The Design of A High Resolution Bio-Printer

Matthew Benning

Introduction

- A definition of **bio-printing**.
- Newcastle University's **work**, **capabilities** and the **rationale** for system development.
- A walk-through of the **design** of Bio-printers and sub-systems.

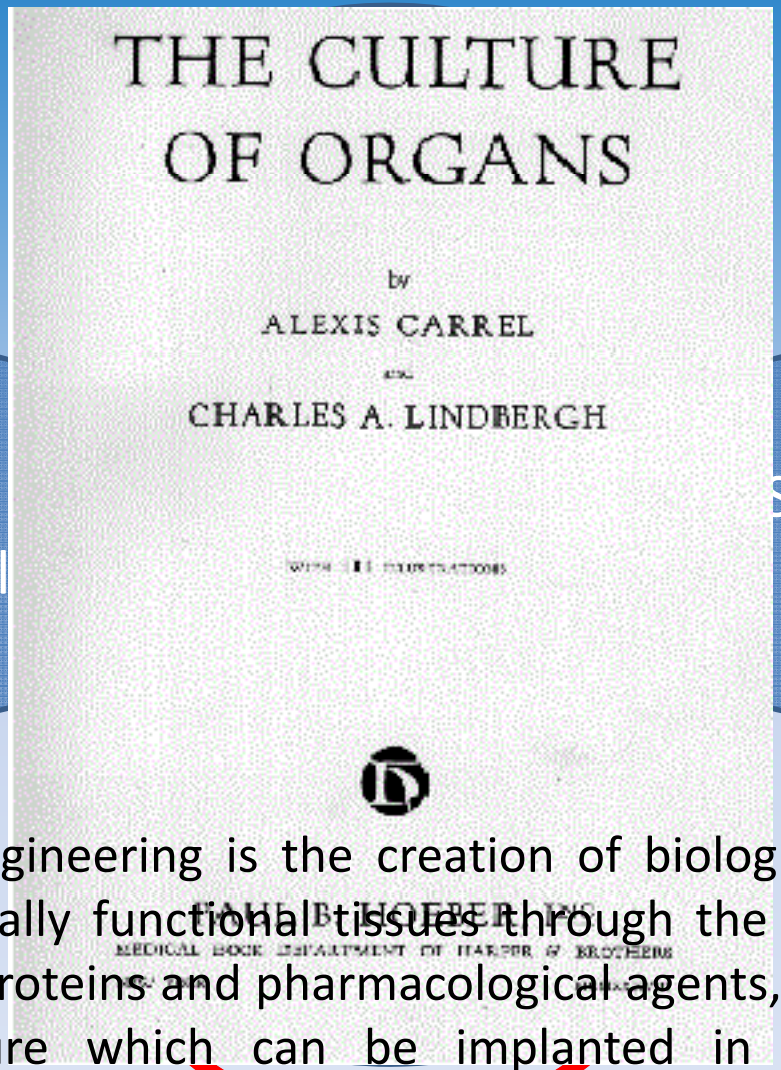
- About me…
  - I completed my PhD at Newcastle with:

"Development of a Novel Electrophotographic Additive Layer Manufacturing Machine"

  - 2011 onwards - Research Associate at Newcastle University
    - Biological printing and bio-fabrication
      - » Specific interest in process design

Bio-Material

Scaffold Design



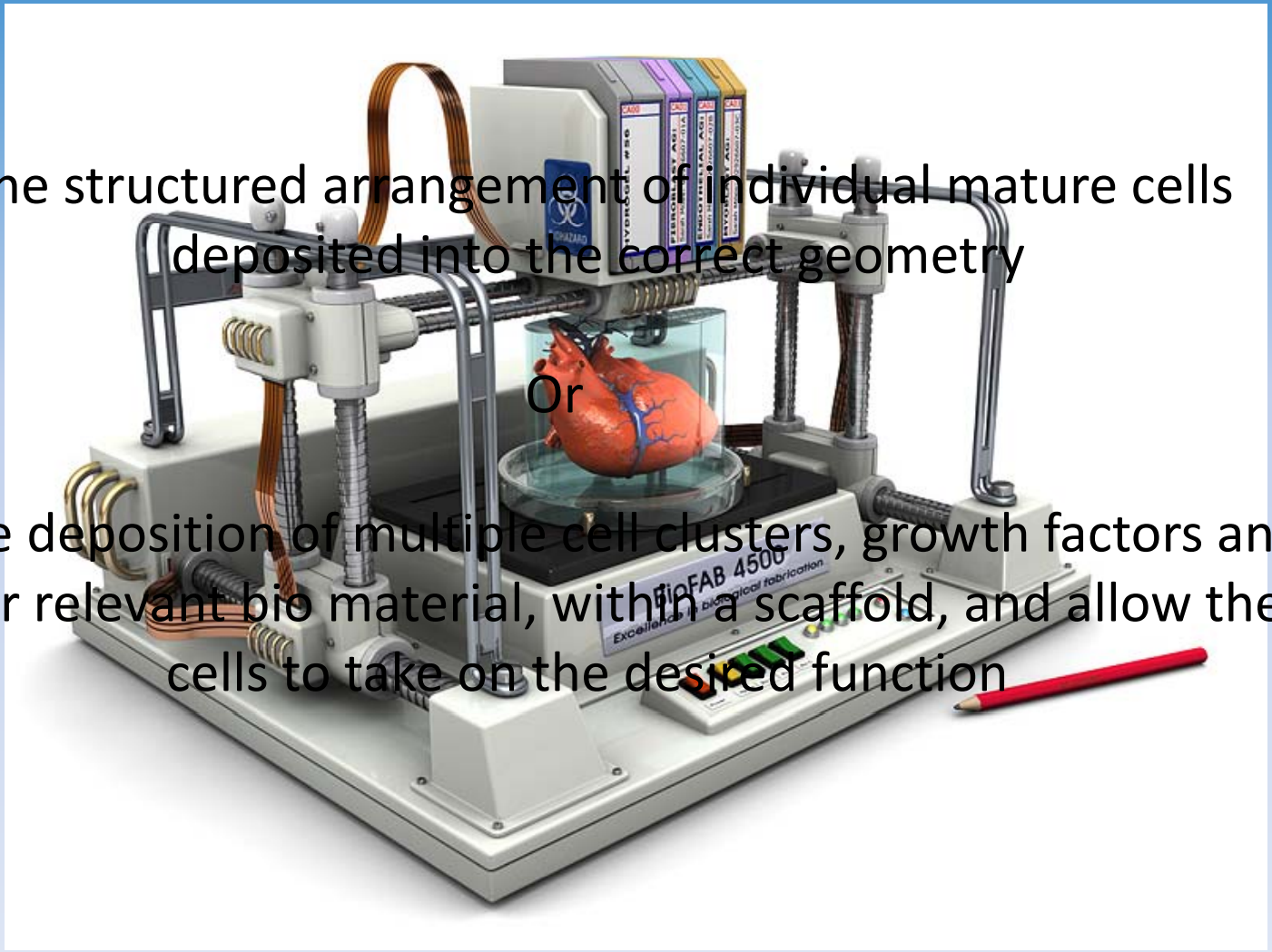
Tissue engineering is the creation of biologically and mechanically functional tissues through the assembly of cells, proteins and pharmacological agents, to create a structure which can be implanted in order to regenerate new tissue *in vivo*.

