Micro Power Storage

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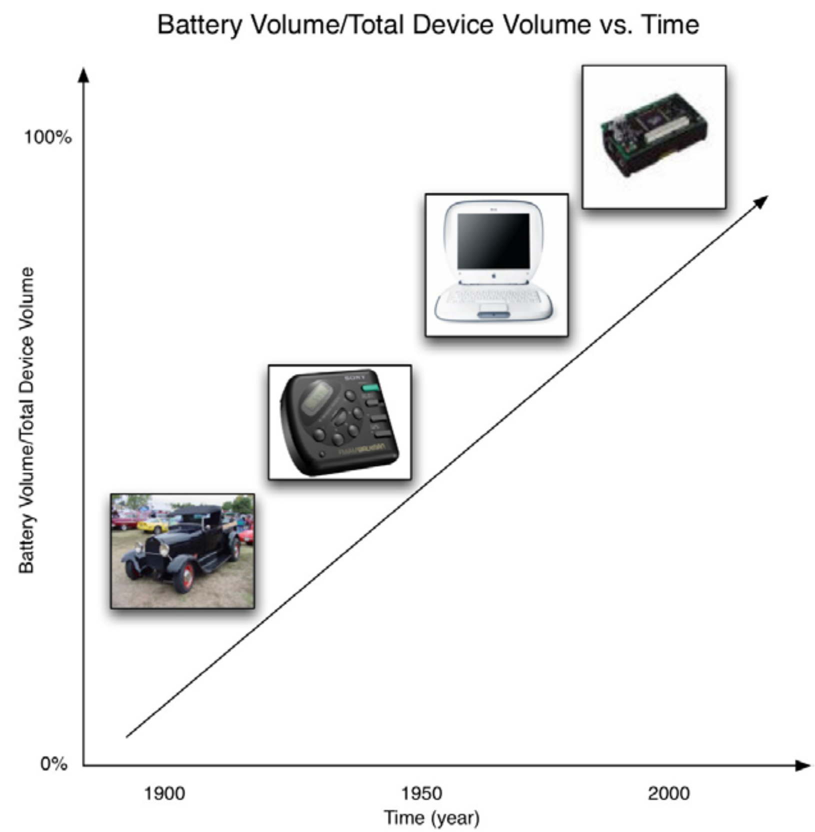
Take Aways

- Thick film batteries provide adequate capacity in a small footprint
- Printing batteries atop circuit boards allows for
  - Package reduction
  - Matching chemistries and capacities for subsystems, minimizing the overhead for power conditioning
- Printable electronics *are* the future, batteries are the opening salvo

Micropower Needs

- Power generation and storage accounts for over 90% of total device volume
- This is not going to change
  - Average Power: 1 V to 3 V @ 10μA to 200μA
  - Lifetime: > 5 days
  - Charge cycle: 1 day
  - Total storage required is at least 240 μAh, likely 1000 - 2000 μAh (assuming it can be recharged daily)

