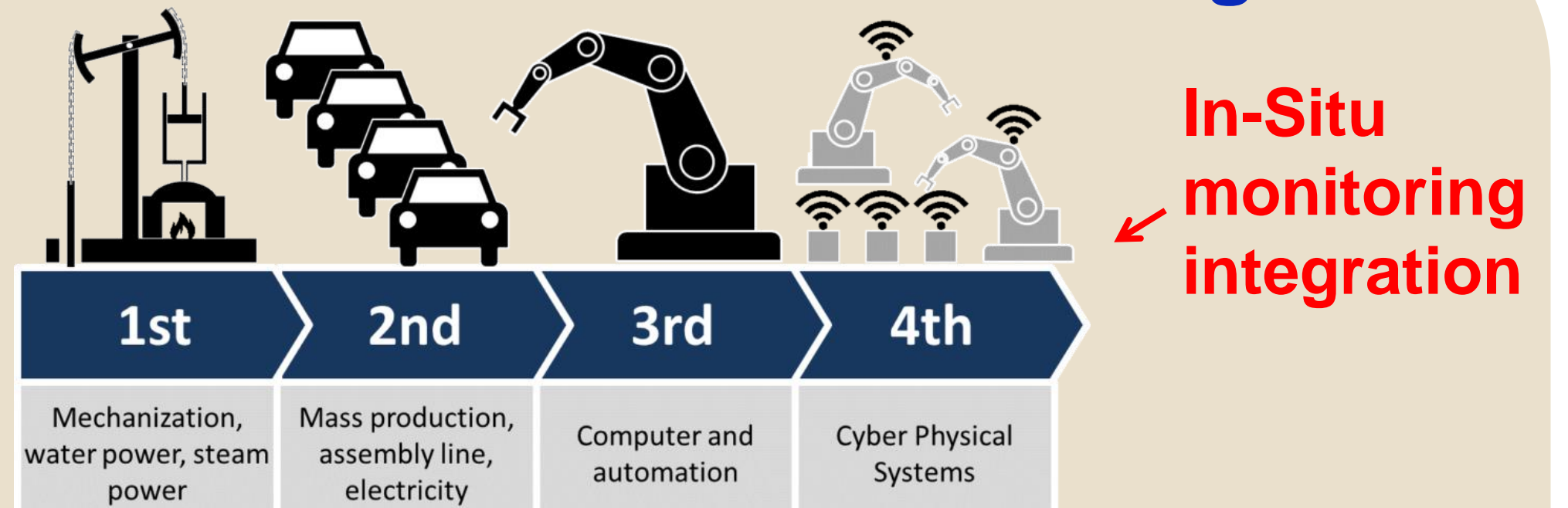# In-situ Electrical Characterization for Local Feature Segmentation and Material-Driven Control

Anthony Psulkowski, Bryant Rodriguez, Dr. Tarik Dickens

Industry 4.0

Data Driven Manufacturing

In-Situ monitoring integration

1st	2nd	3rd	4th
Mechanization, water power, steam power	Mass production, assembly line, electricity	Computer and automation	Cyber Physical Systems

