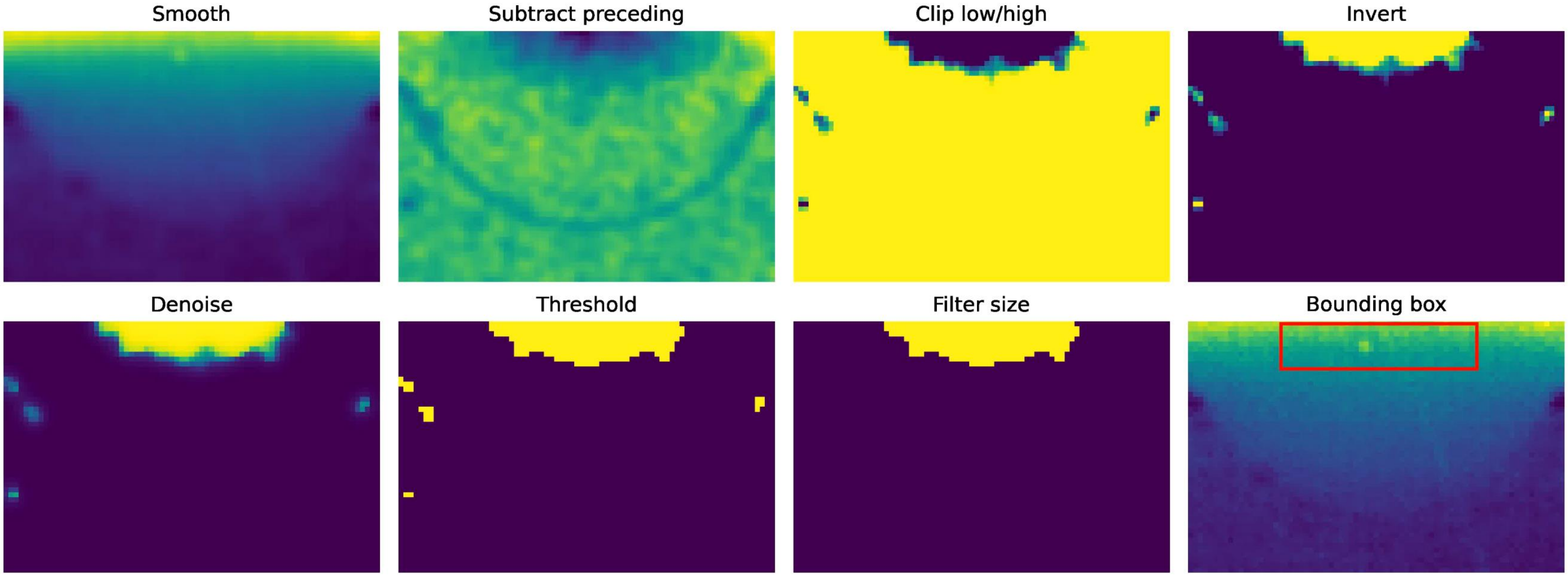
- Solidification velocity to be paired with thermal gradients for modeling
- Ni-based alloy
- Laser power: 108 W (20% max)
- 2 ms dwell time



