Veryst Engineering

Engineering Through The Fundamentals

3D Printed Microfluidic Medical Devices: Rapid Prototyping Using LiveLink™ for MATLAB®

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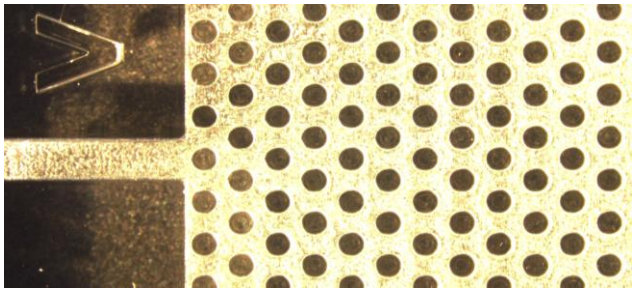
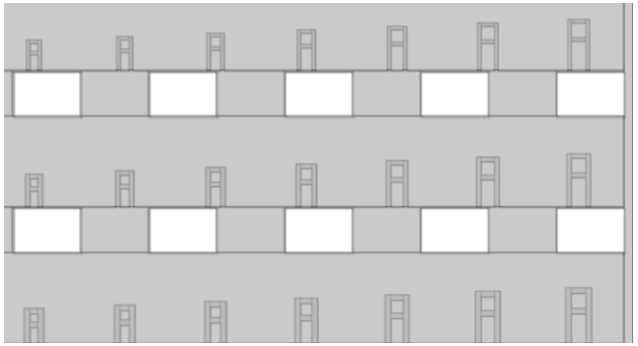
Outline

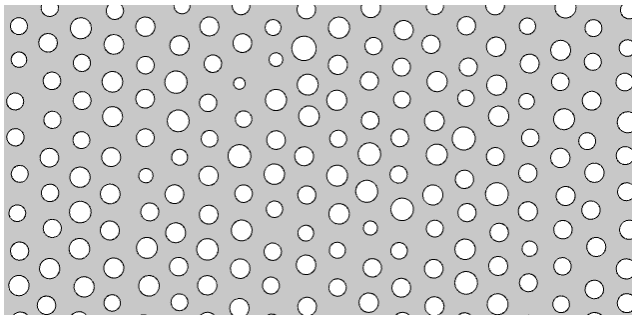
- There are limitations governing the ability to scale 3D printed devices down to the cellular scale



- We use LiveLink for MATLAB or Model Methods to determine the limits of our 3D printing process



- COMSOL Multiphysics simulations discern the effects of uncertainty in printing



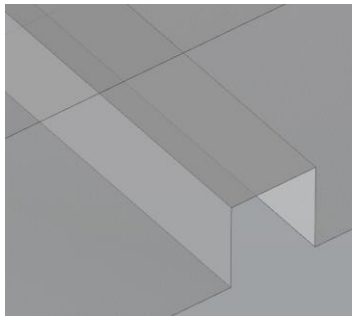
Good News: It is Easy to Start 3D Printing

- COMSOL Multiphysics can export geometry to 3D printer
- Numerous services available where you upload files, get feedback on which design features are likely too small, and receive prints via mail
- Variety of 3D printing technologies to choose from with pros and cons[1]
- For microfluidics, two good options are stereolithography (SLA) and PolyJet
- For this talk, we will use SLA and channels will be 1 mm tall

[1]For an excellent review, see Waheed, S., Cabot, J. M., Macdonald, N. P., Lewis, T., Guijt, R. M., Paull, B., & Breadmore, M. C. (2016). 3D printed microfluidic devices: enablers and barriers. *Lab on a Chip*, *16*(11), 1993-2013.