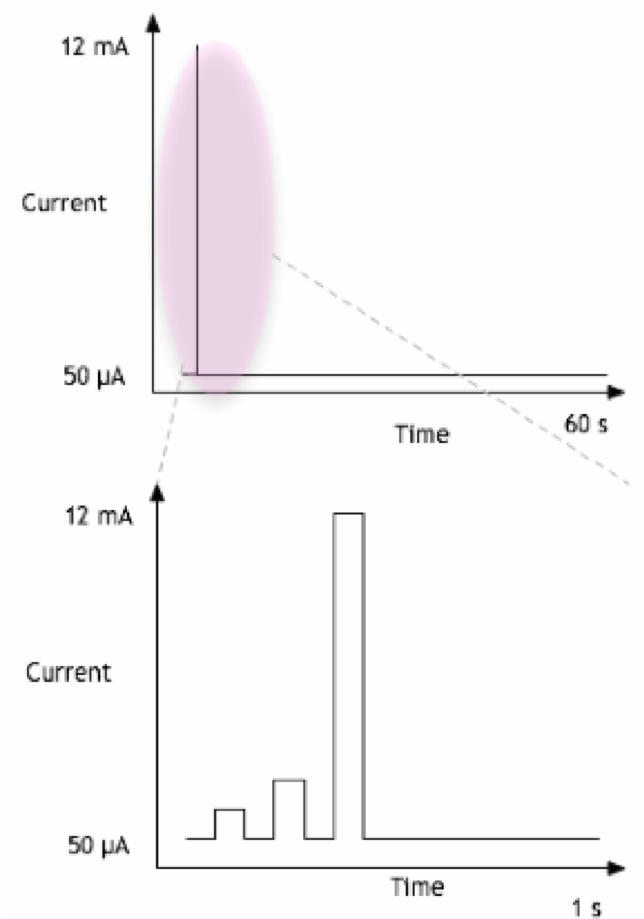


How Small Do We Want It?

- 10’s cm^3
  - Industrial Sensors
  - Thermostats (PCT Hub)
- 1’s cm^3
  - External Body Sensors
  - Tire Pressure
  - PCT Disaggregated Noded (gen 1)
- Less than 1 cm^3
  - Internal Body Networks
  - “Spradio”
  - Future HVAC Controls
  - PCT DN (gen 2)

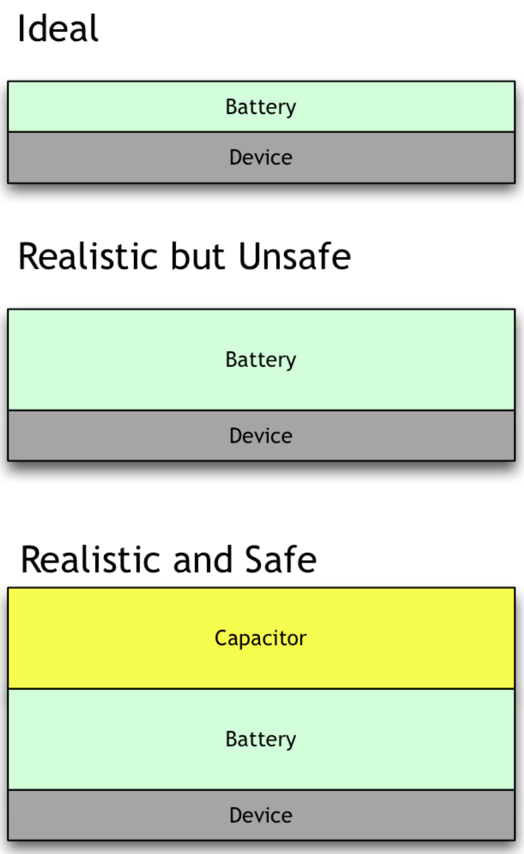
Application

- Smart Dust
  - Small Volume (1 cm^3)
  - Small Footprint (1 cm^3)
  - Low Duty Cycle
    - (< 1% active)
  - Massive Peaks
    - 50 - 100 μA sleep
    - 12 mA active
  - A practical battery should last overnight, thus a capacity of > 800 $\mu Ah/cm^2$ is required



Back of the Envelope

- Batteries
  - 250 μAh ideally could be a achieved in a space of 100 μm thick by 5 mm by 5 mm
  - Realistically > 200 μm thick by 5 mm by 5mm
  - Better yet, 400 μm by 5 mm by 5 mm (hybrid supercapacitor setup)