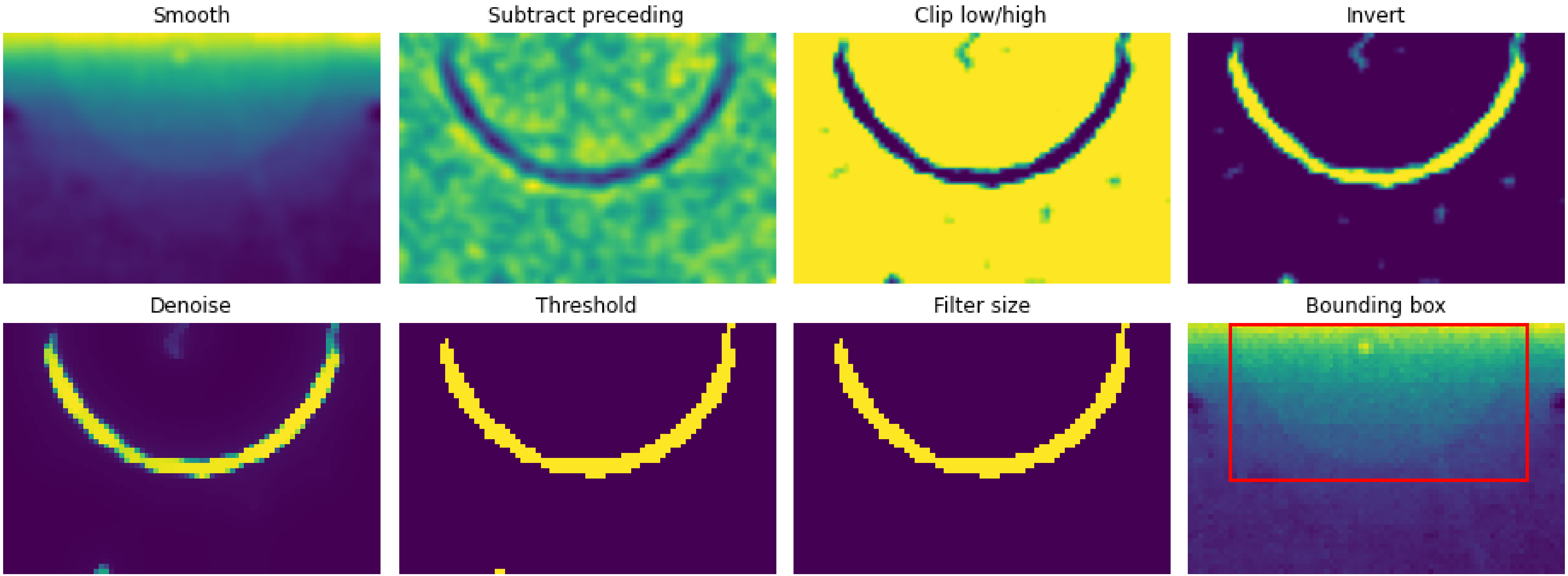
APS AM Simulator: Cropped Example



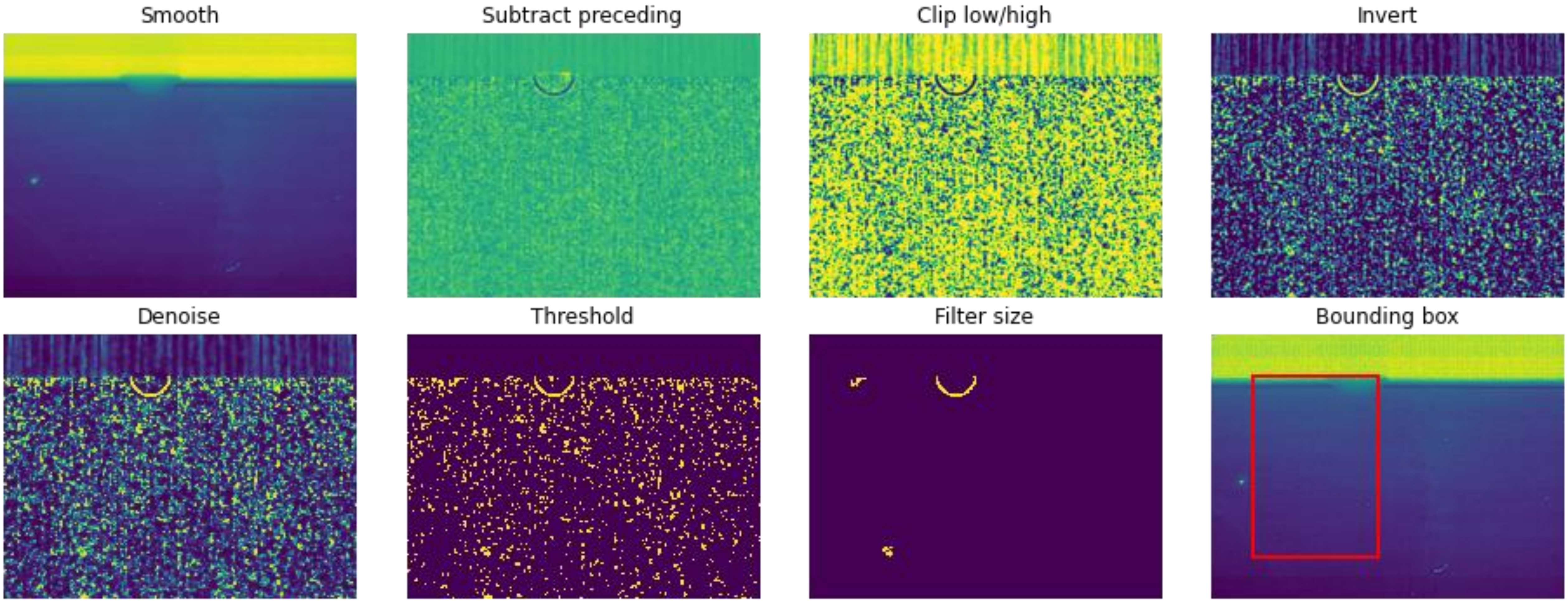
APS AM Simulator: Cropped Sequence



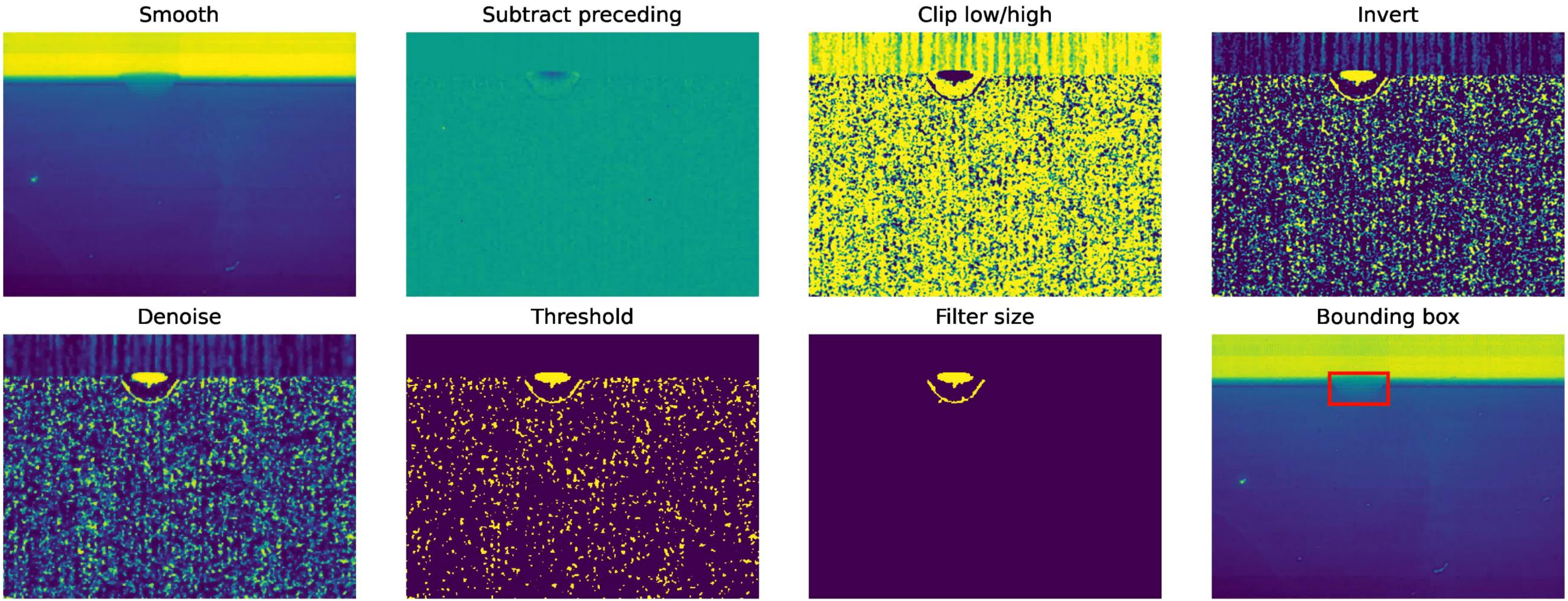
APS AM Simulator: Cropped Example