3D Printers Have Limits in Feature Size

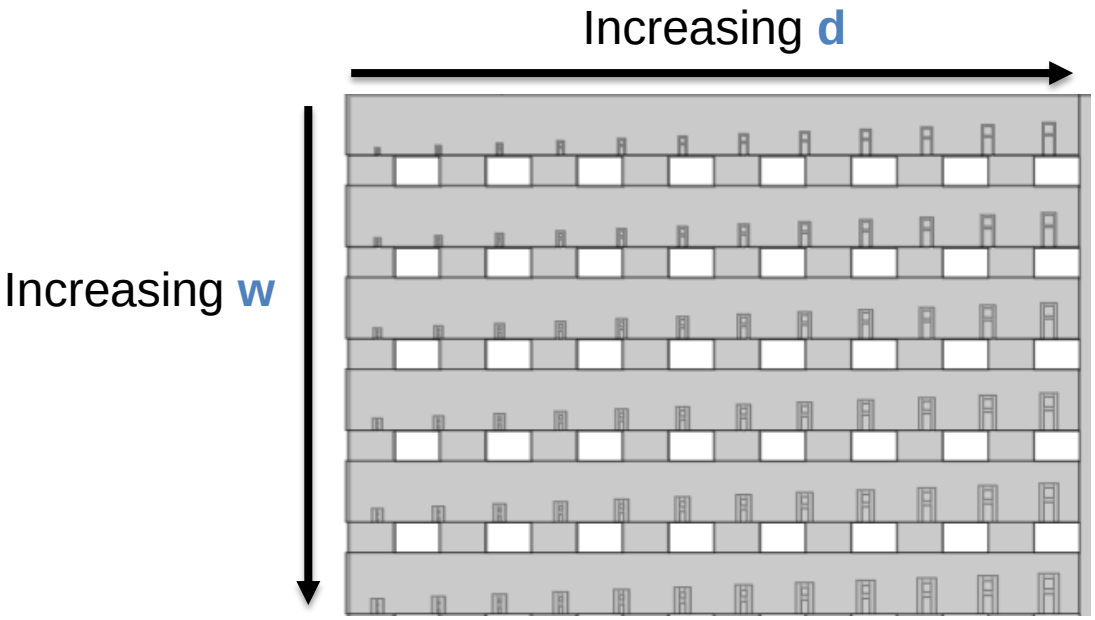
- I can draw a thin channel

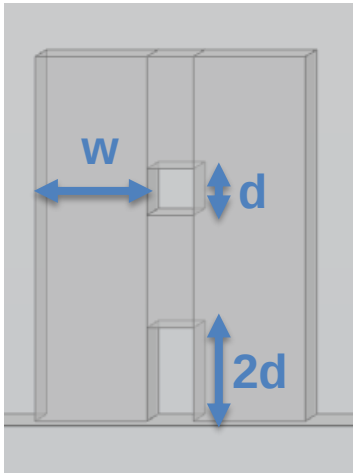


- But it may not print!