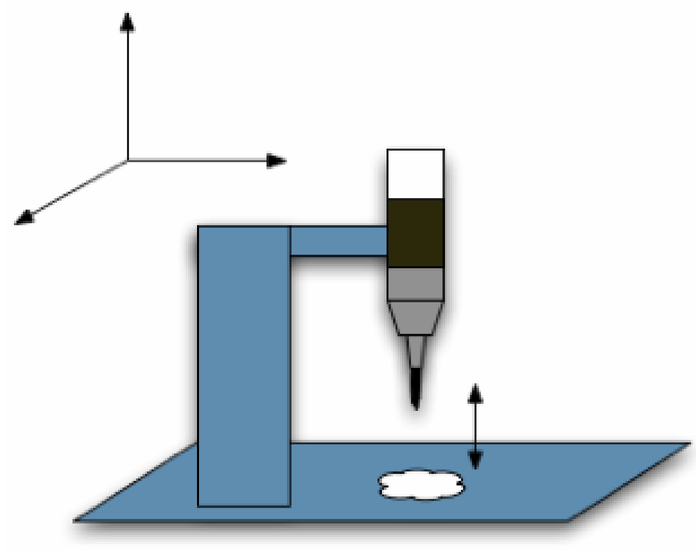


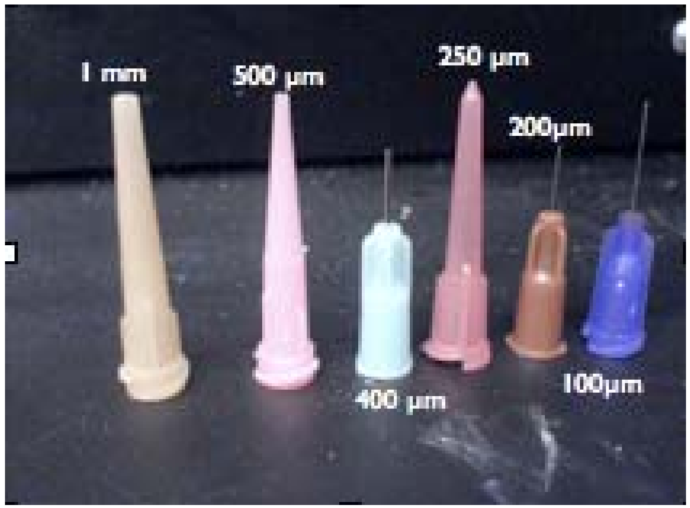
Ockham’s Razor

- Current technology almost works
  - Kokam Lithium-Polymer Ion
    - Can deliver 9 mAh
    - ~2 cm^2, 5 mm thick
    - A lot of packaging
- Why can’t we just use the typical slurries?
  - Too Viscous?
  - Difficult to Etch?
  - Binder is bad?
- Electrolyte still an issue