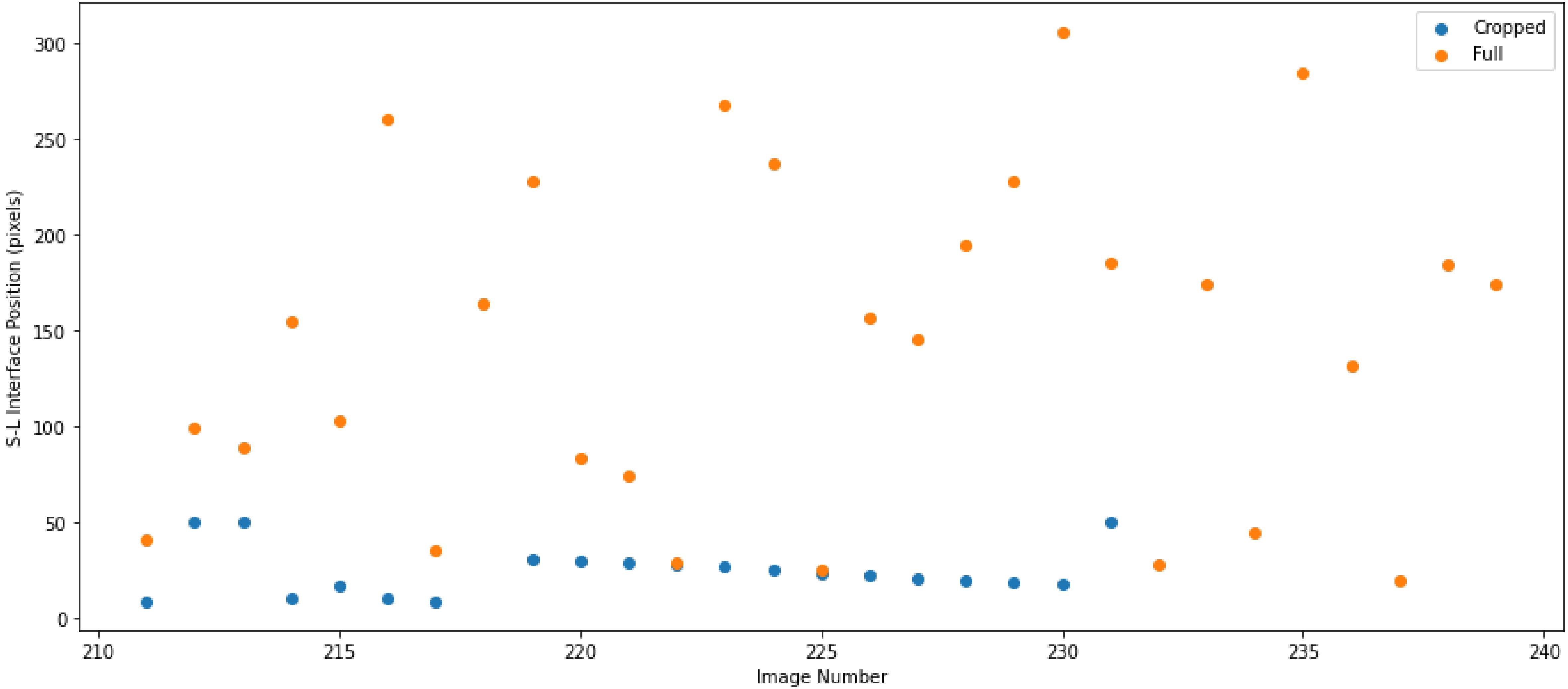
APS AM Simulator: Full Example



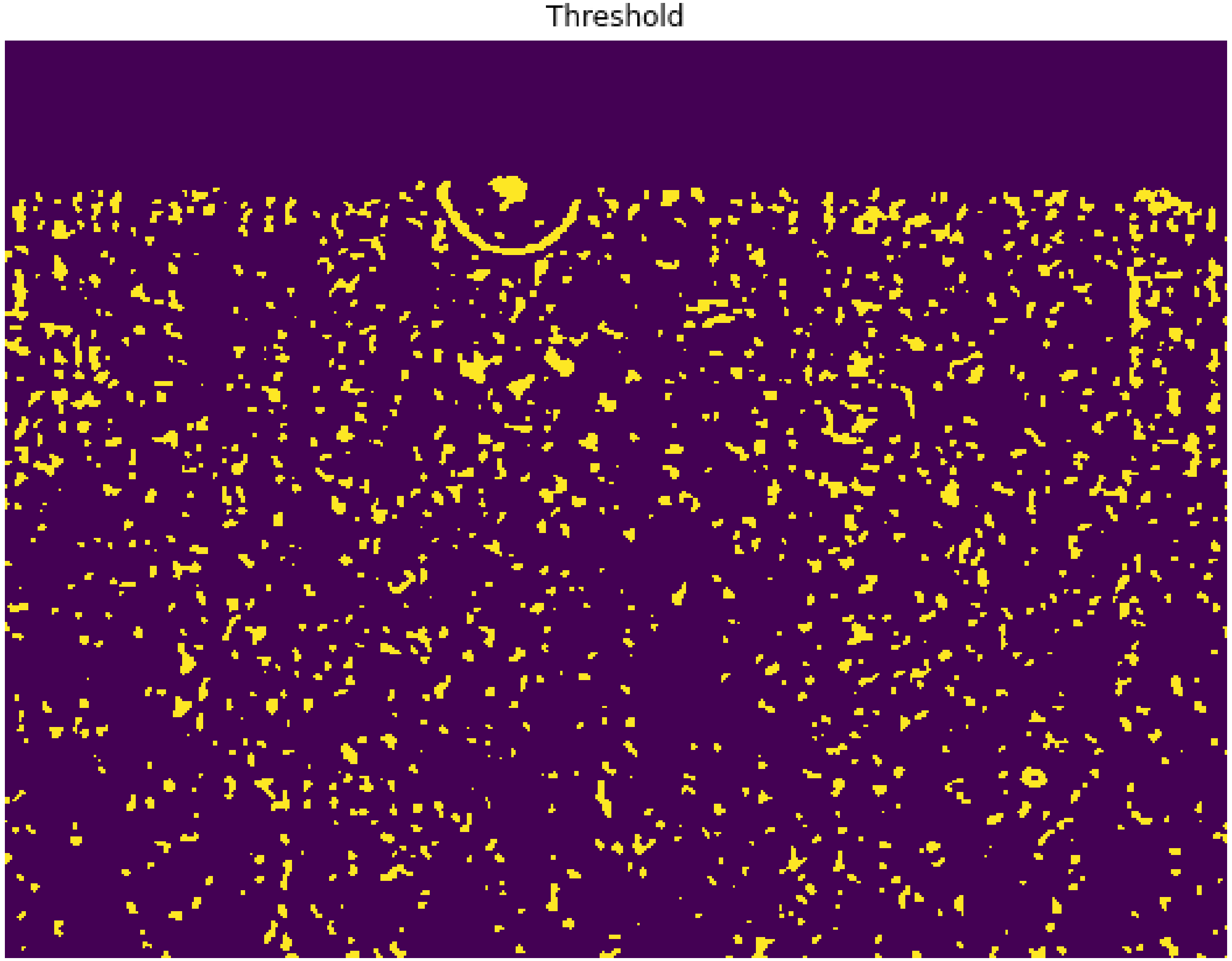
APS AM Simulator: Full Sequence

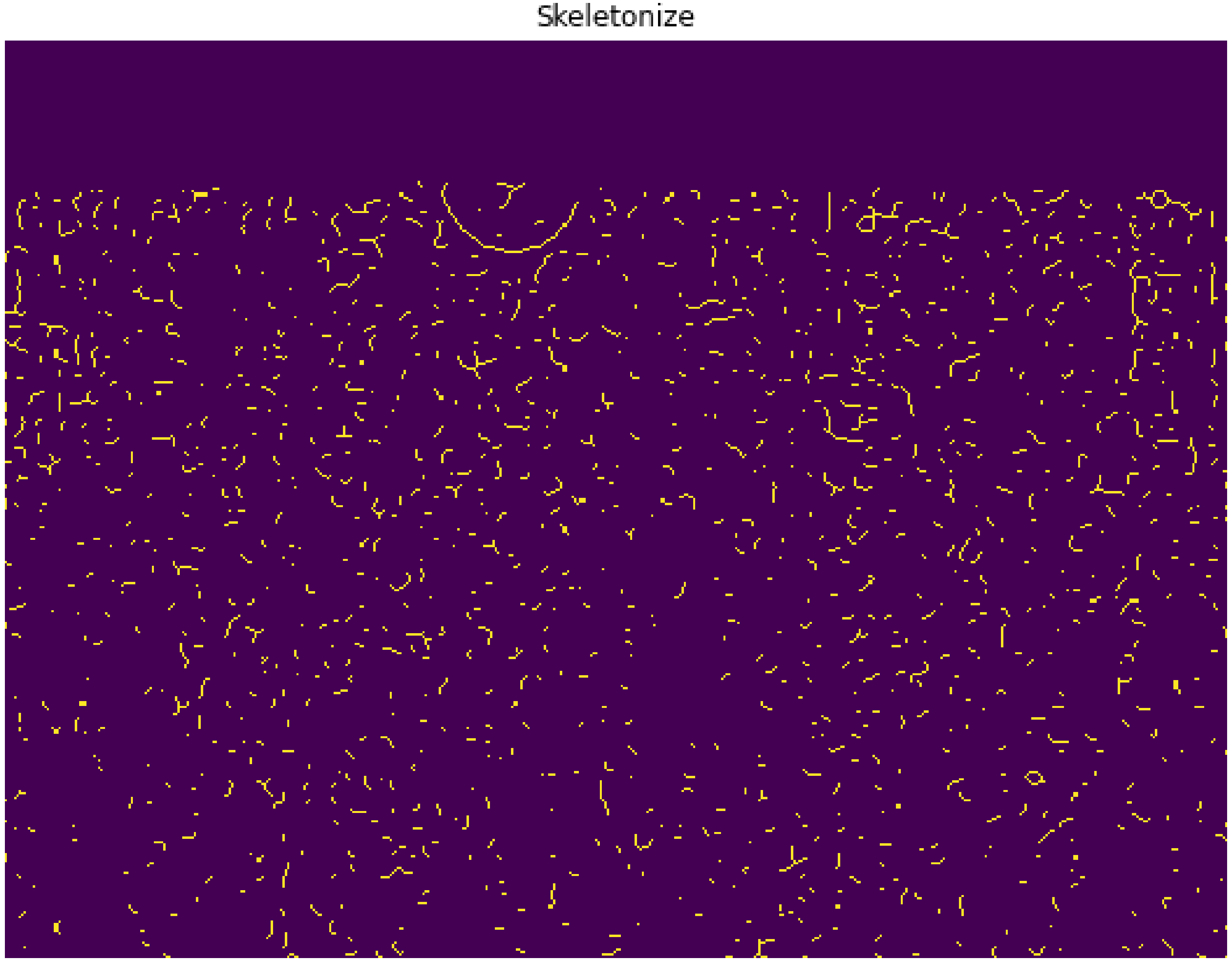


APS AM Simulator: Cropped vs Full IDs

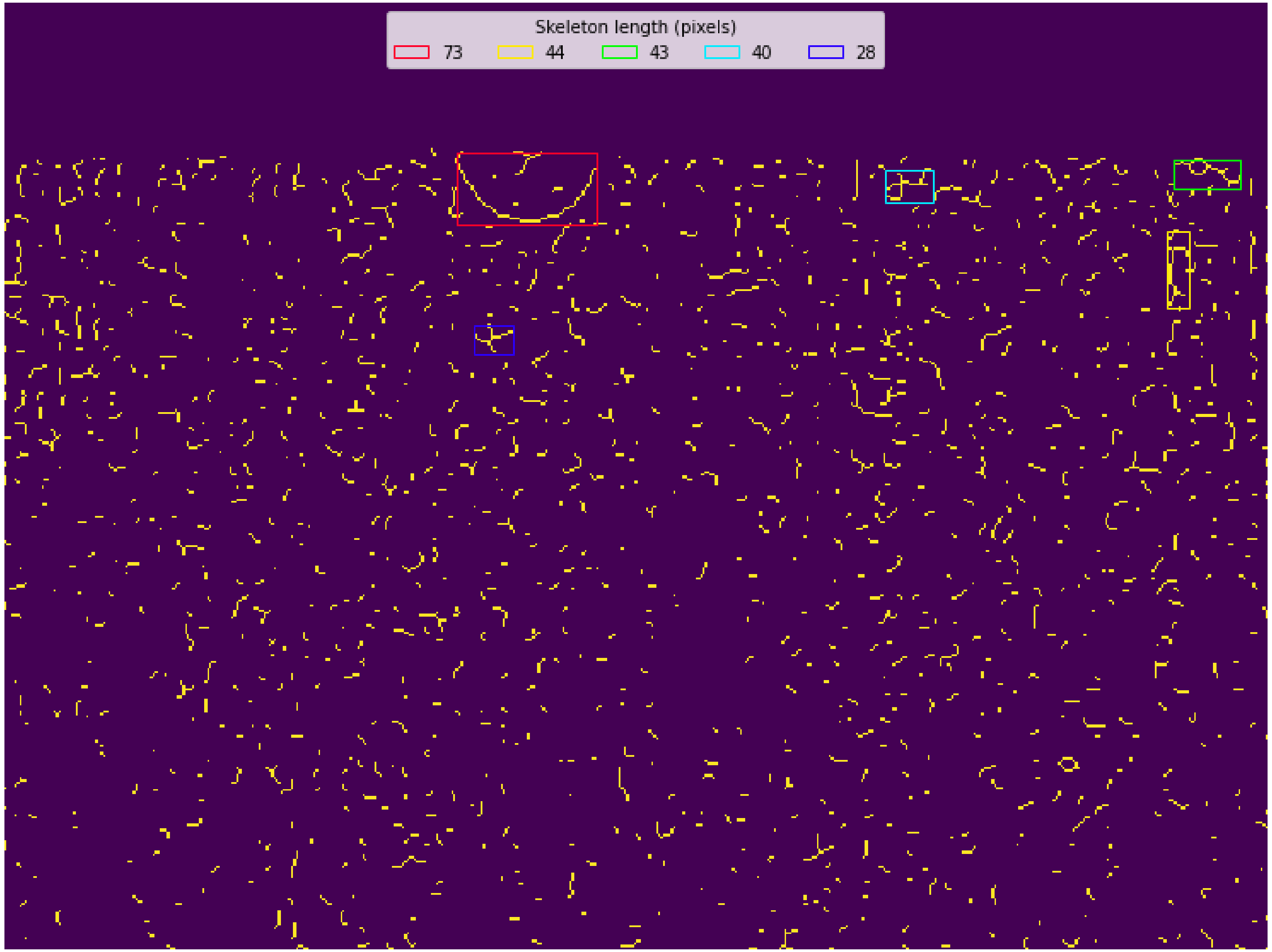