The Bio-Printing Concept

1. The structured arrangement of individual mature cells deposited into the correct geometry

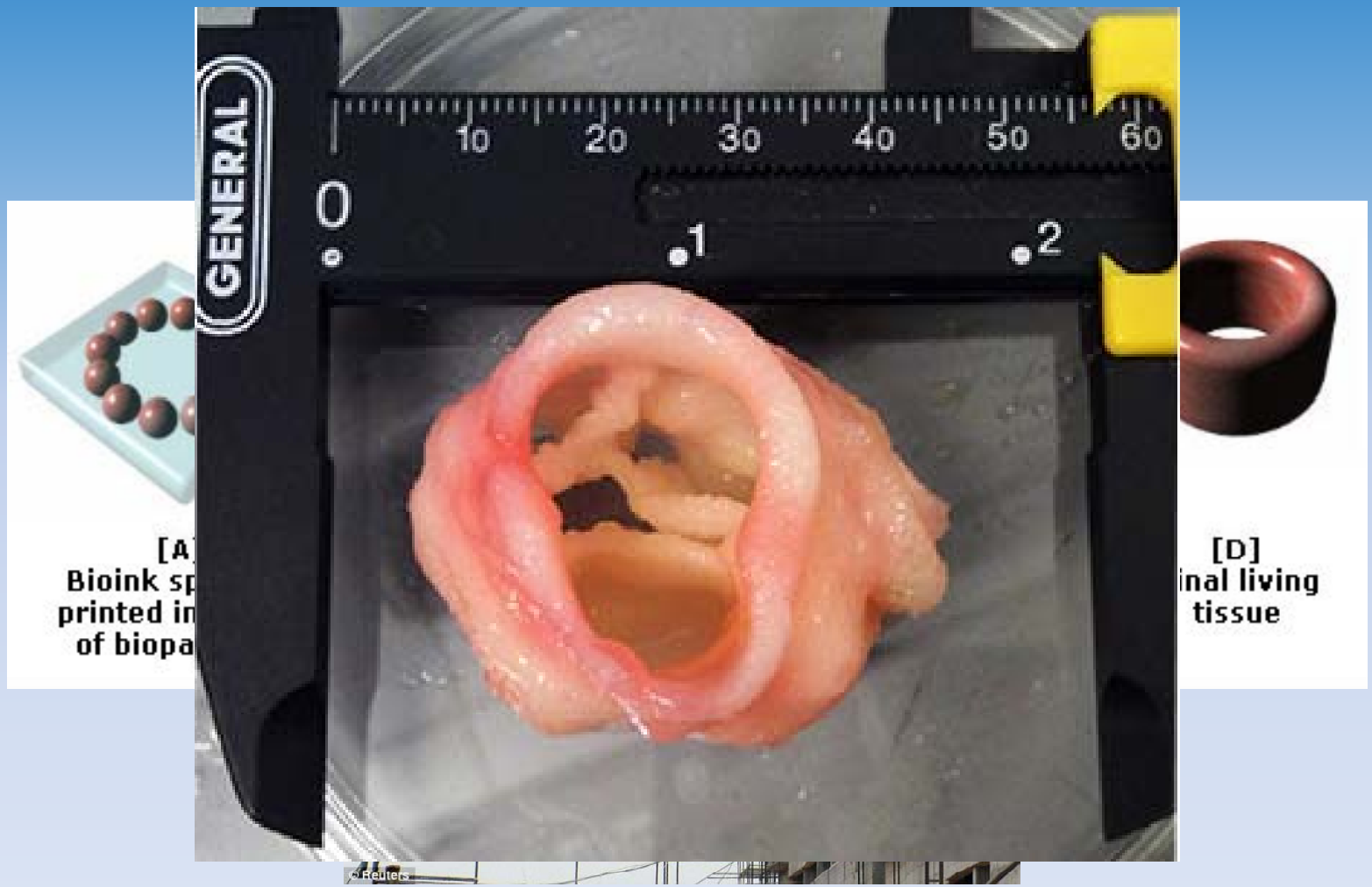
Or

2. The deposition of multiple cell clusters, growth factors and other relevant bio material, within a scaffold, and allow the cells to take on the desired function