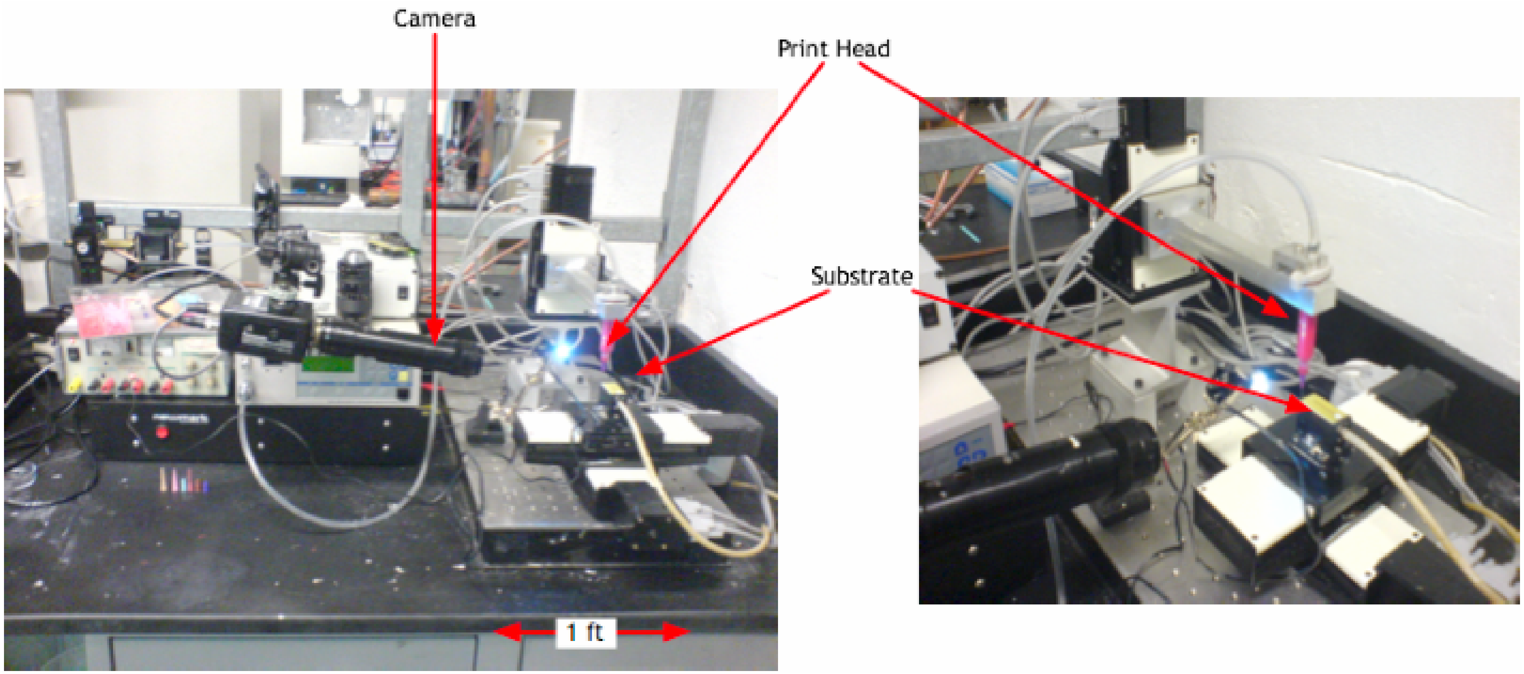
Our Method

- A pneumatic dispenser printer
  - 100 µm feature sizes (and shrinking)
  - 5 µm to 500 µm thicknesses
  - Rasters any image
  - Cheap, Scalable
  - Handles a wide range of viscosities
    - Dishsoap to Molasses



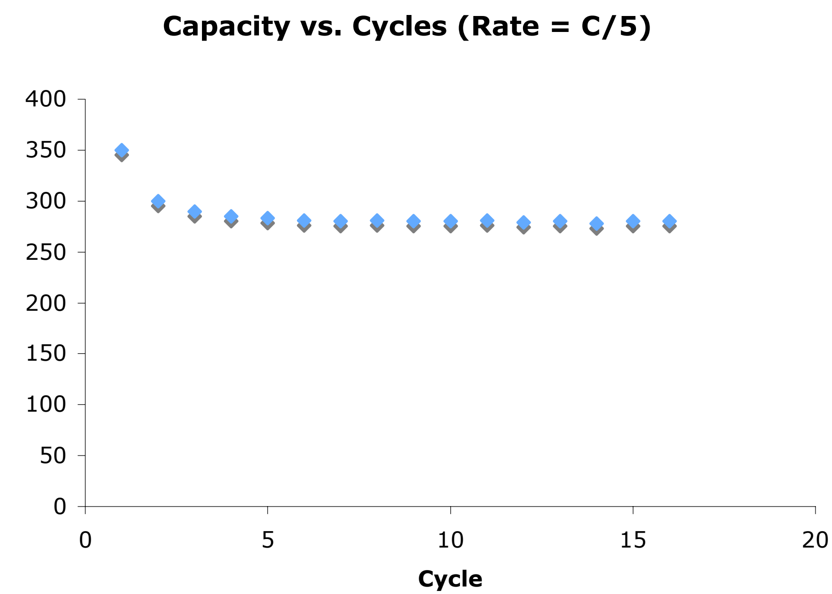


Dispenser printer



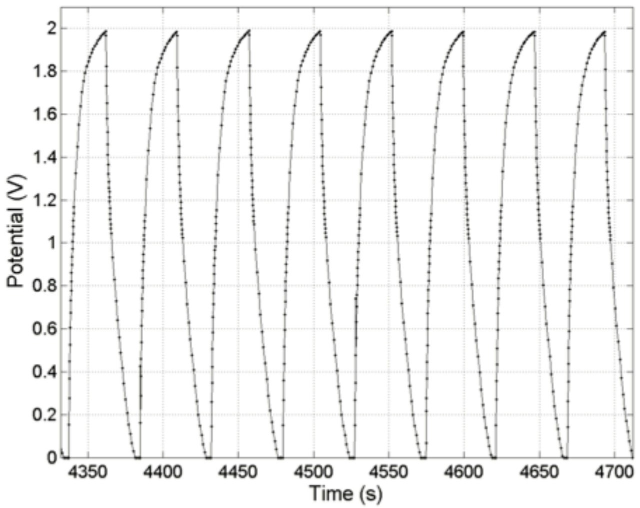
Two Printed Electrodes

- Print $LiCoO_2$ slurry in the same manner
- Two 25 mm^2 electrodes, 50 µm thick
- Place in a sandwich with Cellguard soaked with LiTFSI in EC / PC / DMC