APS AM Simulator: Skeletonize Example

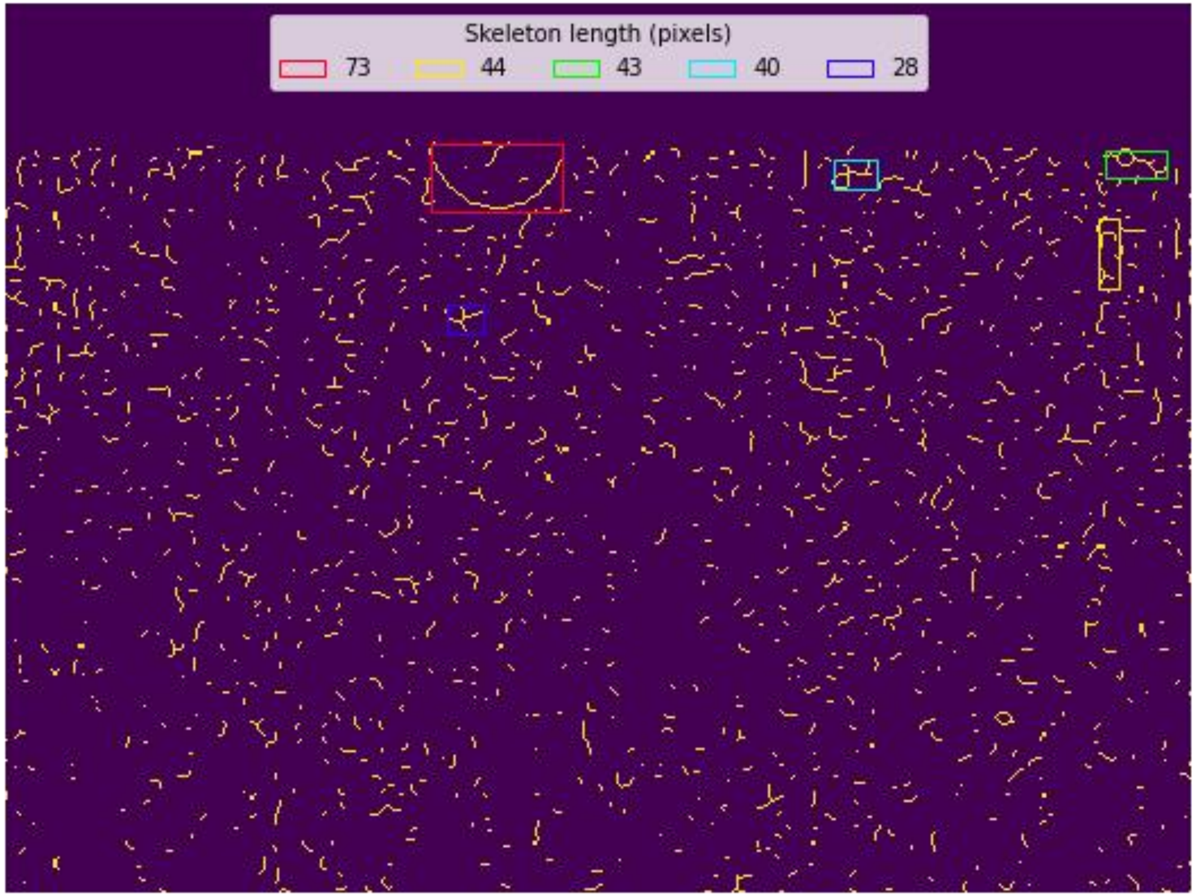


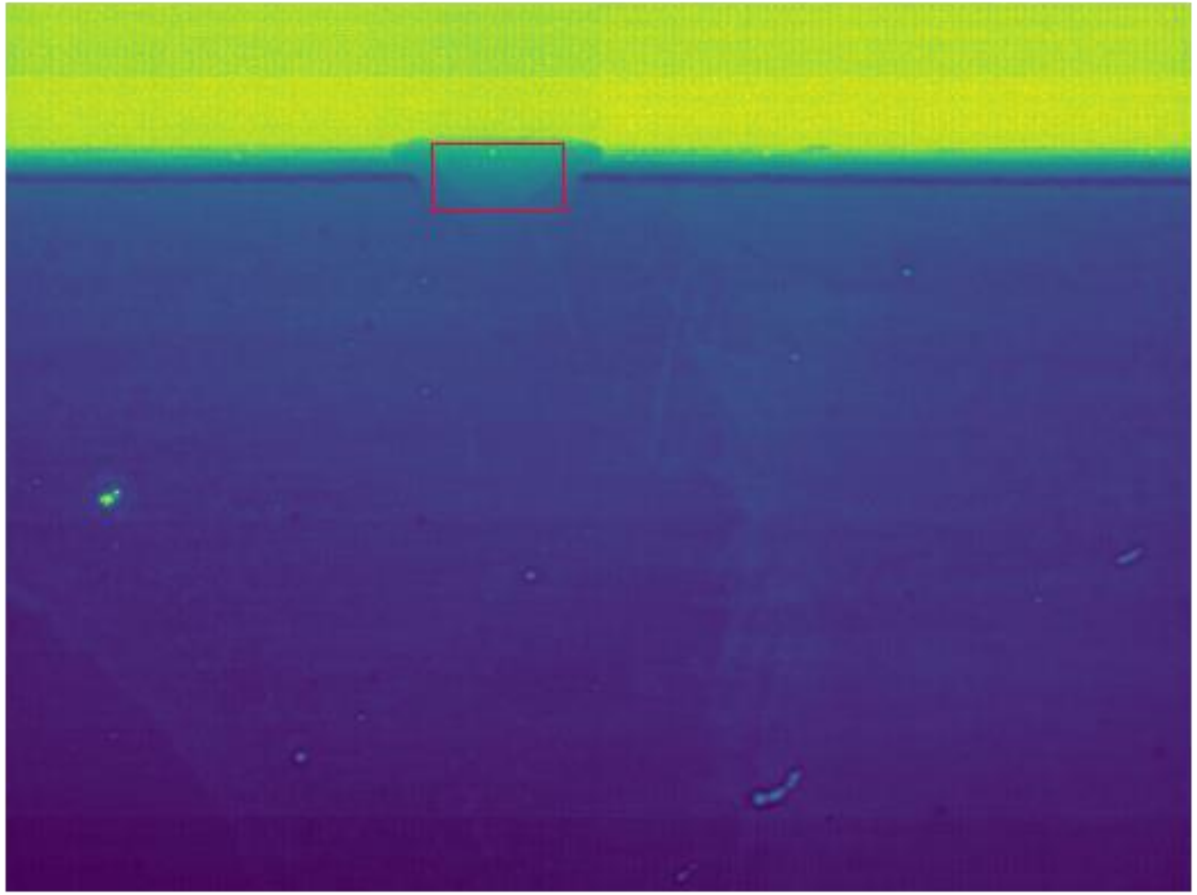


APS AM Simulator: Skeletonize Example

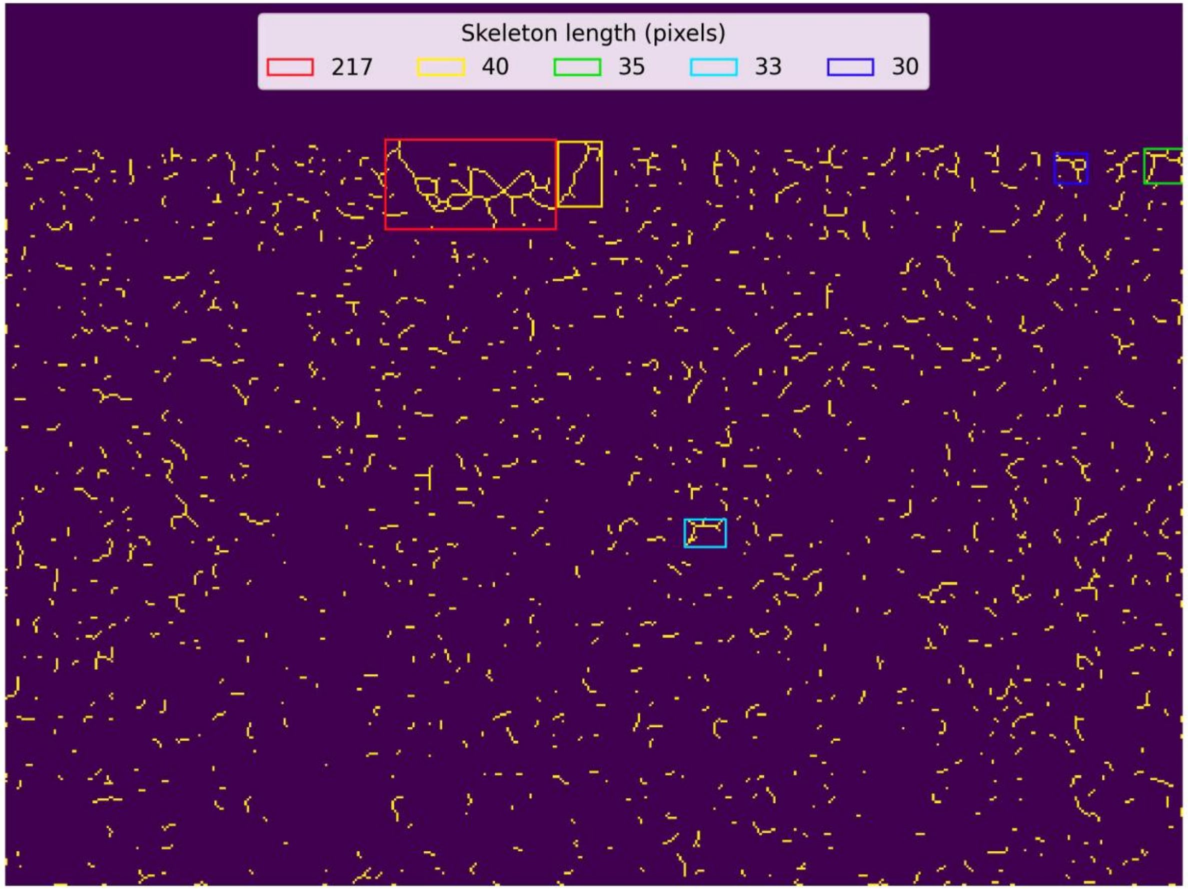


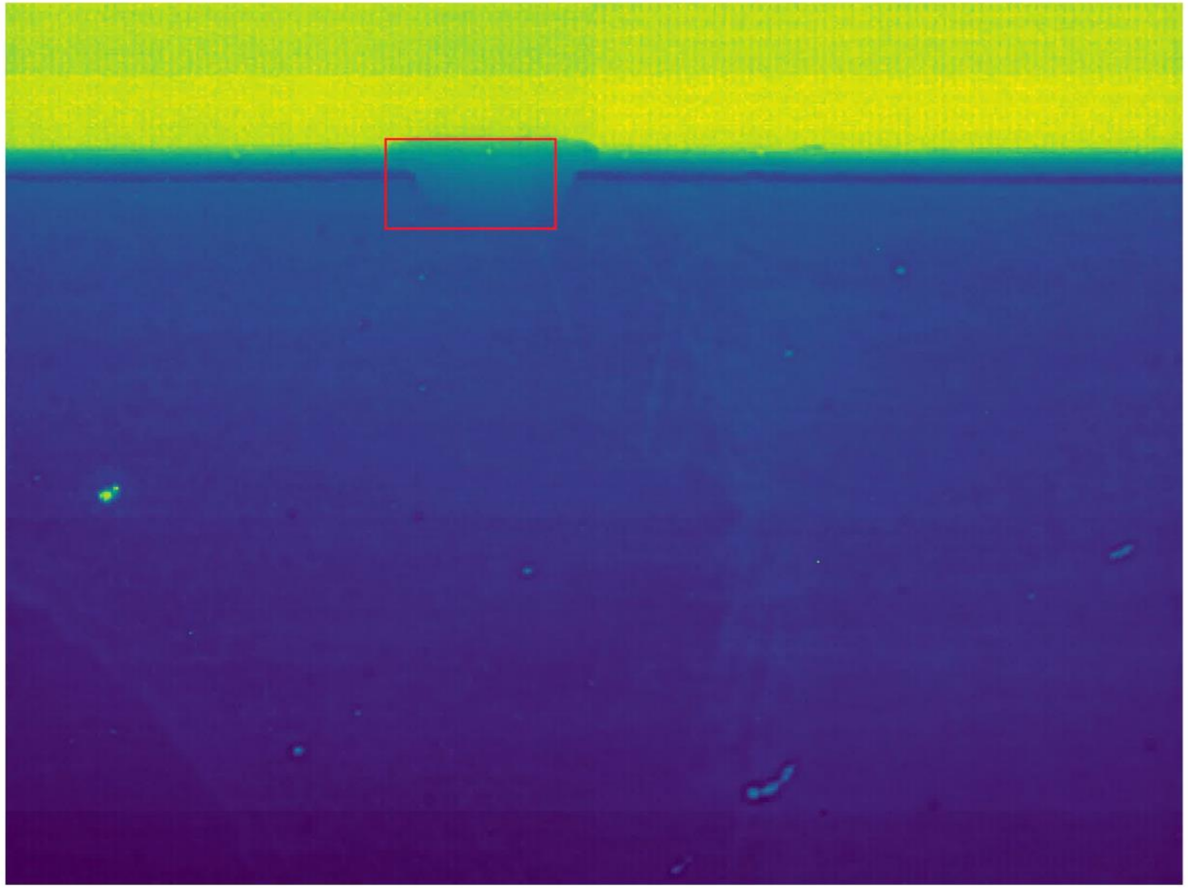