www.explainingthefuture.com/bioprinting.html

Cell Scaffolds



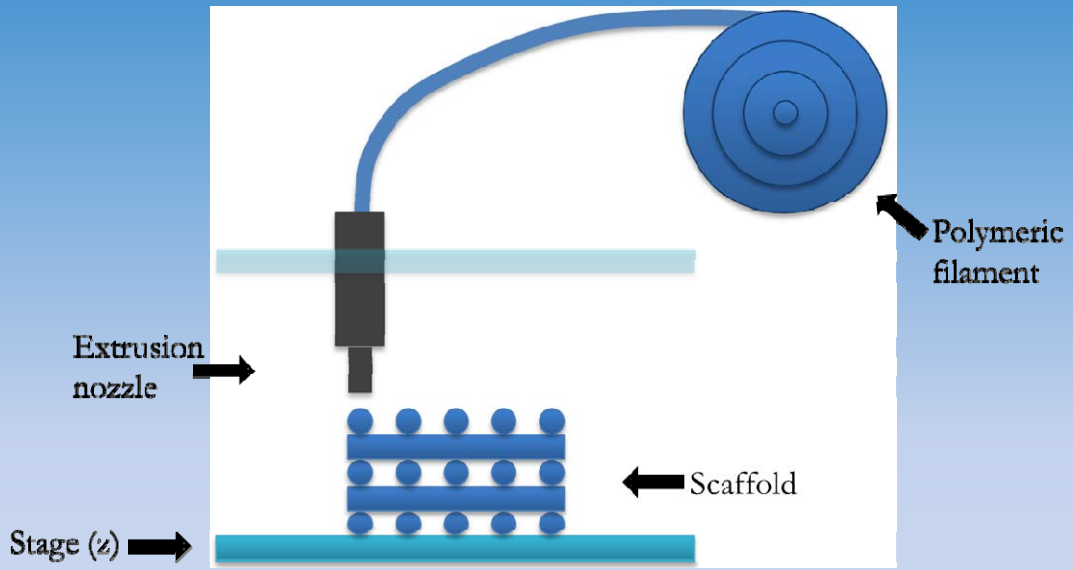
Duan B, Hockaday LA, Kang KH, Butcher JT. 2013. 3D Bioprinting of heterogeneous aortic valve conduits with alginate/gelatin hydrogels. J Biomed Mater Res Part A 2013:101A:1255–1264.

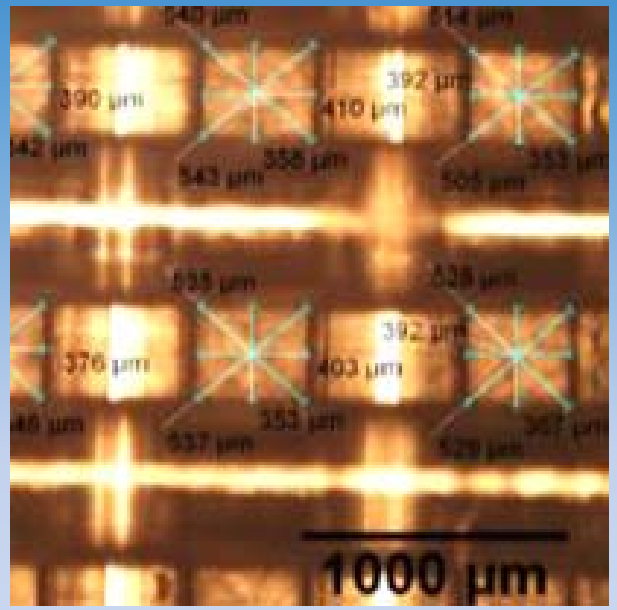
www.organovo.com

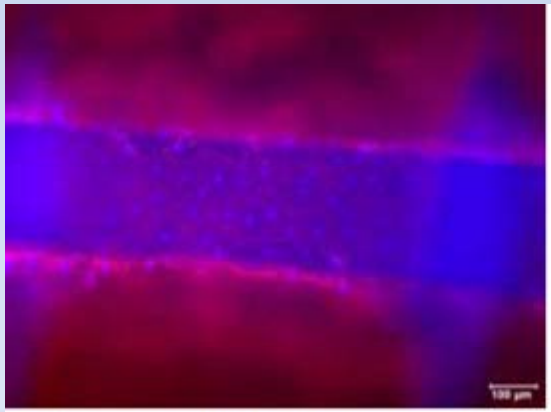
Our Research Aim

- Build rigid, biodegradable, scaffolds for load bearing applications. E.g Bone grafts and Osteochondral plugs…
- Develop focused and affordable printing apparatuses for point of use manufacturing. E.g in clinic production of cell a scaffolds combined with autologous minimally manipulated cells.