  - Resolution of printer
  - Support material
  - Drainage
- Drainage is a large concern for complex designs

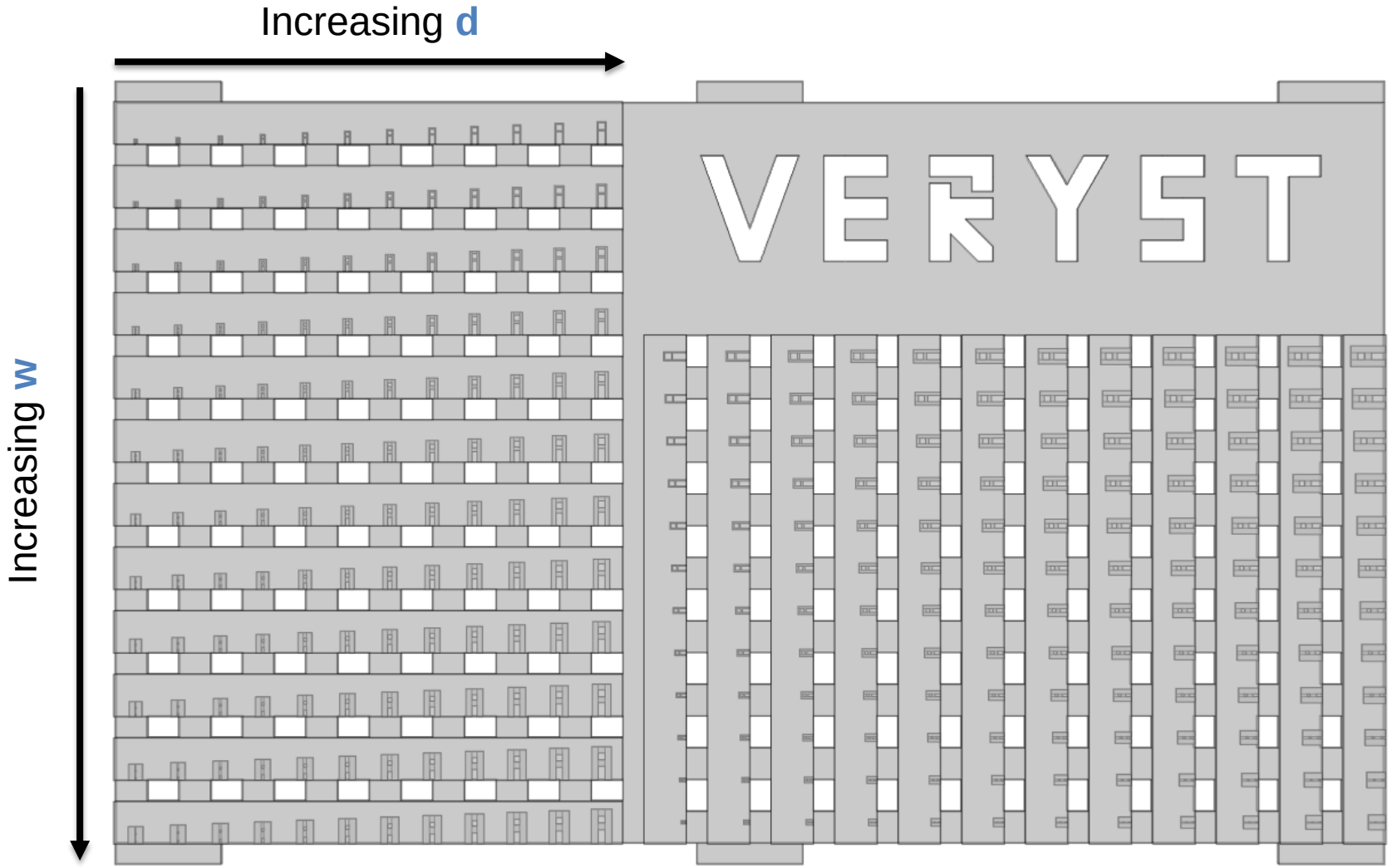
Strategy for Printing Quickly and Effectively