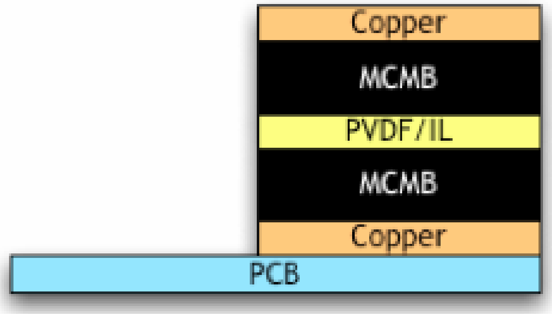


Capacitors

- 5 mm by 5 mm by 100 µm (unsealed)
- Capacity of 9 F/g
- Materials Limited
- Cycles 1000's of times



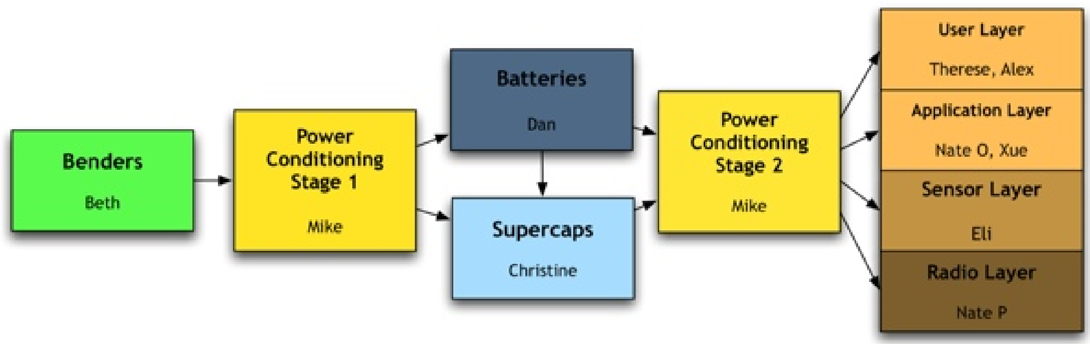
Galvanostatic Cycling at 30 µA



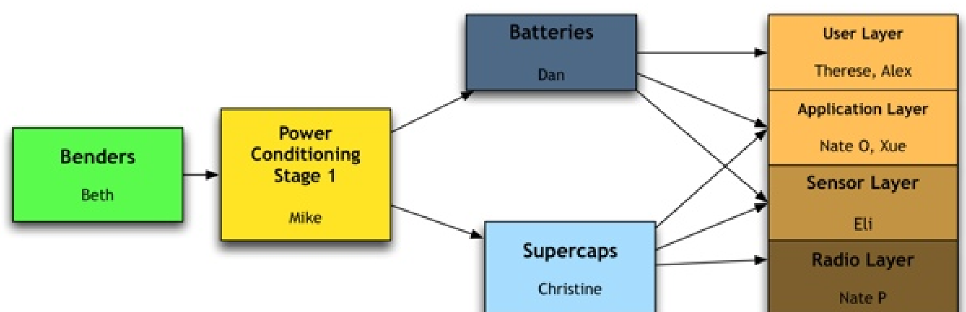
Different Potentials Possible

- Sensor
  - 3 V Lithium
- Radio
  - Super Capacitor
- Memory/Logic
  - 1.5 V Ag/Zn