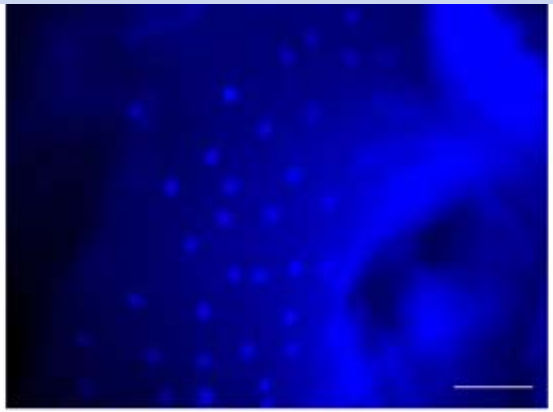
Ridged Scaffold Production - FDM



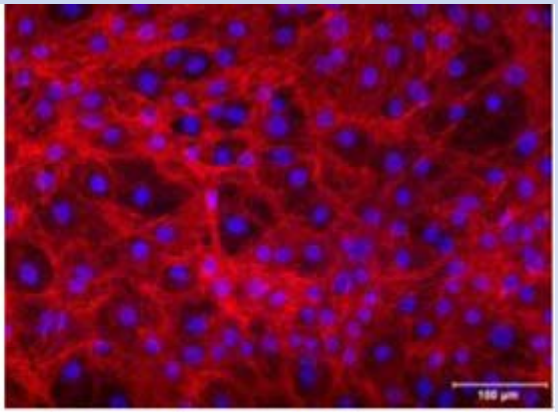




Cell atachment to 3D PLA scaffold

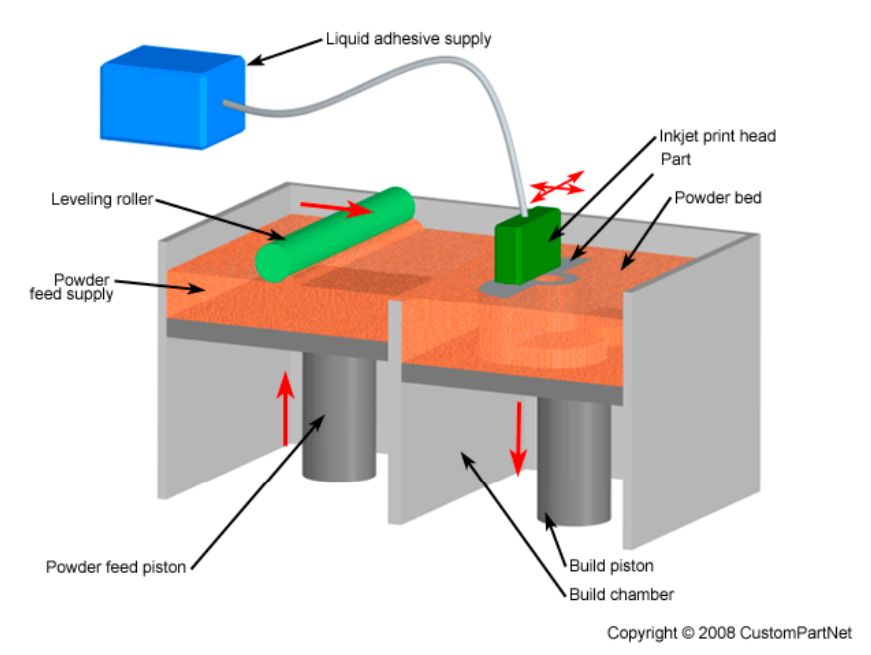


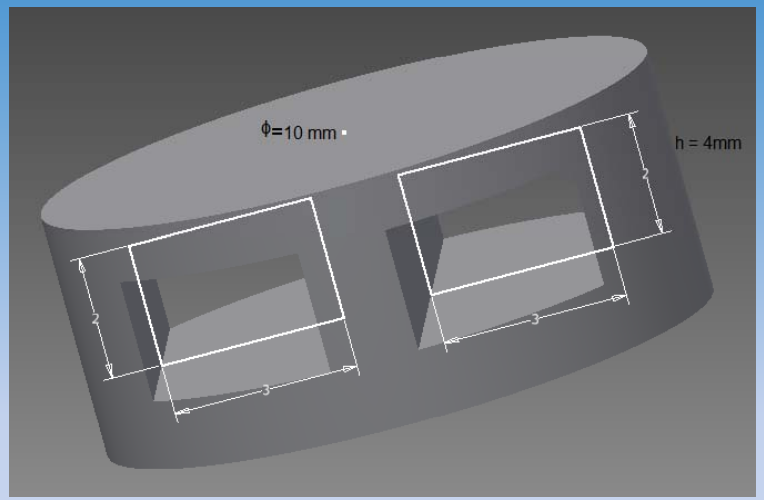
Cross-section veiw of PLA scaffold

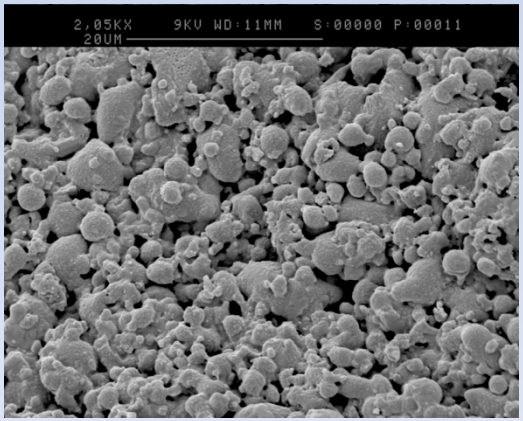


Cell attachment on Glass control

3D Printed Ceramics





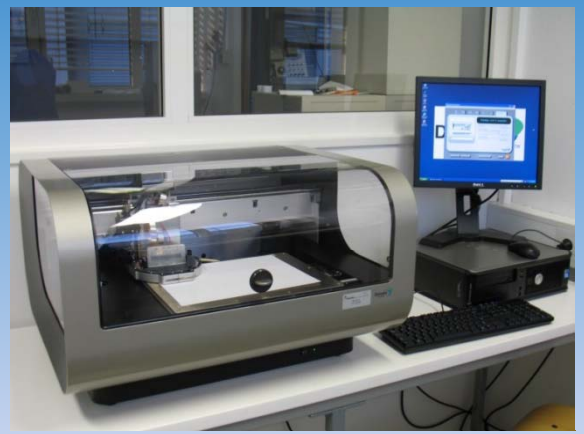


Typical Sintered Microstructure

What About The Cells?

- Scaffolds can be seeded – e.g. centrifugation or perfusion
  - Print scaffold and cells concurrently
- FDM
    - 110°C to 250°C = ☹ Cells
- 3DP
    - 20°C to 25°C (room temperature) = ☺ Cells
      - Sintering 1150°C = ☹ Cells
- What can we do to build cell friendly rigid scaffolds?

Low Temperature Deposition



Fujifilm Dimatix Material Printer

Jetlab – MicroFab Inc.