APS AM Simulator: Skeletonize Example





APS AM Simulator: Skeletonize Example



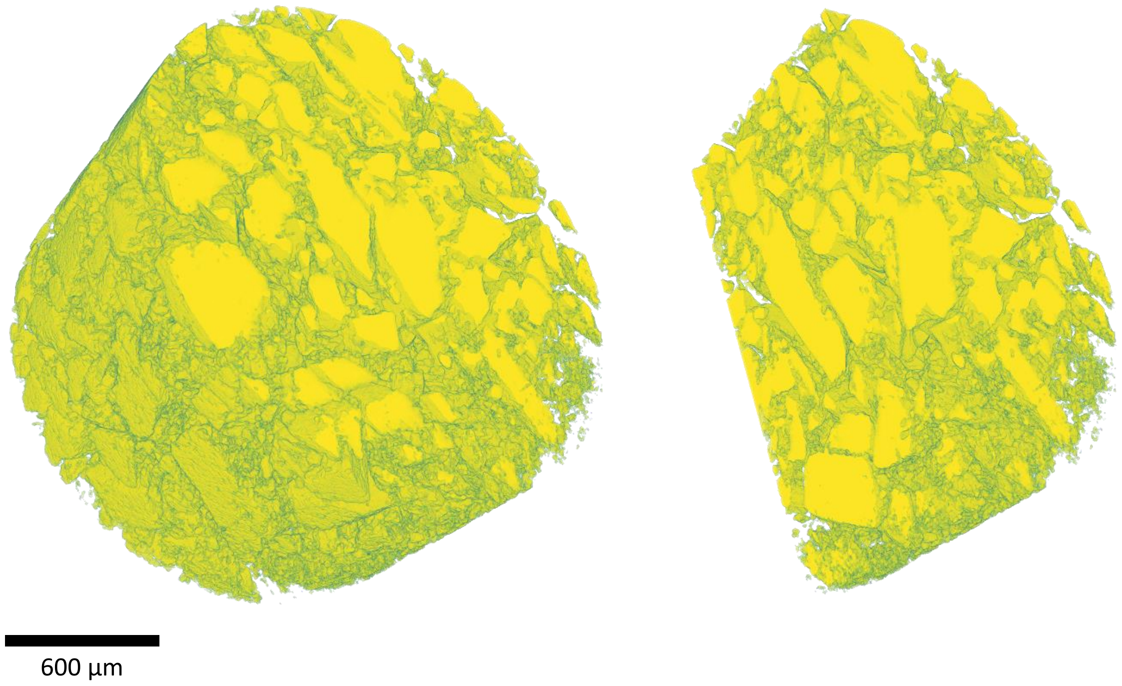


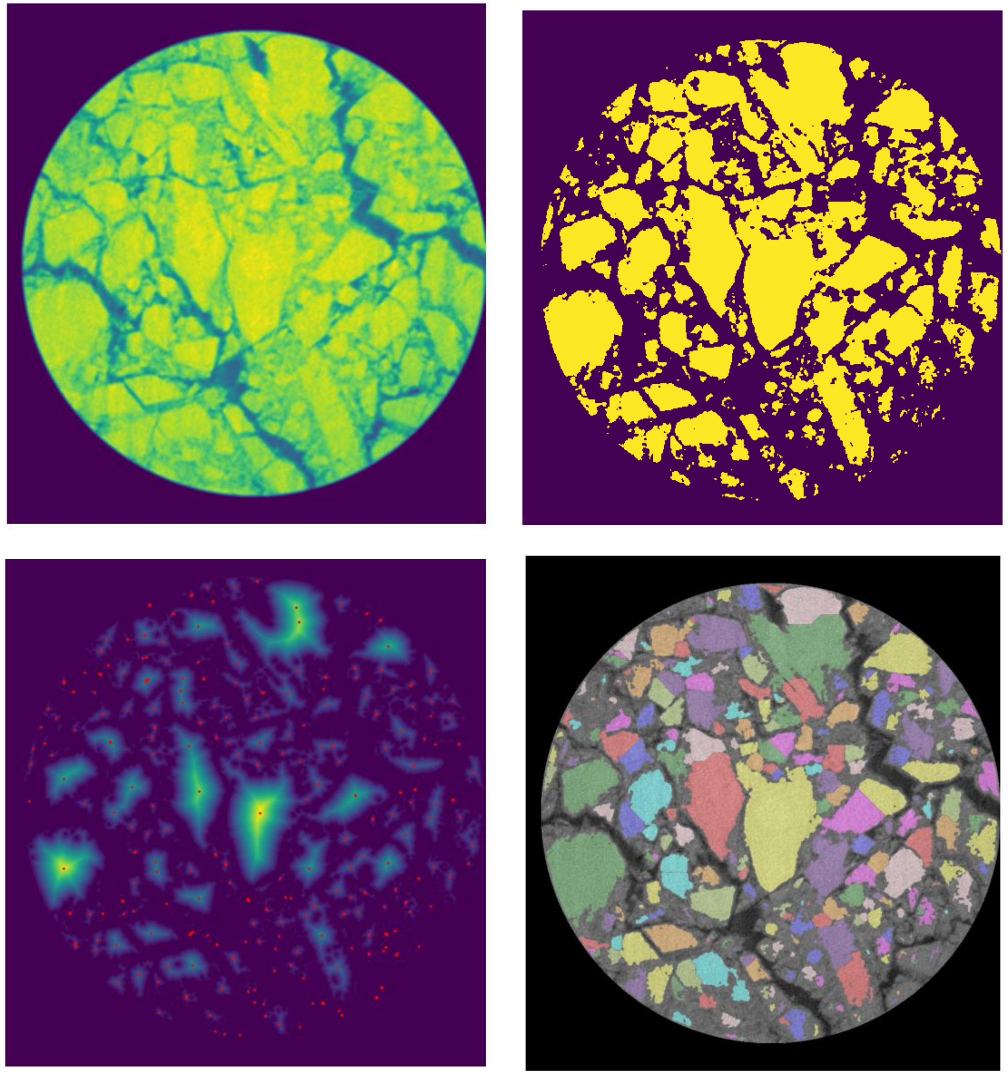
Center Proprietary – Terms of CANFSA Membership Agreement Apply