- New phase of industrial revolution focusing on integration of advanced manufacturing technologies like additive manufacturing to increase efficiency and reduce waste
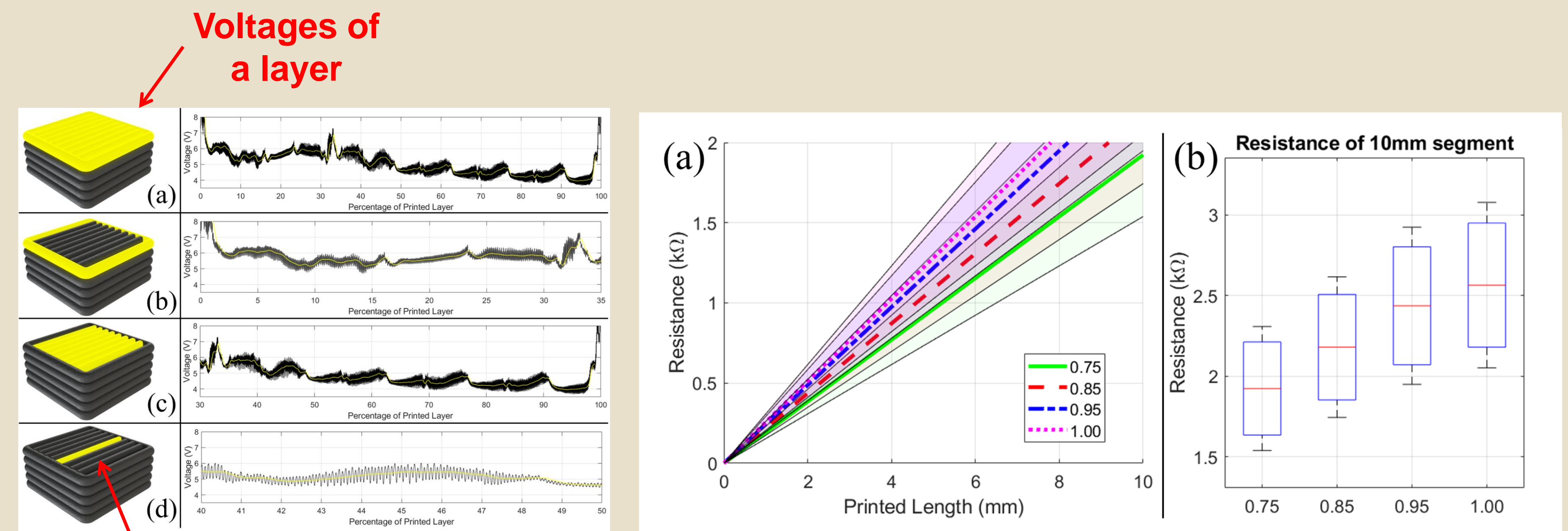
Barriers of Entry
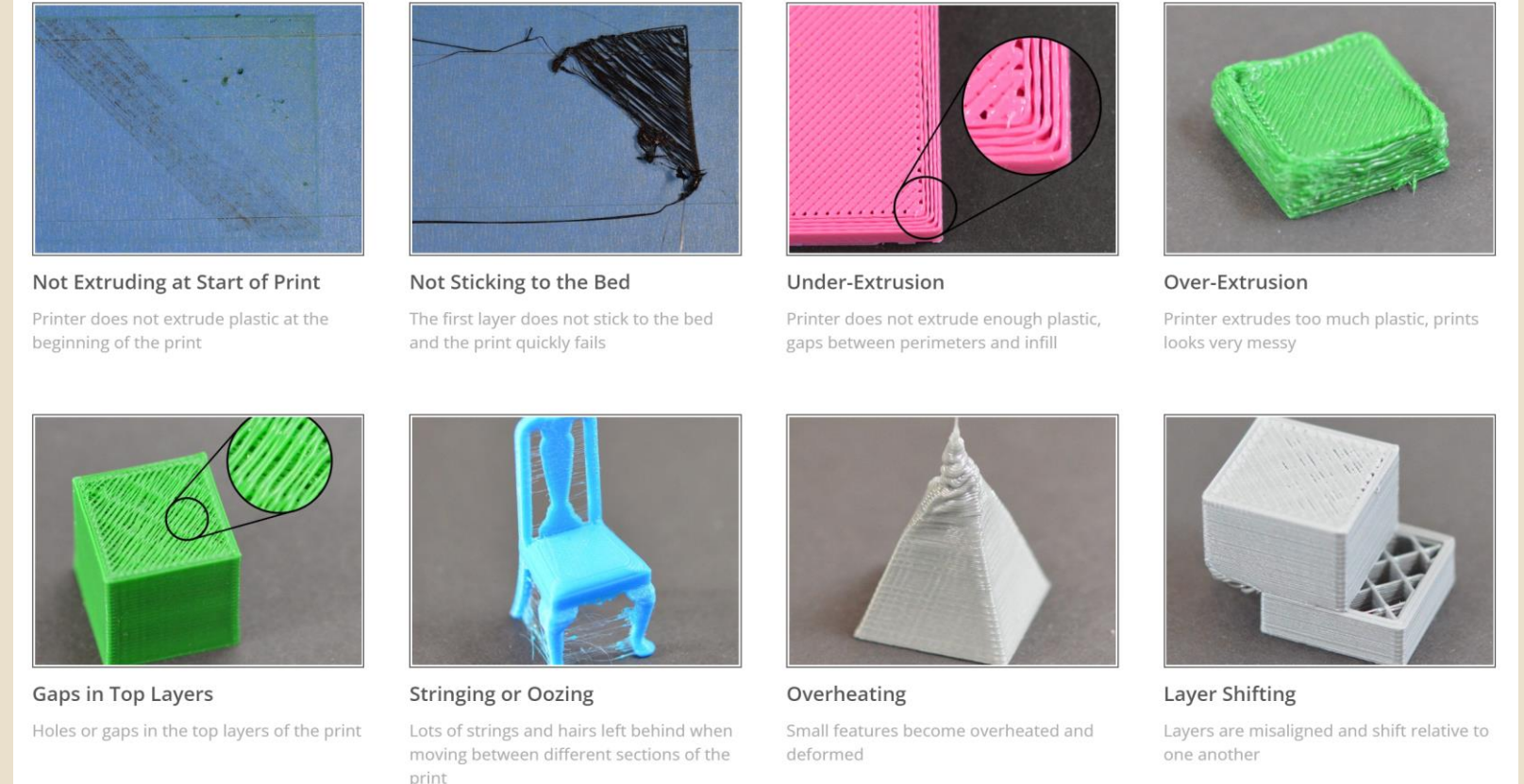
- Defects can compromise the integrity of the part, limiting additive manufacturing integration into the wide-scale manufacturing environment