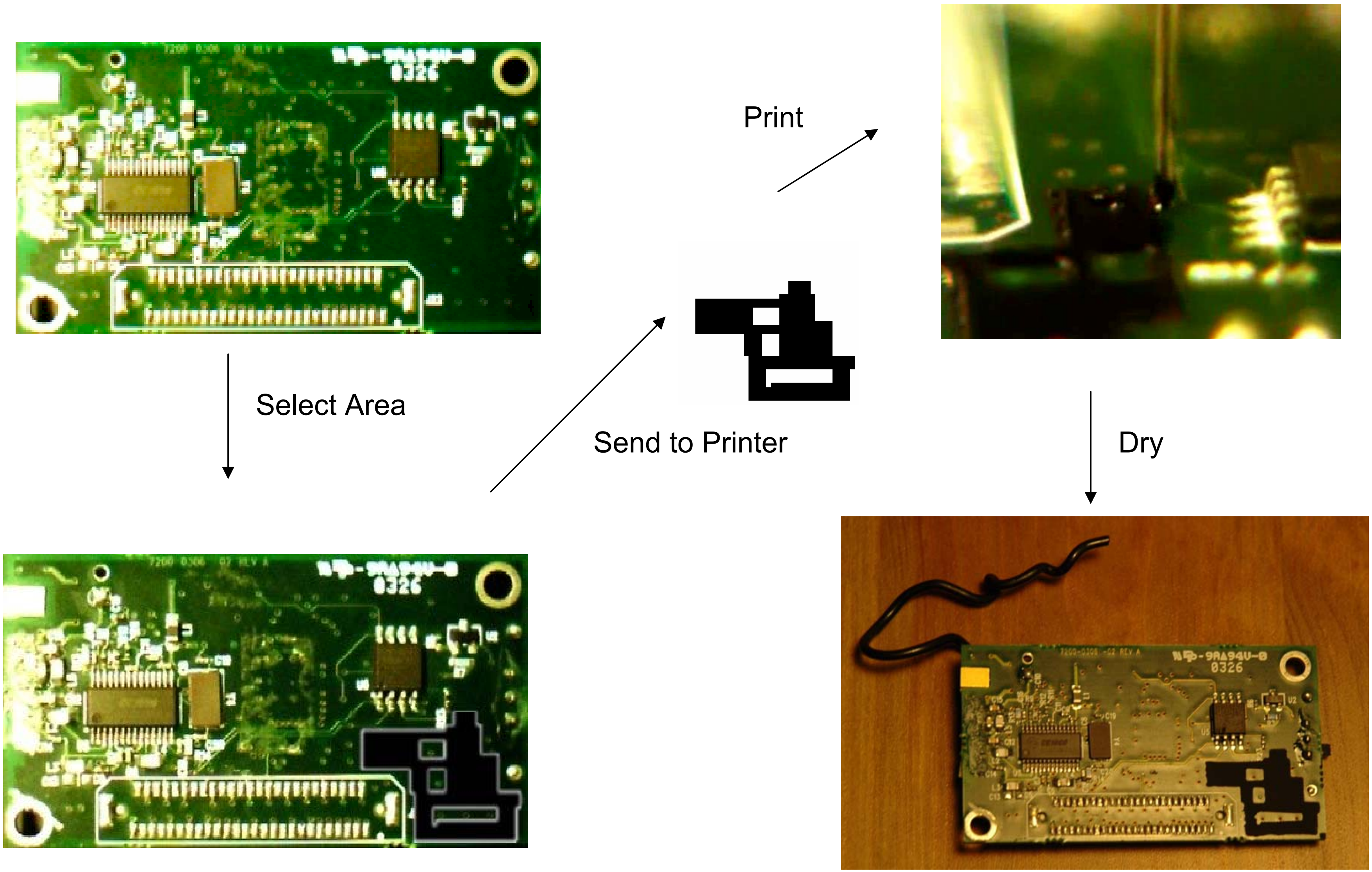
Phase 1 Power Train



Phase 2 Power Train



Goal: Print Anywhere



Summary

- A viable method for printing Li-Polymer-Ion batteries has been developed
  - Method is material and substrate independent
  - “If it oozes”
  - Printing at STP is fine
- Capacitors seem reasonable
- Storage needs can be customized not only for system level, but tiered device level