Mock HE Segmentation

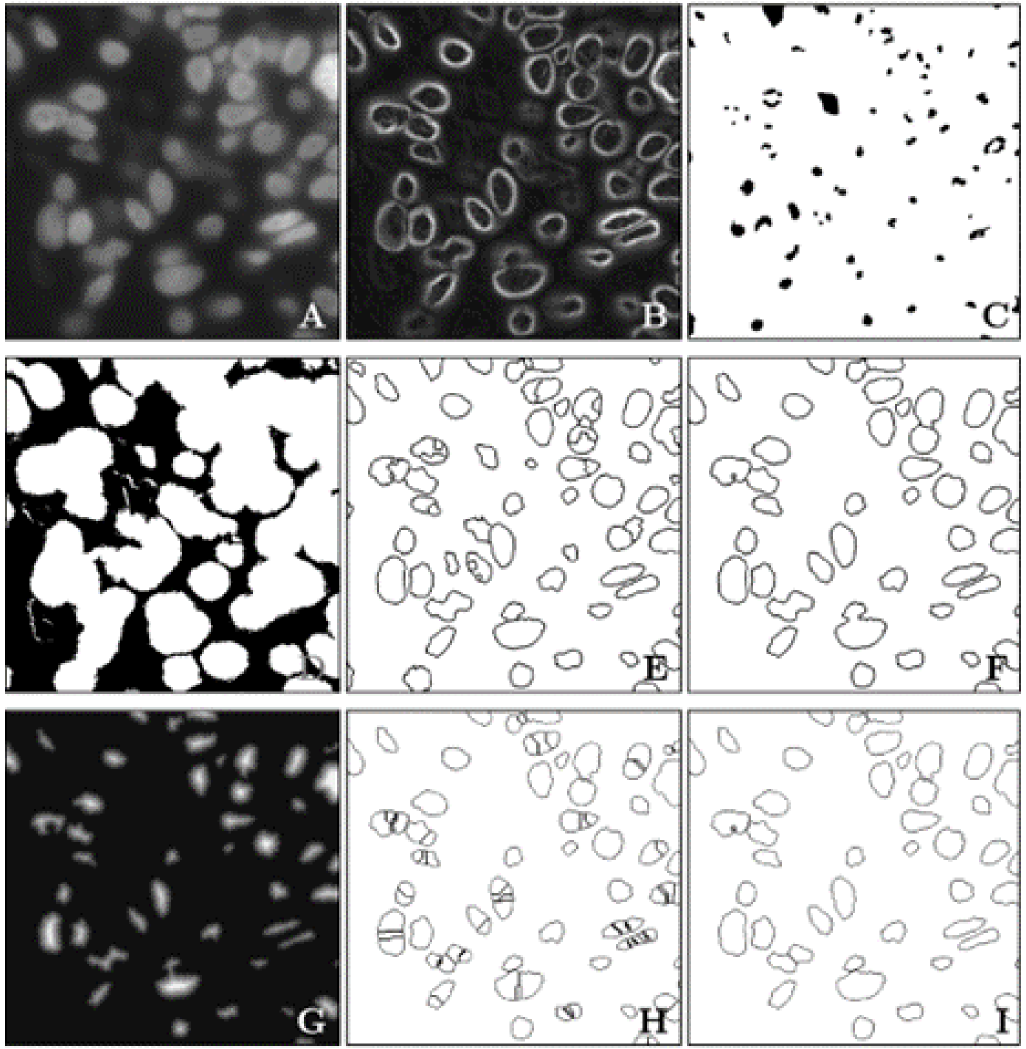
CENTER FOR ADVANCED NON-FERROUS STRUCTURAL ALLOYS

- IDOX surrogate material for HE
- Understand behavior during processing and deformation

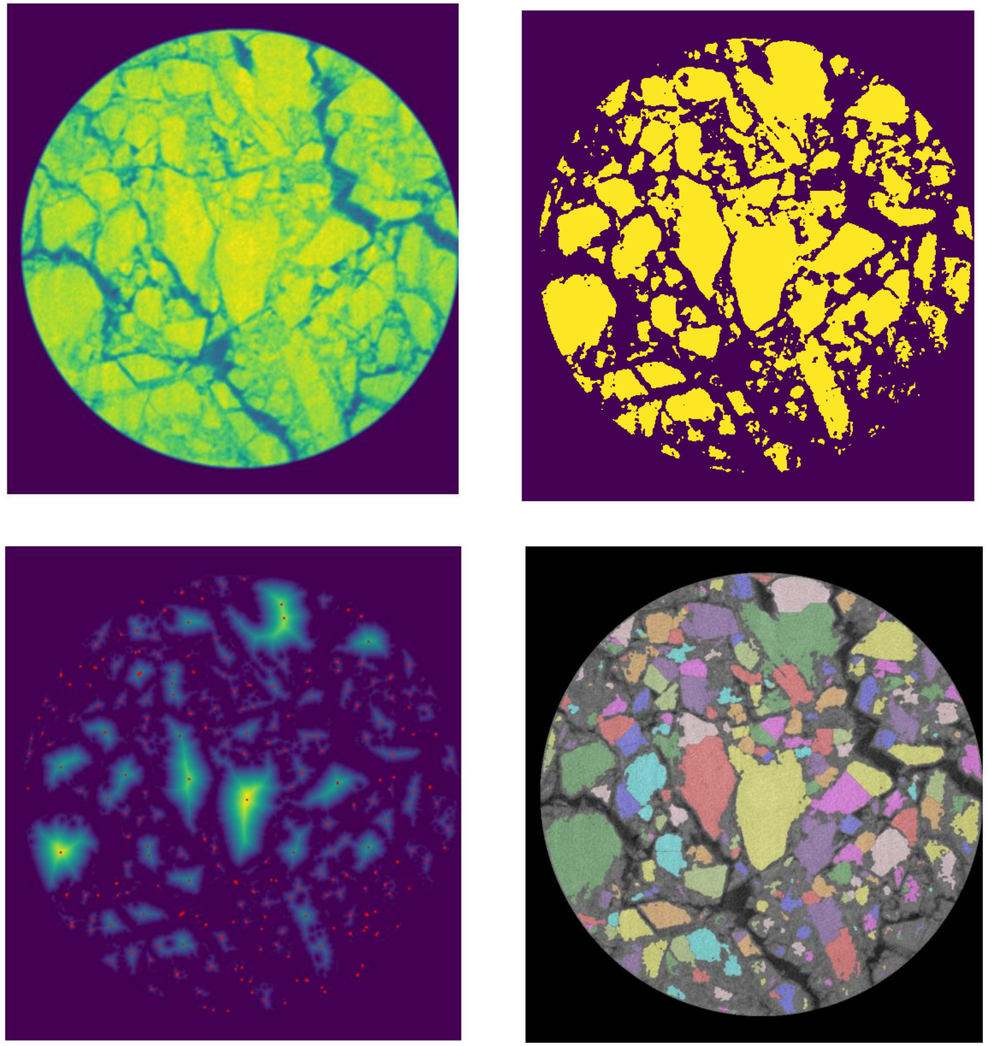




Mock HE Segmentation



[2] C. Wählby et al. J. Microsc. 215 (2004) 67–76.



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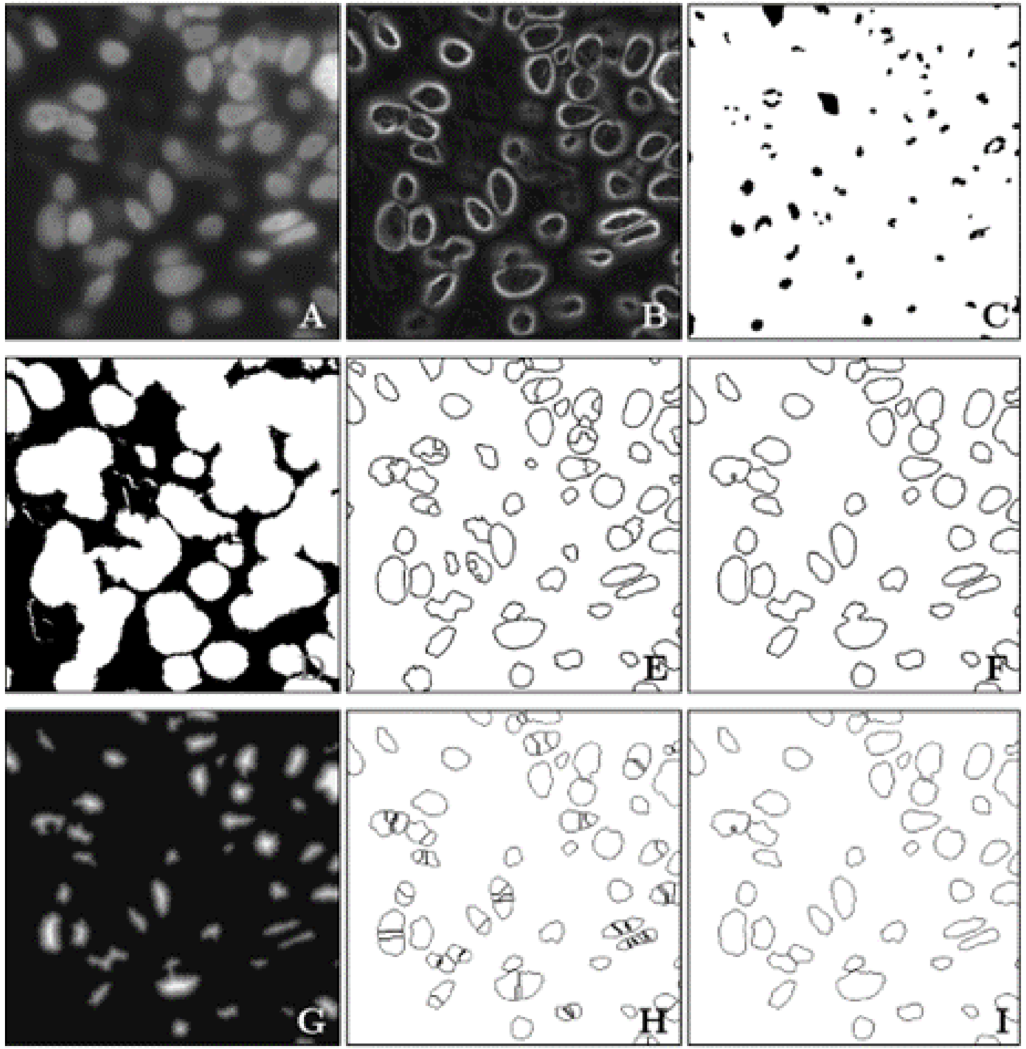


[2] C. Wälhby et al. J. Microsc. 215 (2004) 67–76.