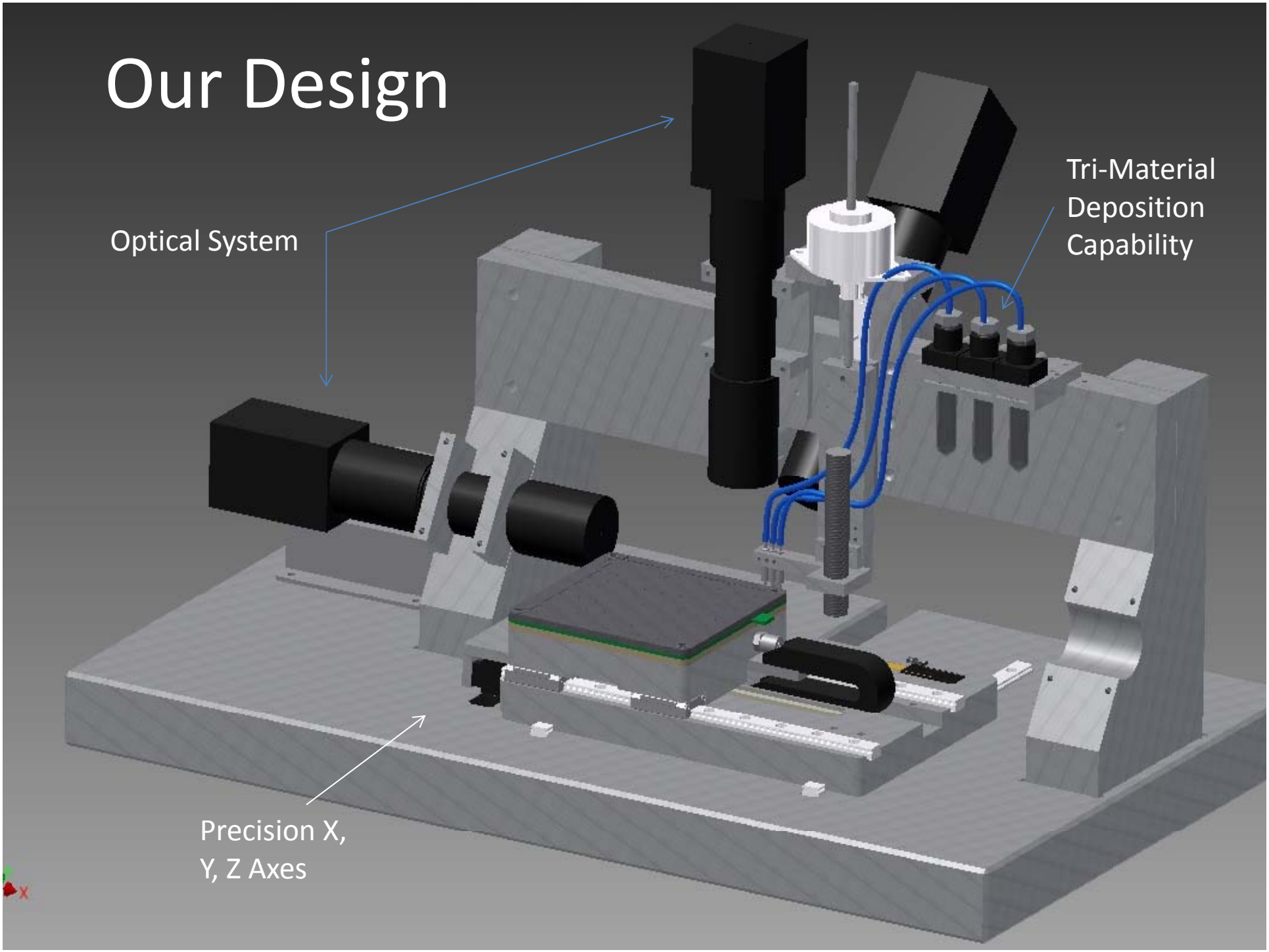
nScrypt Micro Dispensing Machine

- High value machines with diverse capability
- Large system footprint
- Issues with repeatability.

Rational For System Design

- Design specific to our need:
  - Low(er) cost system
  - Materials
    - Ability to deposit cell friendly structural materials
      - Polymers in solution
      - Monomers
    - Ability to deposit Cells
  - Substrate Positioning System
    - High accuracy,
    - High repeatability,
    - High resolution,
  - Compact footprint