- Find important features in medical device
- Break features down into parameterized geometry
- Use Livelink with Matlab or Model Methods to create a calibration test grid and determine what can be printed

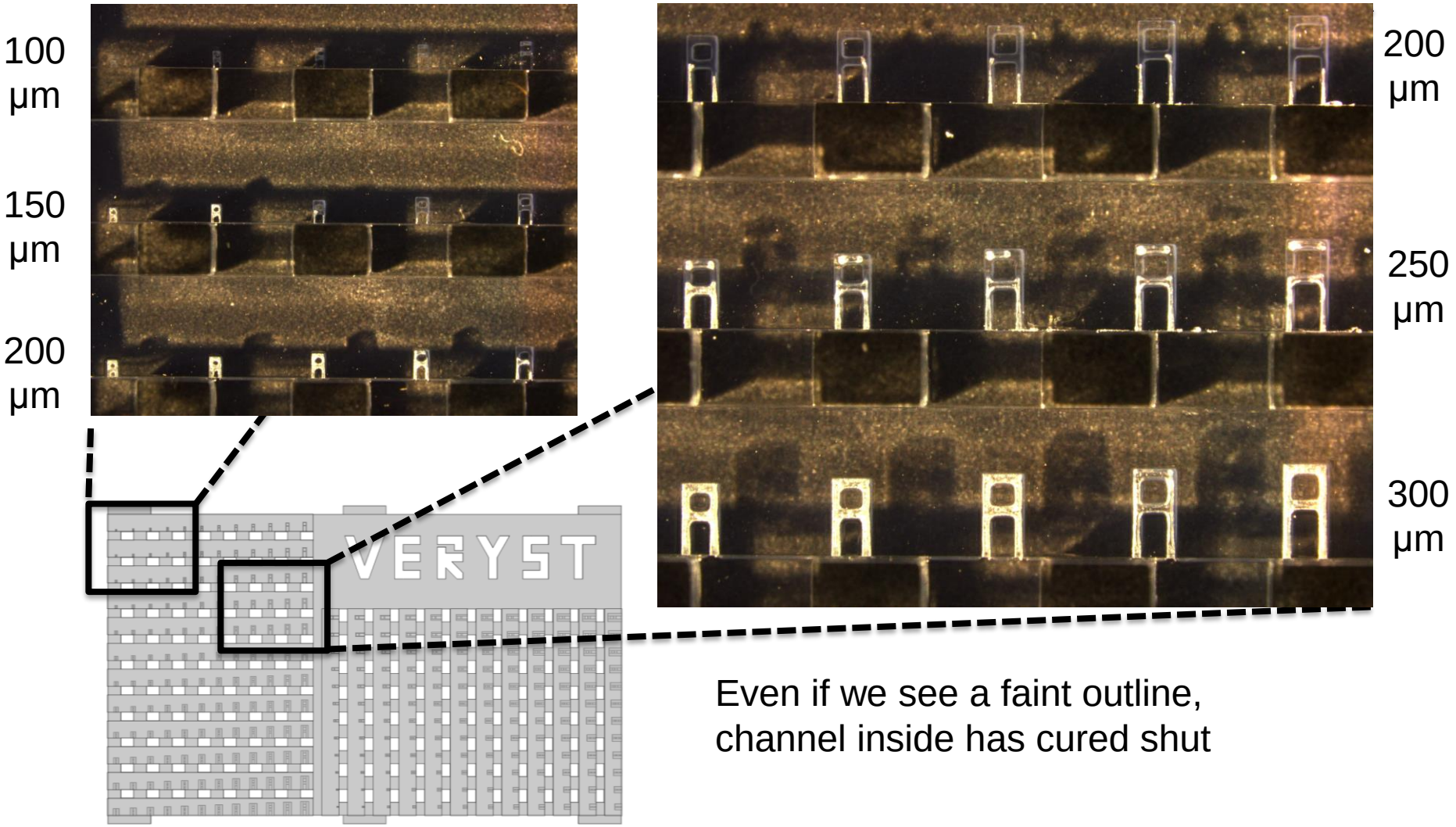




Grid with **d**, **w** in Range(100 µm, 50 µm, 650 µm)



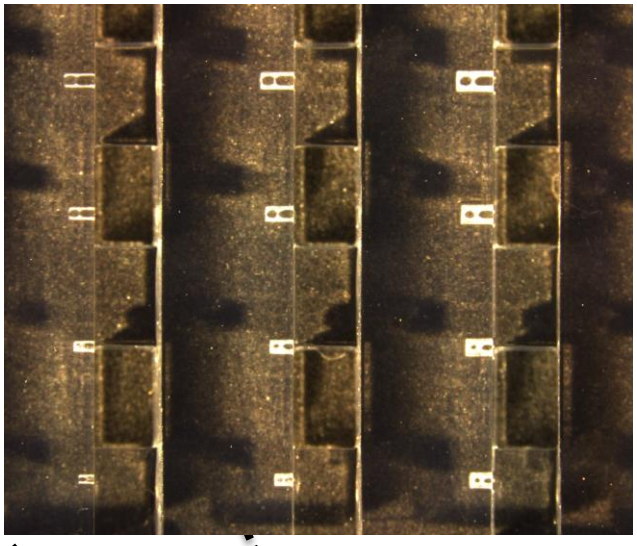
Result: Can't Reliably Print Channels Below 300 µm