Experimental Design

Circuit Design and Noise Reduction

Clear noise reduction

- Closed circuit signifies the filament contacting the copper tape
- Open circuit represents a break or defect in the filament

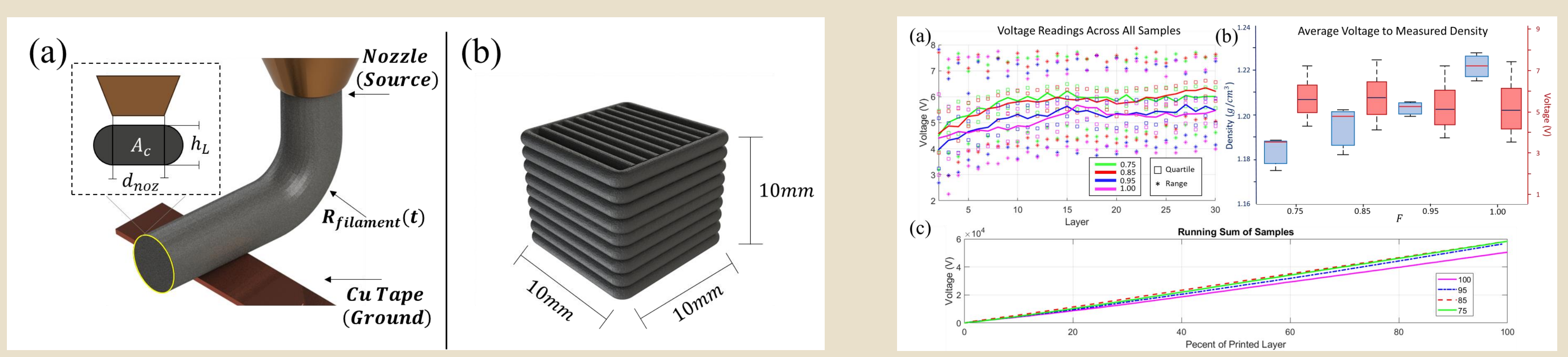- A conductor can be introduced into the circuit to reduce low-frequency noise