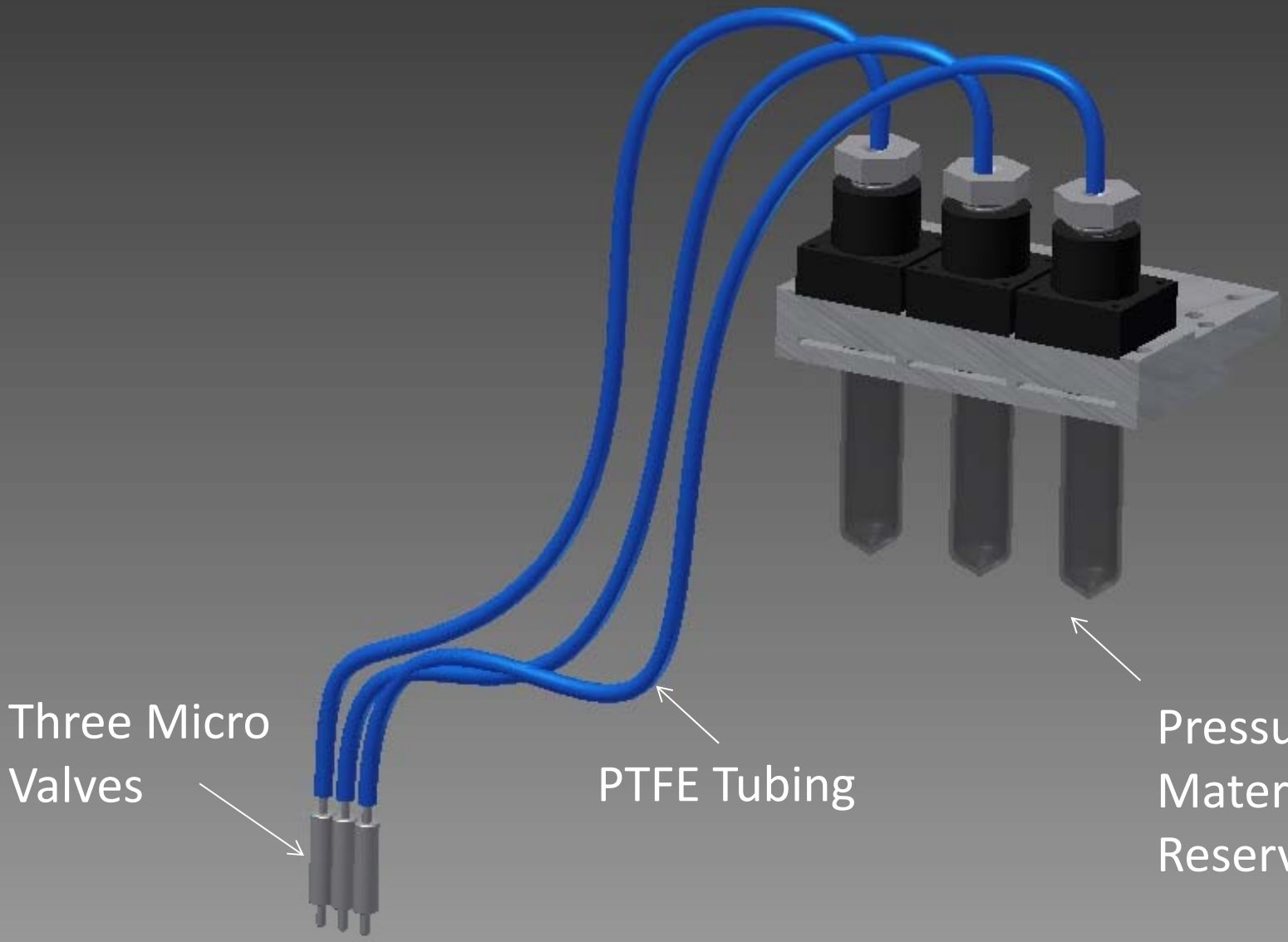
Our Design


Optical System
Tri-Material Deposition Capability
Precision X, Y, Z Axes

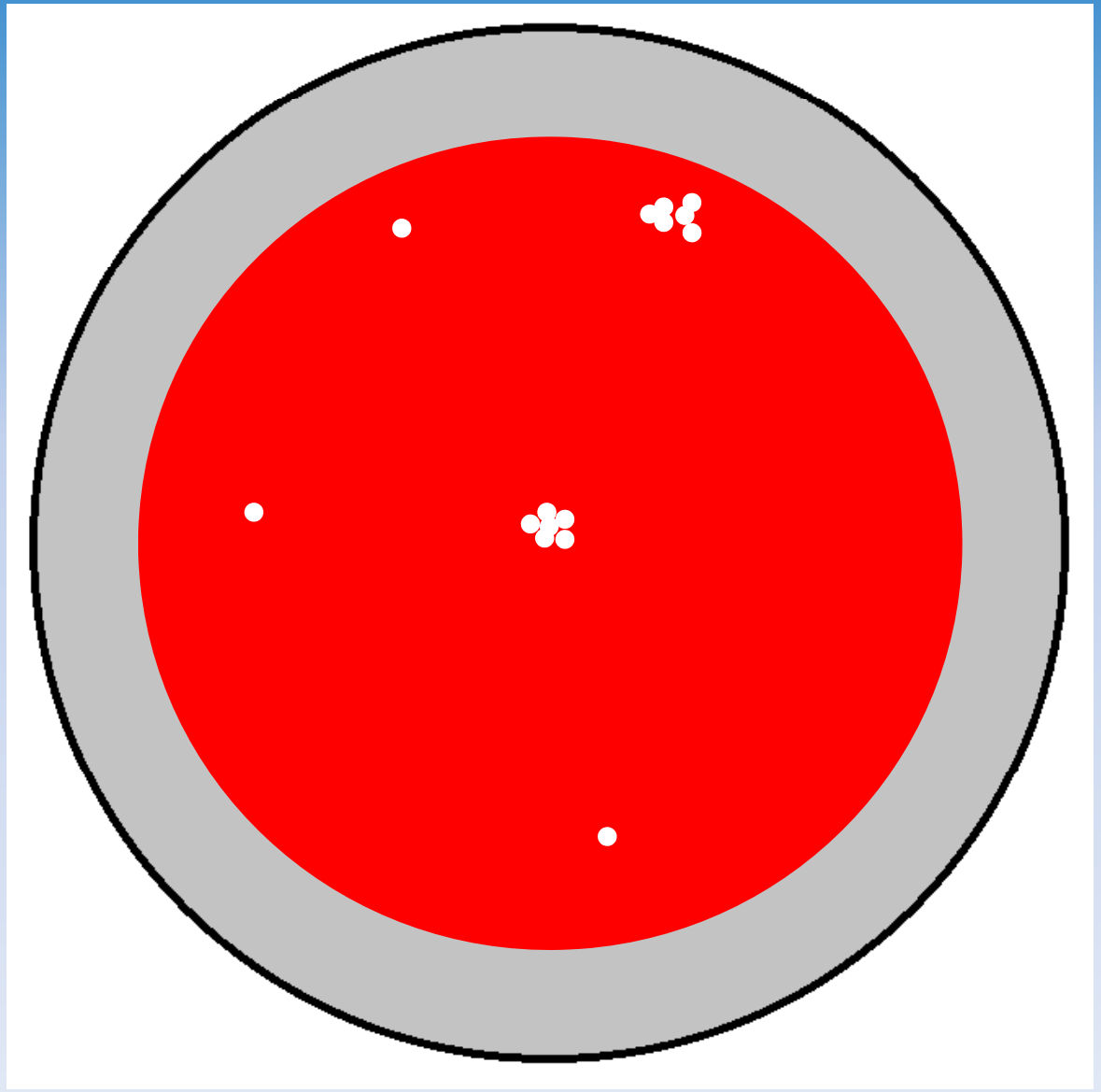
Selecting a Deposition Technology

- Fused Deposition Modelling (FDM)
- Selective Laser Sintering (SLS)
- Stereo Lithographic Apparatus (SLA)
- Laminated Object Manufacturing (LOM)
- Syringe Plotting
- Three Dimensional Printing (3DP)
  - Inkjetting / Microdispensing

Deposition Assembly



What is Accuracy, Repeatability and Resolution?



Take 5 shots for the bullseye.

Why not just make the bullseye bigger?

Target – red bullseye.

Shots are neither repeatable nor accurate.

Shots are now repeatable but not accurate.

Shots are now accurate and repeatable.