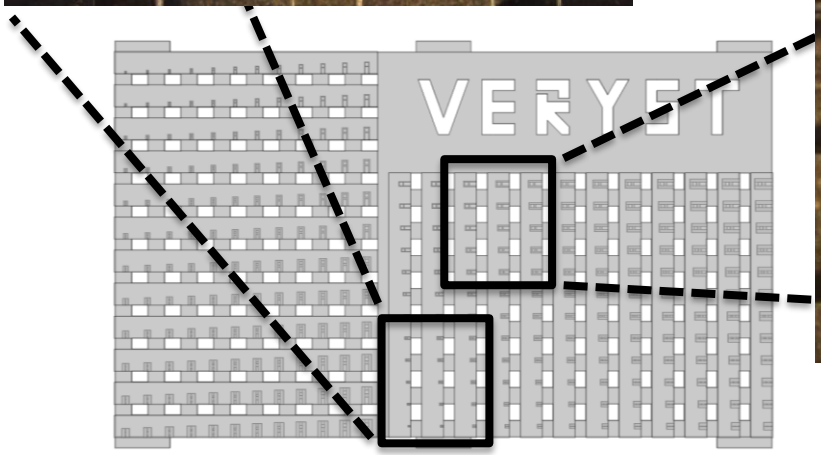


Even if we see a faint outline, channel inside has cured shut

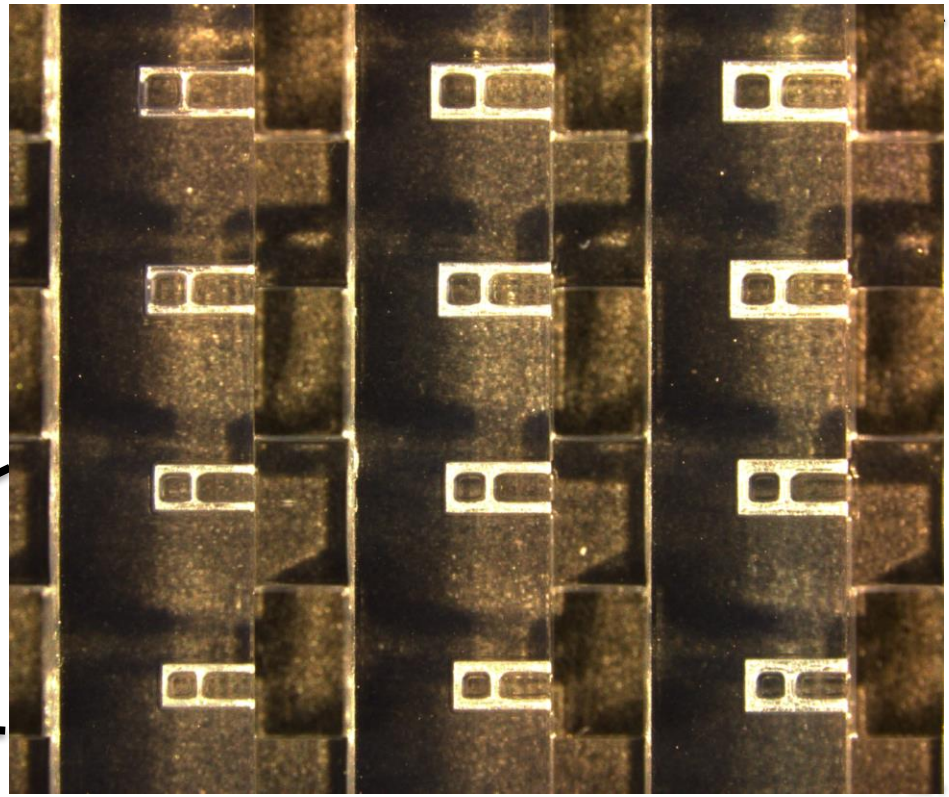
Rotated Grid to Test Printer Orientation Bias

100 µm 150 µm 200 µm



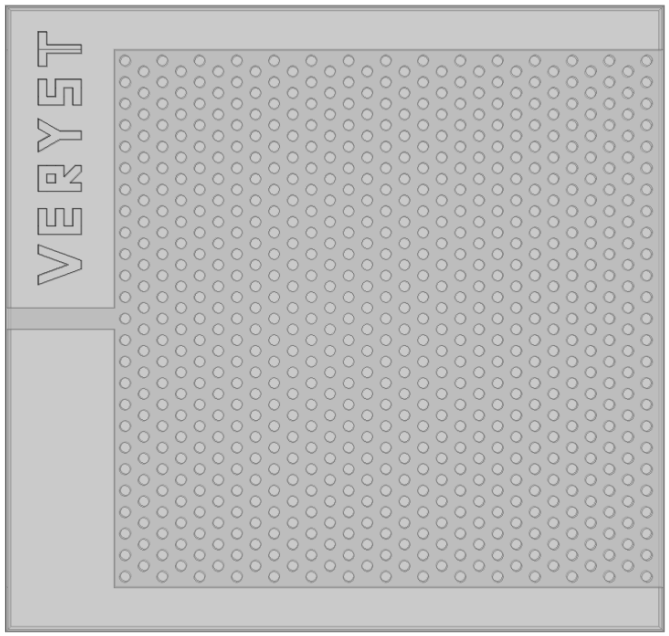


200 µm 250 µm 300 µm



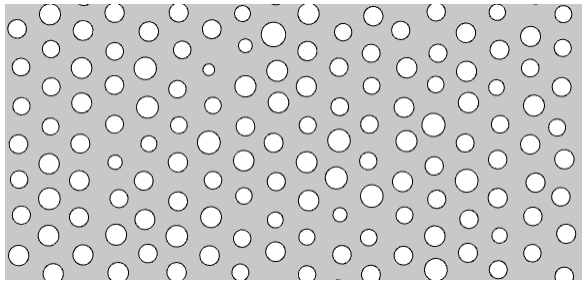
Incorporating COMSOL Simulation: Post Test