Main Achievement

- Characterize local feature segments through electrical readings
- Identify anomalies as errors or defects within the printing process
- Pinpoint the exact location throughout fabrication using forecastable features such as walls, lines, and layers
- Developing volumetric ohmic models using electrical readings and part density

Voltages of a layer

Voltages of a single line

- By tracking the voltage along each feature, baseline part characteristics can be made to establish deviations as defects or errors during fabrication

- Resistance reading based on variation of infill percentages, ranging from 75% - 100%

Methodology

- 10x10x10mm cubes were printed with varying infill percentages, and a 10V current was passed through a conductive filament during the entire print with a collection rate of 100kHz
- The voltage data collected from the samples was cleaned to reduce noise and analyzed to identify local changes in voltage that helped to characterize the location of features
- Probes were attached to both the nozzle and build plate to record voltage throughout the entire fabrication process, while a data collection unit measured voltage through a circuit board to minimize noise
- The density of each sample was then calculated to develop volumetric ohmic models that help to better understand the relationship between voltage and density in 3D printing

Filament Resistance

Theoretical

$$R = \rho L / A$$

$$R = \frac{30\ (\Omega \cdot cm) \cdot 0.9\ (cm)}{0.12783 (cm^2)}$$
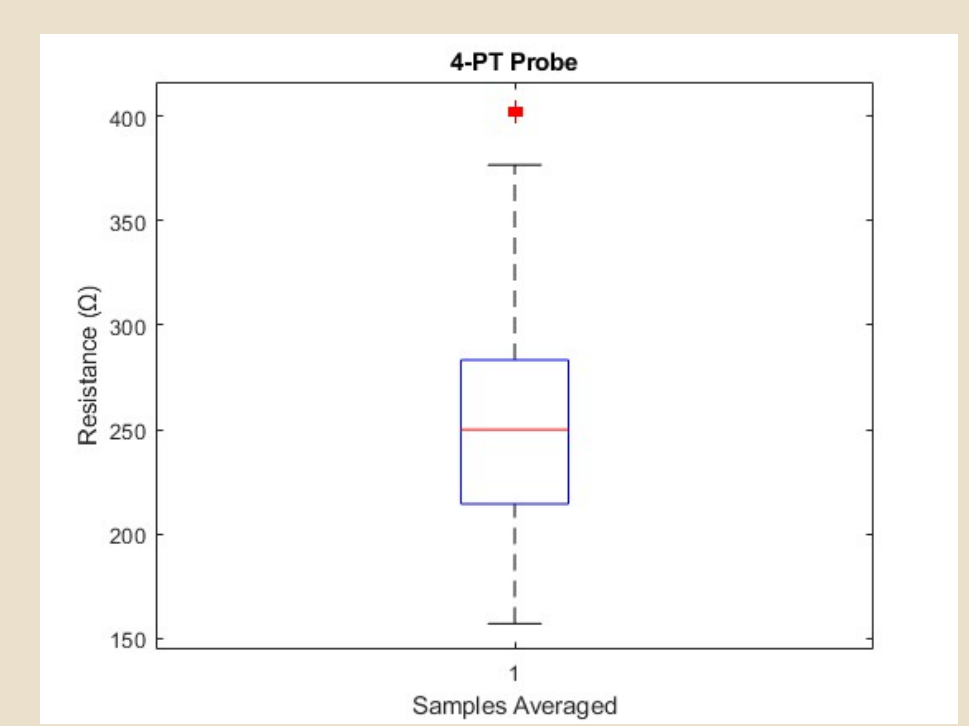
$$R = 211.218\ \Omega$$