A: Original fluorescence microscopy image slice of a tumor

B: Gradient of A.

C: Foreground seeds from local maxima.

D: Background seeds from local maxima of B (with removal of small components).

E: Seeded watershed segmentation.

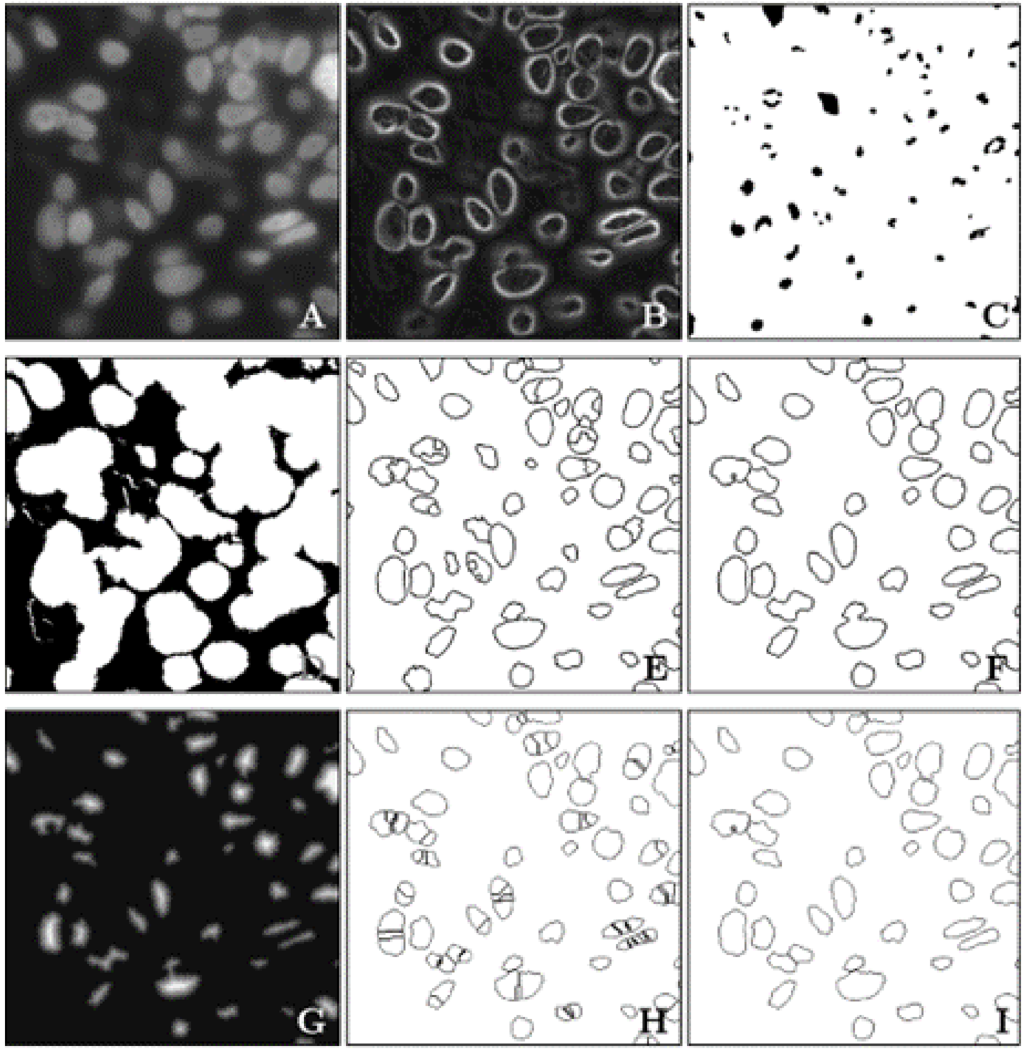
F: Merging of seeded objects based on edge strength.

G: Distance map of E.

H: Watershed segmentation of distance transform before merging.

I: Final segmentation result based on intensity, edge, and shape information.

Mock HE Segmentation



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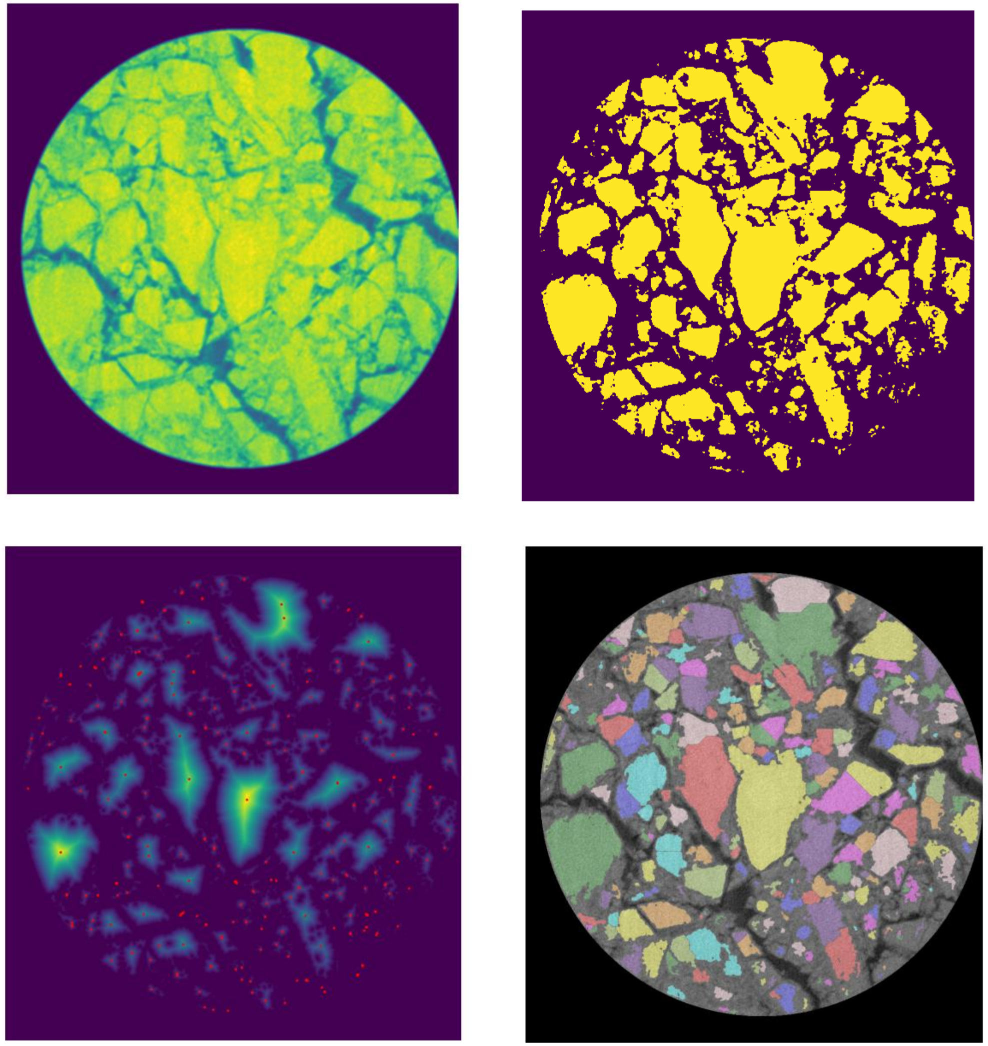
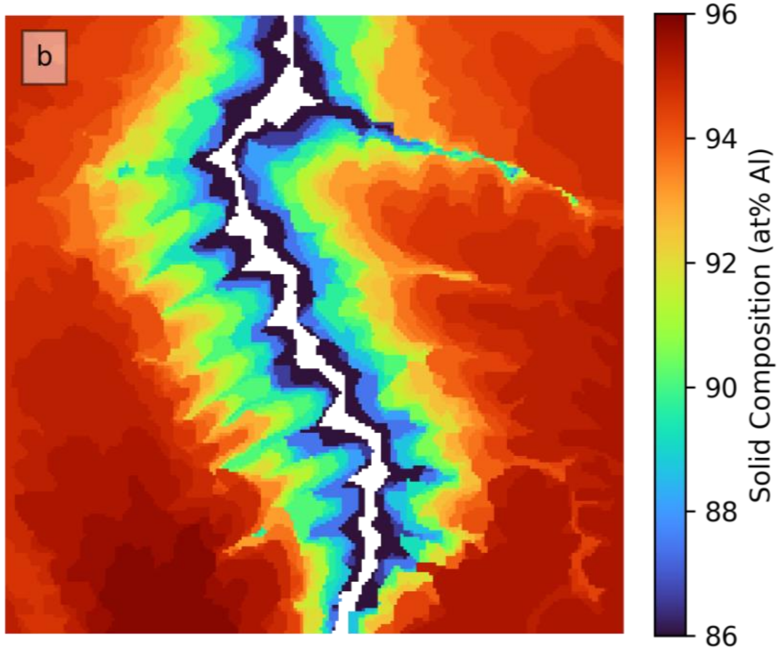
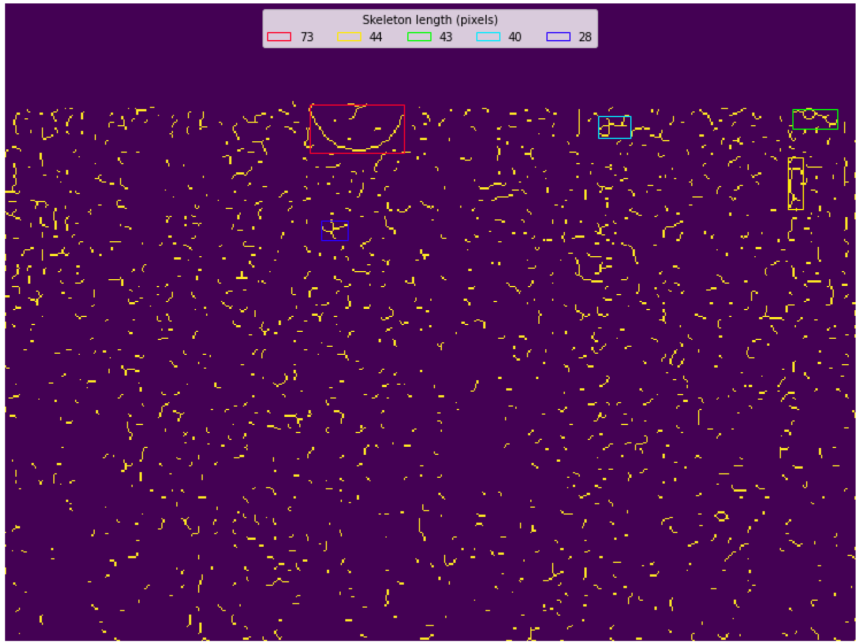