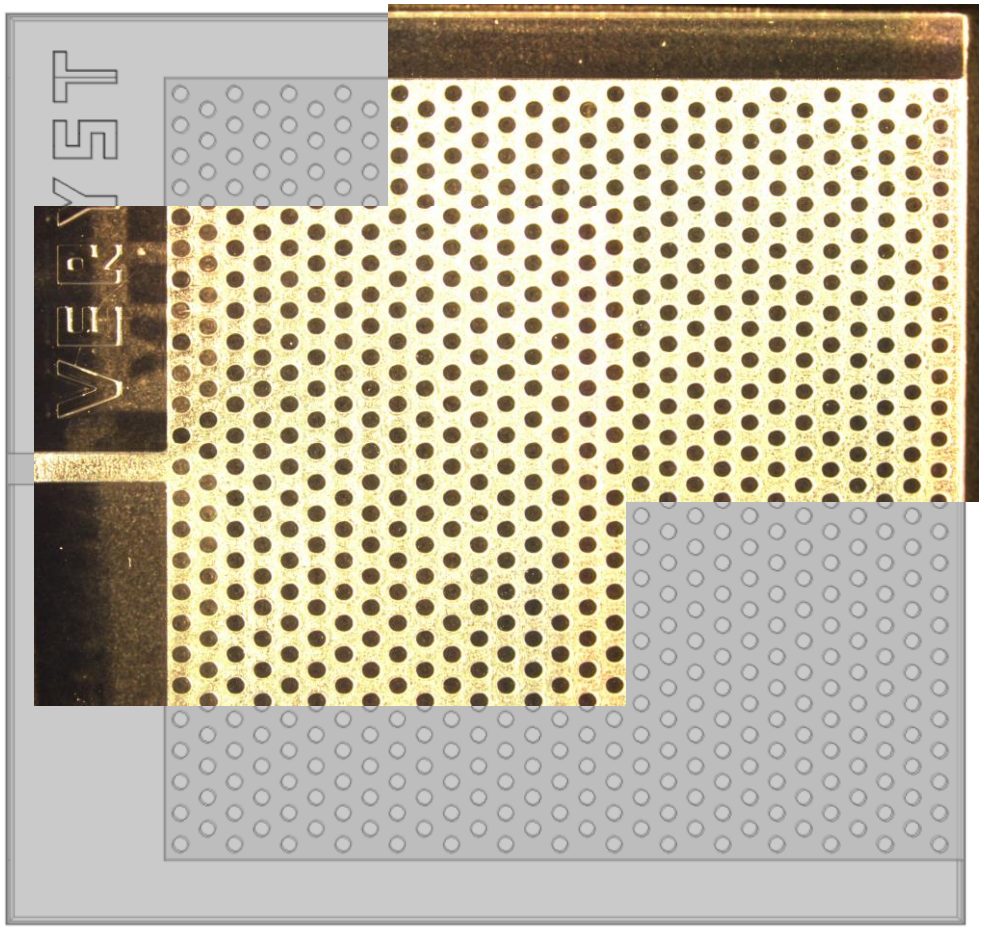
- We've established there is a gap between what we specify and the print we receive
- How would this affect our flow pattern?
- We use Livelink for MATLAB and COMSOL Multiphysics to perturb the geometry to see the effect on flow simulations



Uncertainty in Geometry

- In a perfect world
  - 500 μm post diameter
  - 1 mm distance between post centers
- For our uncertain world, add Gaussian noise of standard deviation 50 μm to
  - Post diameter
  - Post center x-coordinate
  - Post center y-coordinate