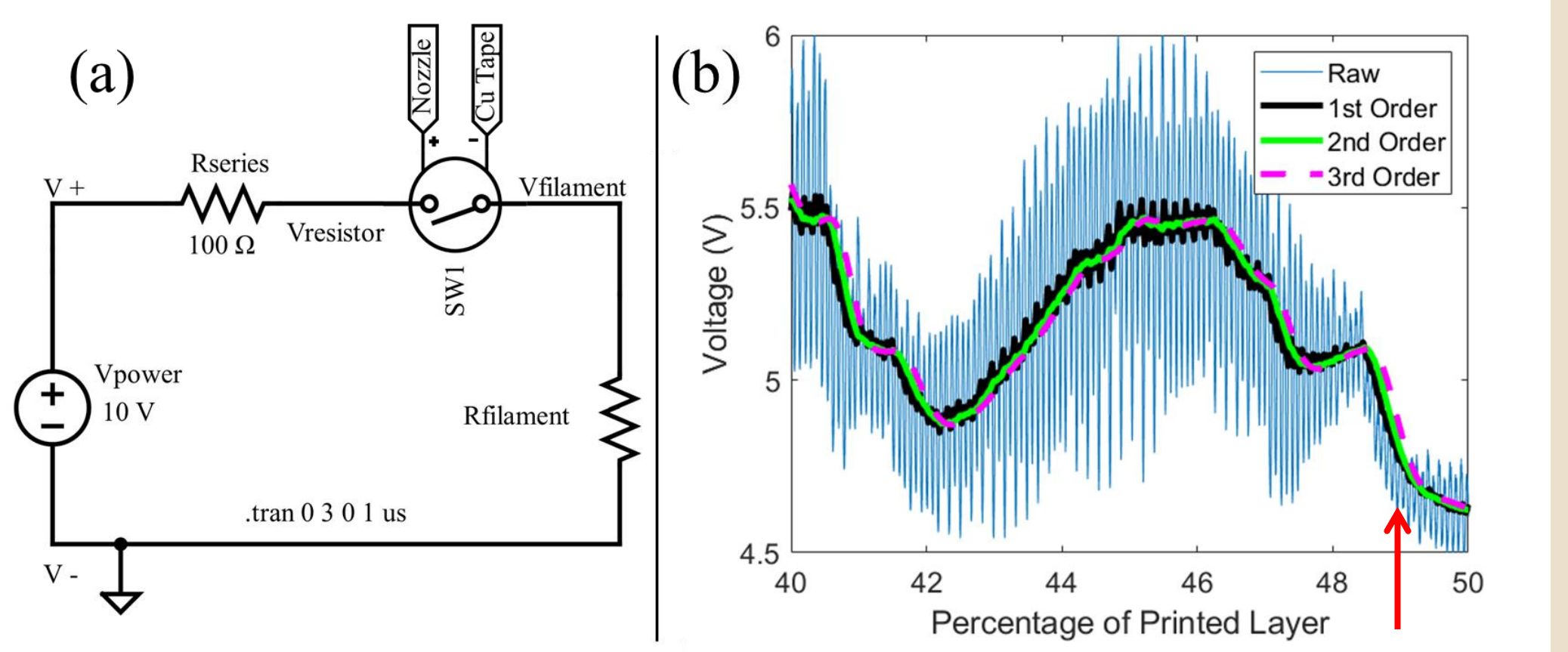- Using Proto Pasta Conductive PLA with carbon black