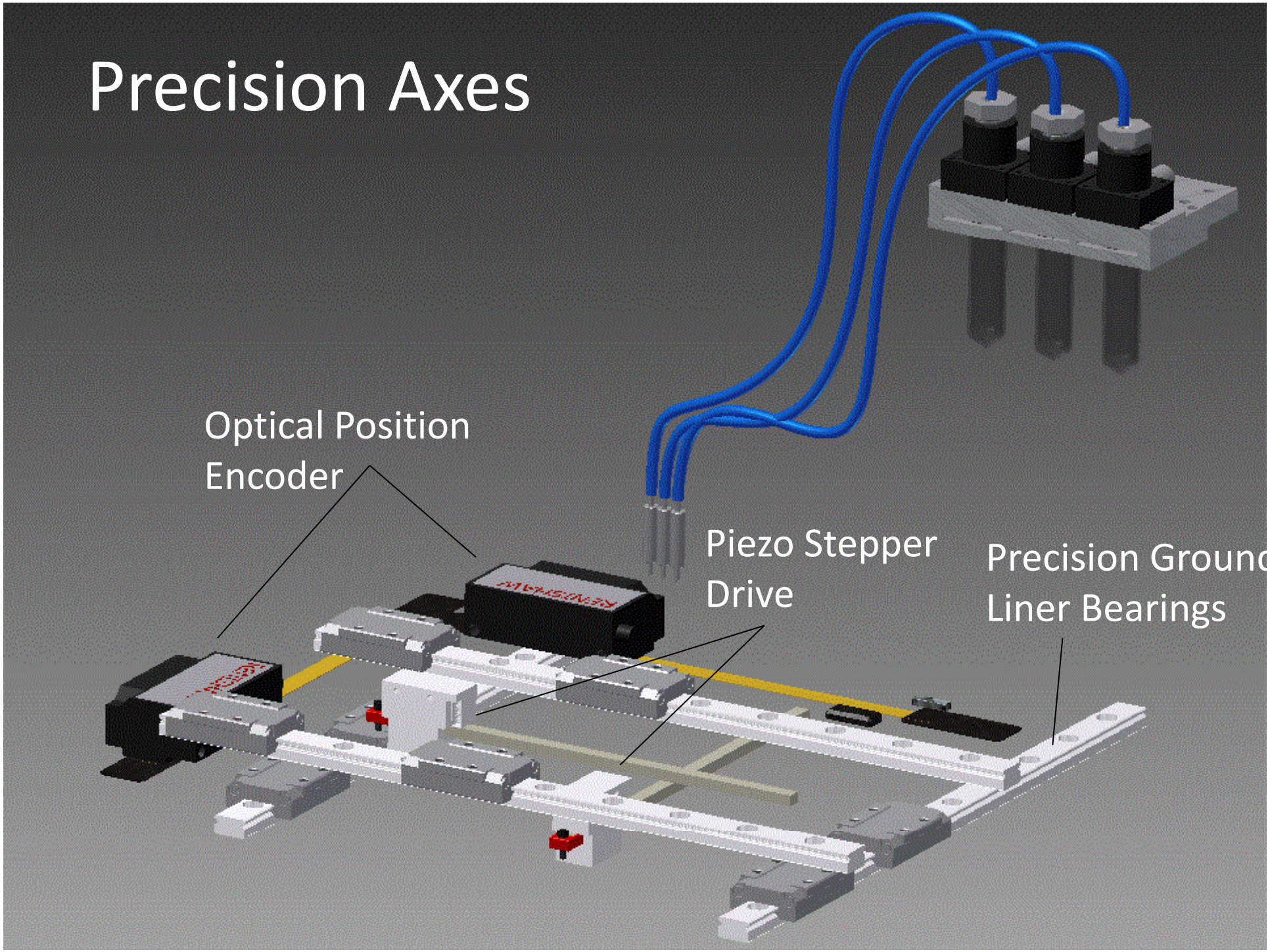
Effectively reduces resolution.

How to Reduce Error

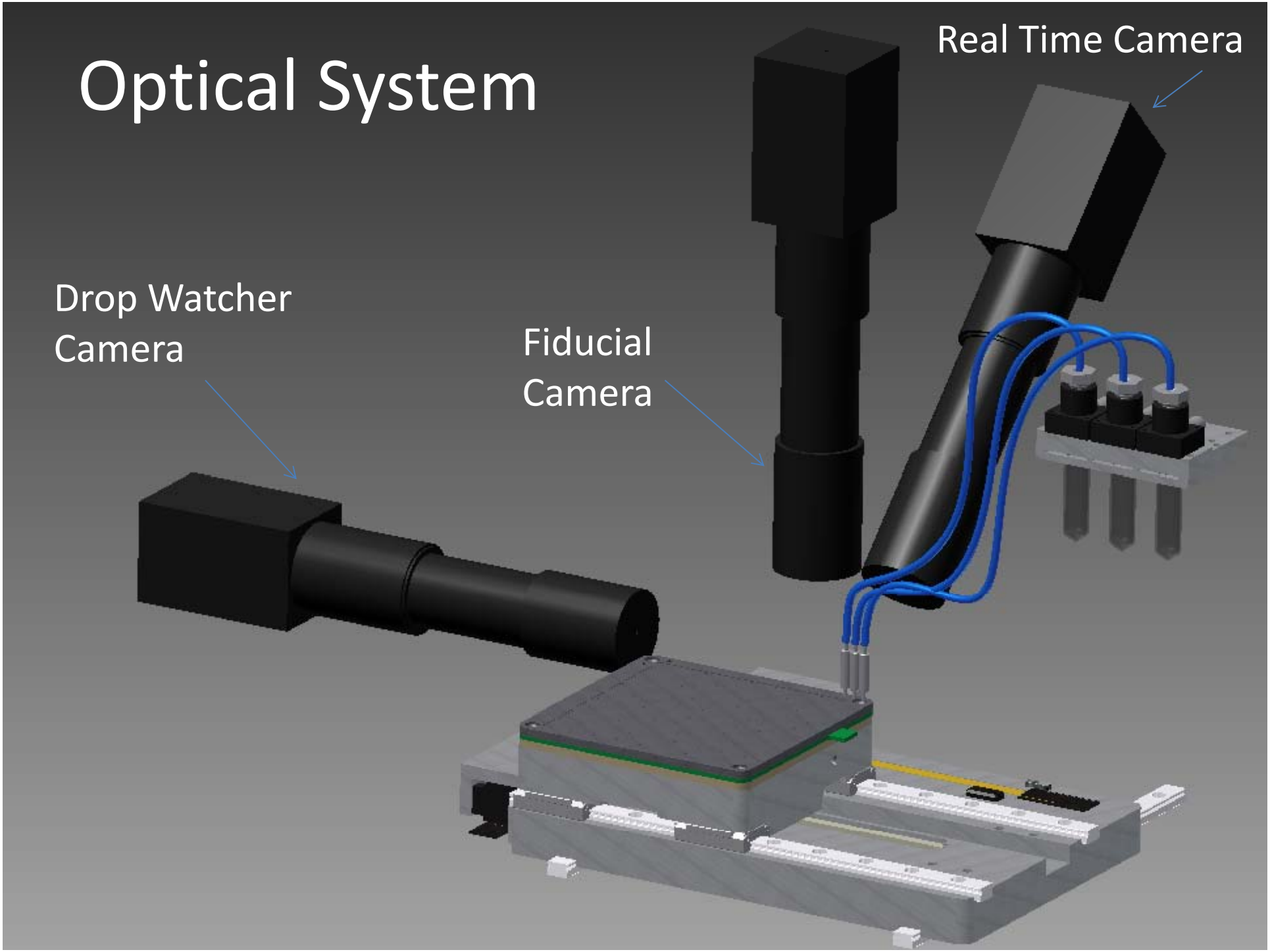
- Increase resolution
  - Use closed loop feedback, i.e. a encoders
- Decrease component error
  - Use precision bearings, control environment
- Choose the best drive
  - High quality Lead screw <1um repeatability >£10,000 for 100mm travel
  - Piezo stepper <2nm repeatability < £500 for 100mm travel