Summary

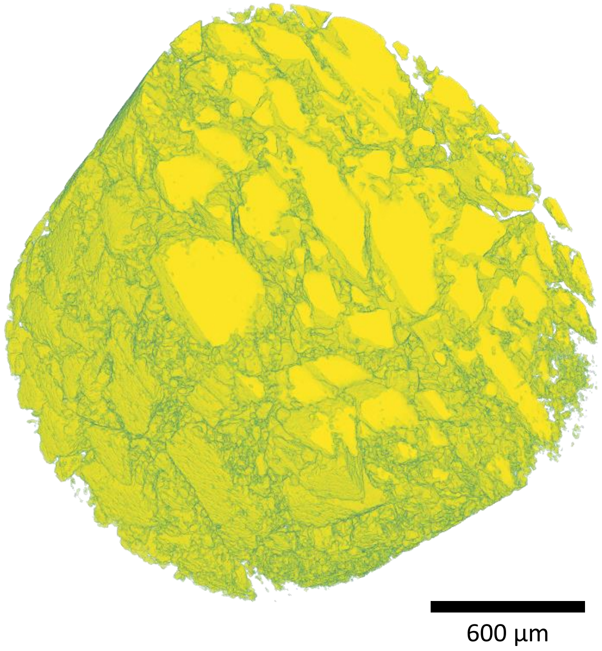
Correlating In Situ with Postmortem and Modeling



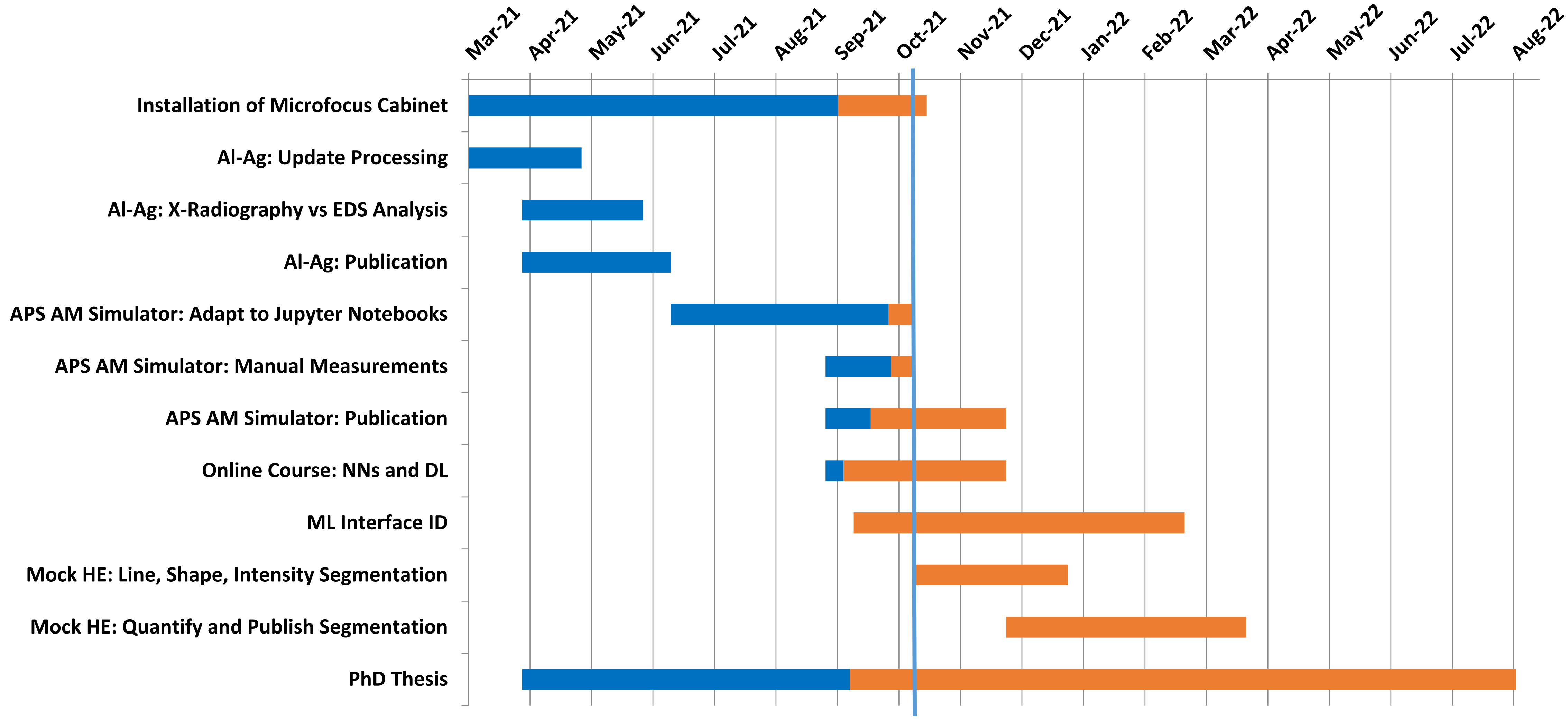
Automating Information Extraction for Modeling



Informing Deformation and Processing Modeling



Progress


Mar-21
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Oct-21
Nov-21
Dec-21
Jan-22
Feb-22
Mar-22
Apr-22
May-22
Jun-22
Jul-22
Aug-22
Installation of Microfocus Cabinet
Al-Ag: Update Processing
Al-Ag: X-Radiography vs EDS Analysis
Al-Ag: Publication
APS AM Simulator: Adapt to Jupyter Notebooks
APS AM Simulator: Manual Measurements
APS AM Simulator: Publication
Online Course: NNs and DL
ML Interface ID
Mock HE: Line, Shape, Intensity Segmentation
Mock HE: Quantify and Publish Segmentation
PhD Thesis

Challenges & Opportunities

- Python and Jupyter Notebooks for data processing and analysis
  - Reproducible workflows
  - Maximize data transfer across grad student “generations”
- Machine learning applications in identification and segmentation
- Quantifying success of segmentation

Thank you!

C. Gus Becker

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References

- [1] C. G. Becker, D. Tourret, D. Smith, B. Rodgers, S. Imhoff, J. Gibbs, J. Hunter, M. Espy, K. Clarke, A. Clarke, Integrating In Situ x-Ray Imaging, Energy Dispersive Spectroscopy, and Calculated Phase Diagram Analysis of Solute Segregation During Solidification of an Al-Ag Alloy, JOM. (2021). https://doi.org/10.1007/S11837-021-04884-8.
- [2] C. Wälhby, I.M. Sintorn, F. Erlandsson, G. Borgefors, E. Bengtsson, Combining intensity, edge and shape information for 2D and 3D segmentation of cell nuclei in tissue sections, J. Microsc. 215 (2004) 67–76. https://doi.org/10.1111/J.0022-2720.2004.01338.X.