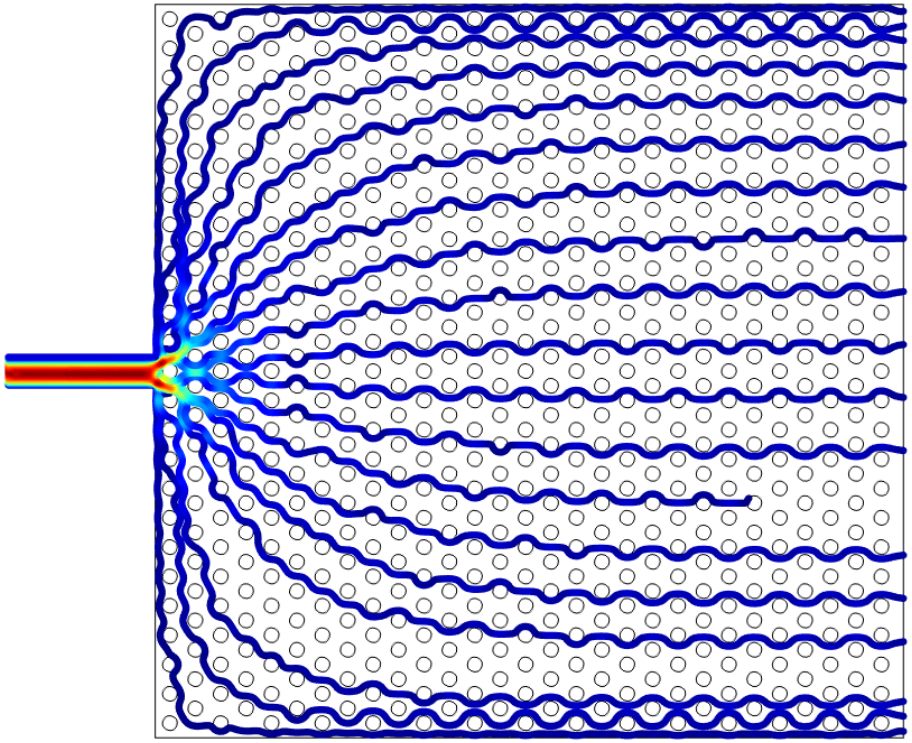




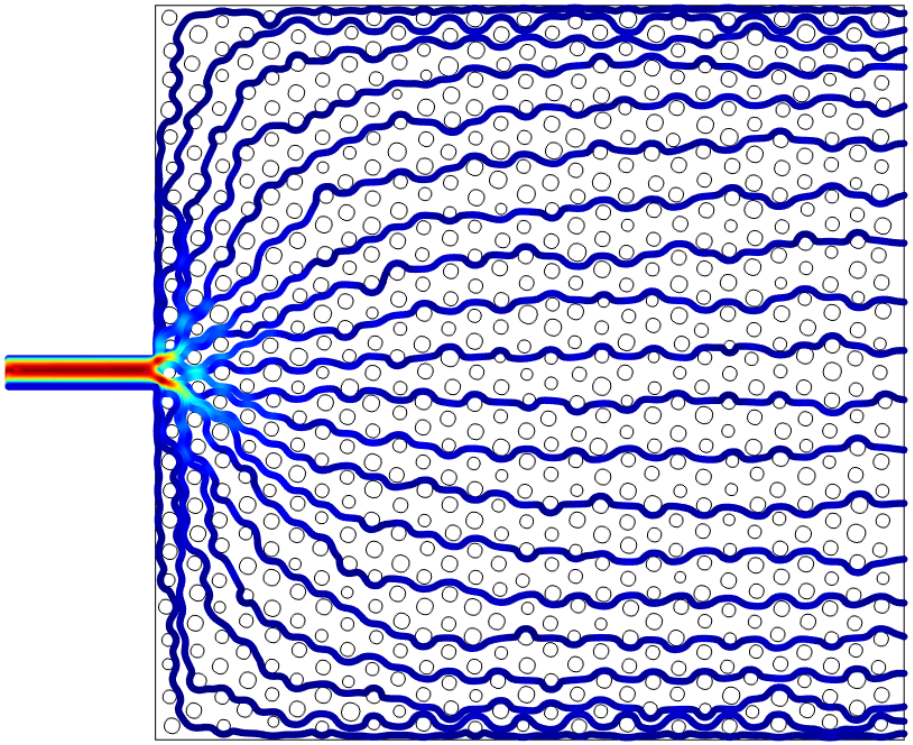
Modular connections omitted

Creeping Flow Streamlines

Perfect Geometry



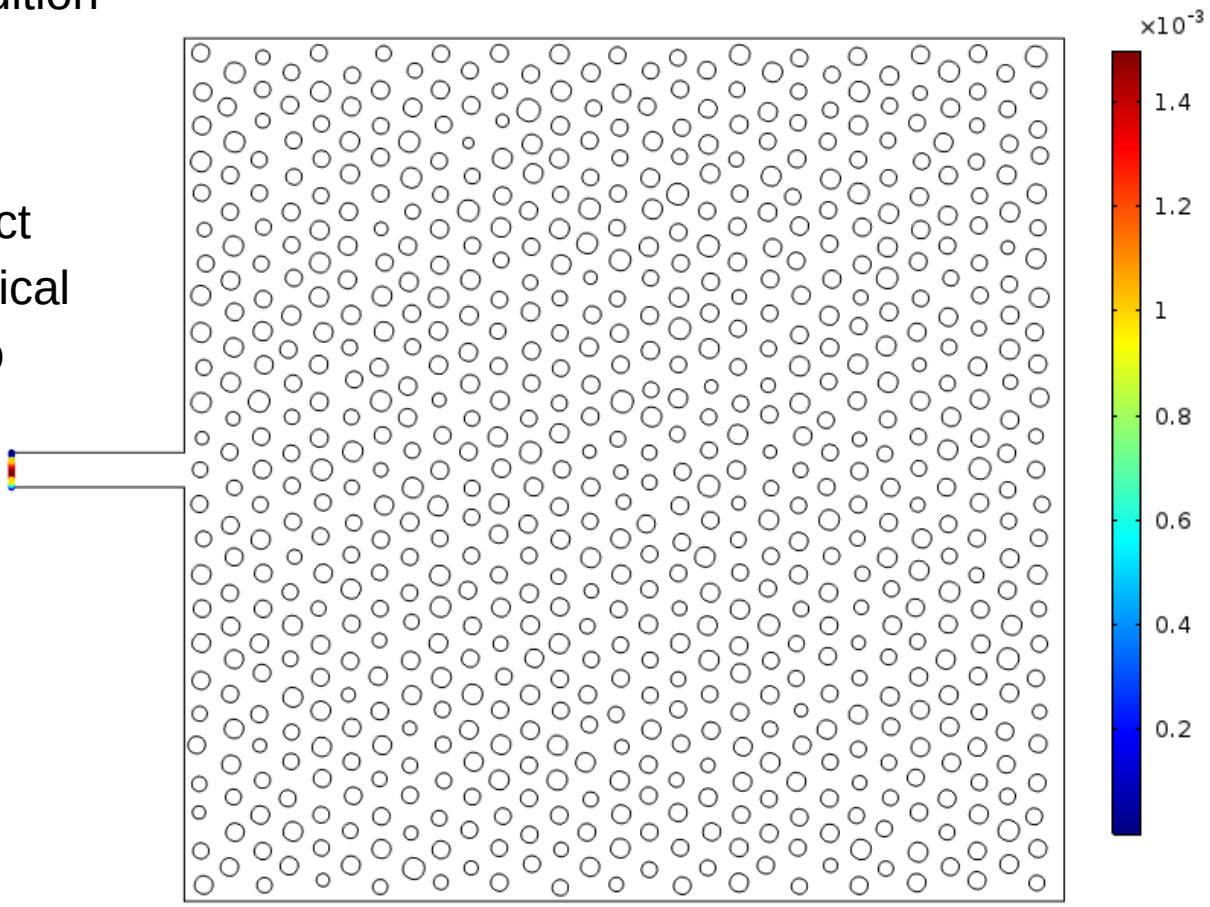
Perturbed Geometry



Colored by velocity

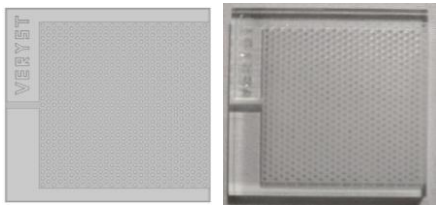
Particle Tracing Visualization

- 10000 particles
- Diffuse scattering condition at walls and posts
- Perturbed geometry
- Not intended as a direct representation of physical parameters relevant to application

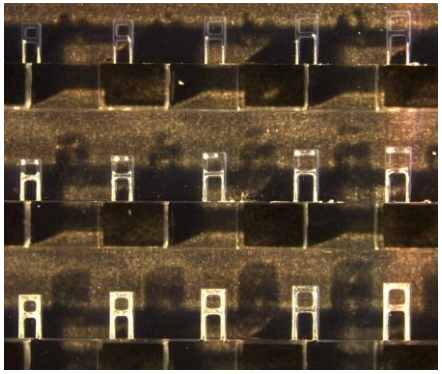


Summary

- COMSOL Multiphysics makes it easy to realize your designs with 3D printing



- Test the limits of your 3D printer using Livelink for MATLAB or Model Methods



- Use Livelink for MATLAB and COMSOL Multiphysics to ask how simulations can change under perturbed conditions