Piezo Actuators

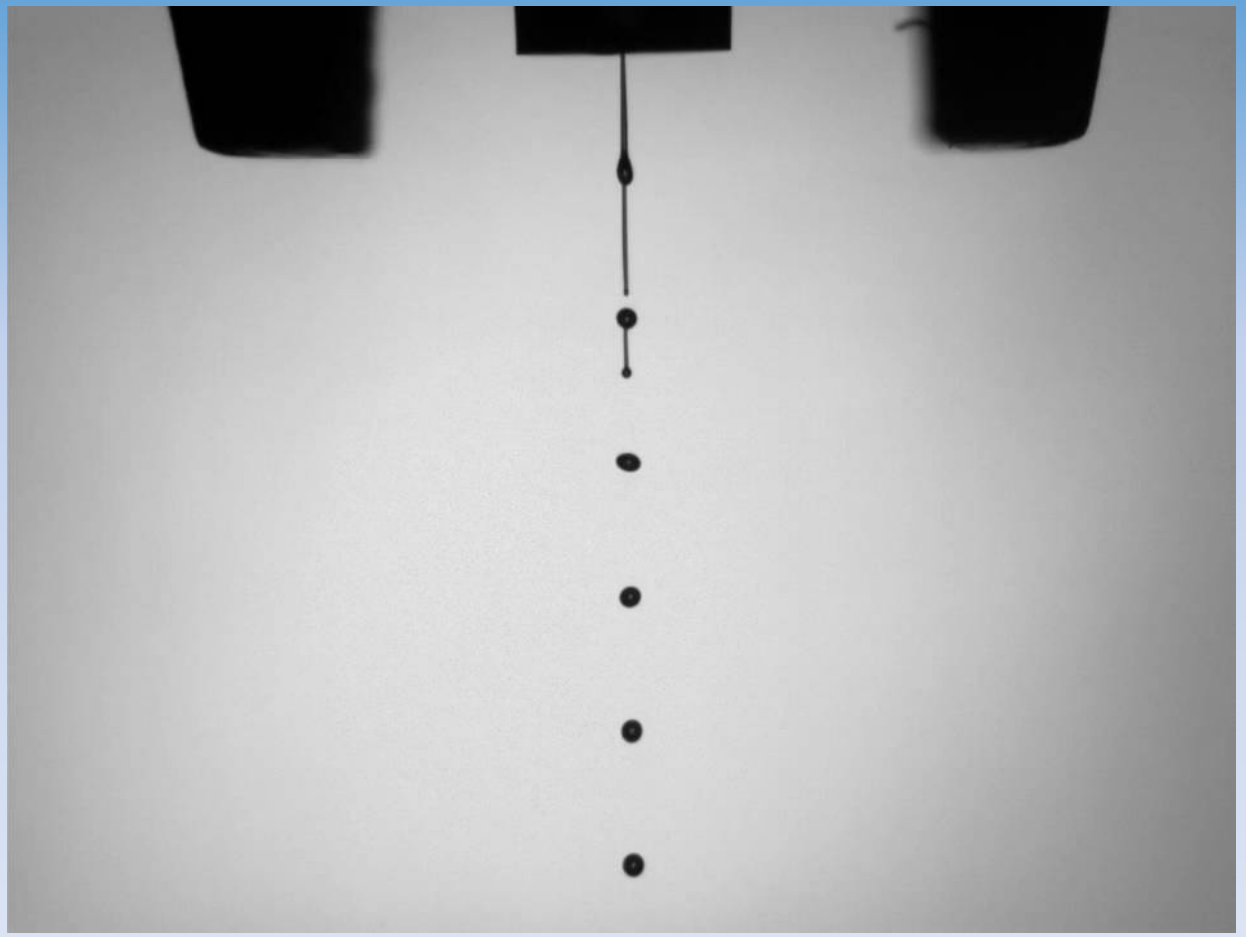
Precision Axes



Optical System



Optical System – Drop Watcher



Control

- Write your own control software
  - Lab view, National instruments – very high level
  - Python – high level
  - C++ - intermediate
- Use existing CNC software
  - Mach3
  - EMC2
  - KCam

Summery

- We have designed a system specific to our needs of:
  - Reduced cost
  - Decreased deposition error
  - Provided a multi material platform
  - Reduced system footprint to fit within a sterile environment.
- Commissioning and Testing will come next!

Thank You

- Acknowledgements
- Mark Birch, Ria Toumpaniari, Naif Alharbi