Experimental

- 21 samples were conducted via 4-PT Probe to corroborate theoretical filament resistance
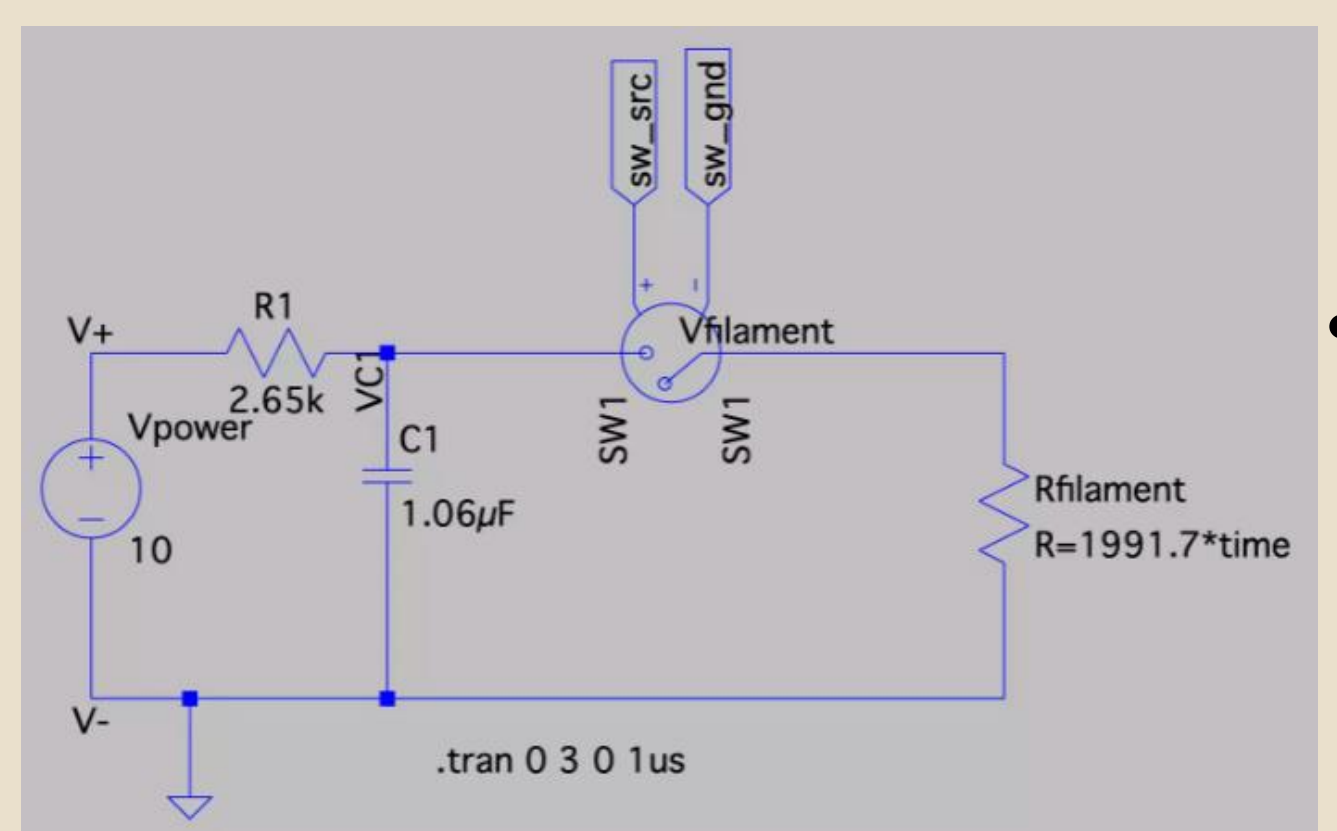
END-OF-PHASE GOAL

Future Research

- Development of machine learning algorithms to predict errors during manufacturing process
- Adaptive manufacturing processes through correcting defects during fabrication
- Increasing the overall efficiency of the 3D printing process by reducing waste through the reduction of defects

Applications

- Defense, Automotive, Marine, Aerospace, Electronic Manufacturing, and Biomedical
- Being able to accurately monitor the health and possible defects of a part is a vital step before integral application