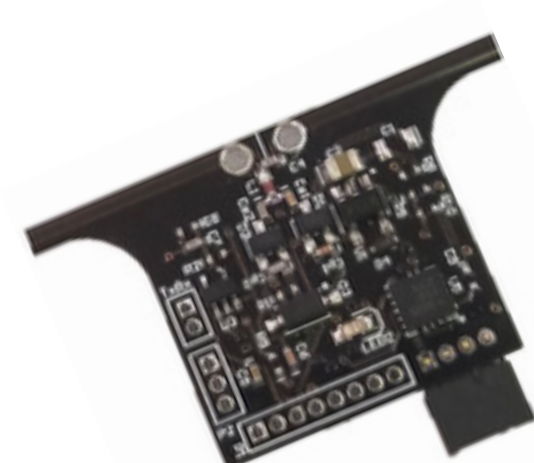# The **Internet of Things** has a **battery problem.**

Jacob Sorber, Josiah Hester, Kevin Storer
Clemson University, School of Computing

The IoT Promise: large scale, low cost, low maintenance

Infrastructure
pipelines
bridges

Wearables
clothing
fitness

Buildings
occupancy
energy use

Wildlife
habitat use
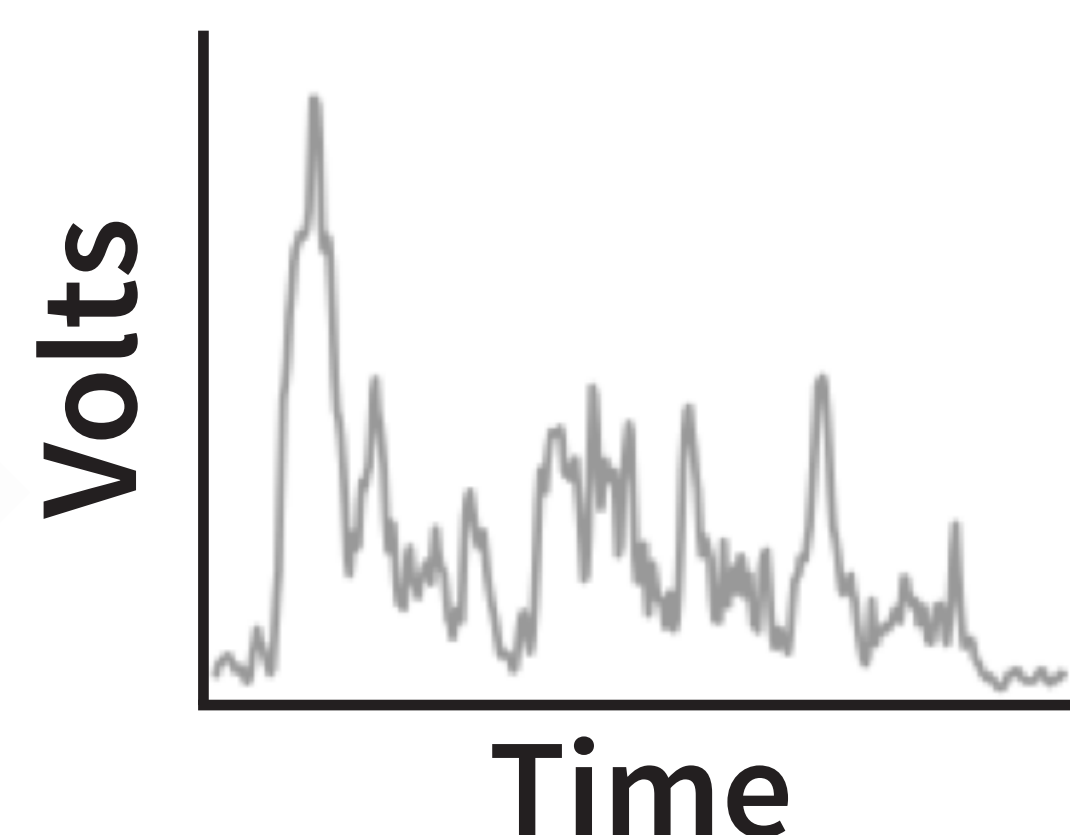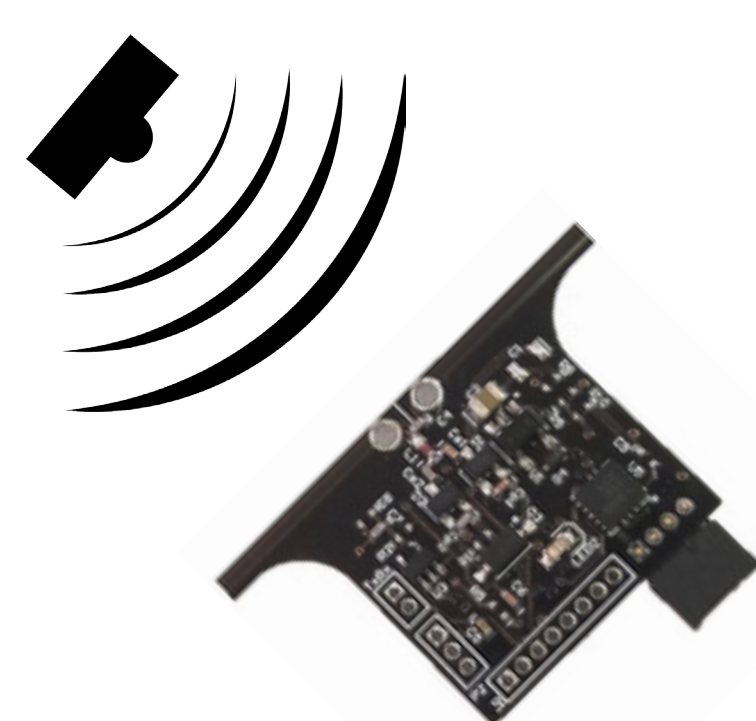behaviors

Extreme Locales
deep sea
space

Reality: expensive, dangerous, and short-lived **or** volatile and error-prone

Batteries

large
heavy
expensive
hazardous
wear out (2–5 yrs)

No battery, harvested energy

unpredictable, volatile power

Volts / Time

Intermittent execution

How long between operations?
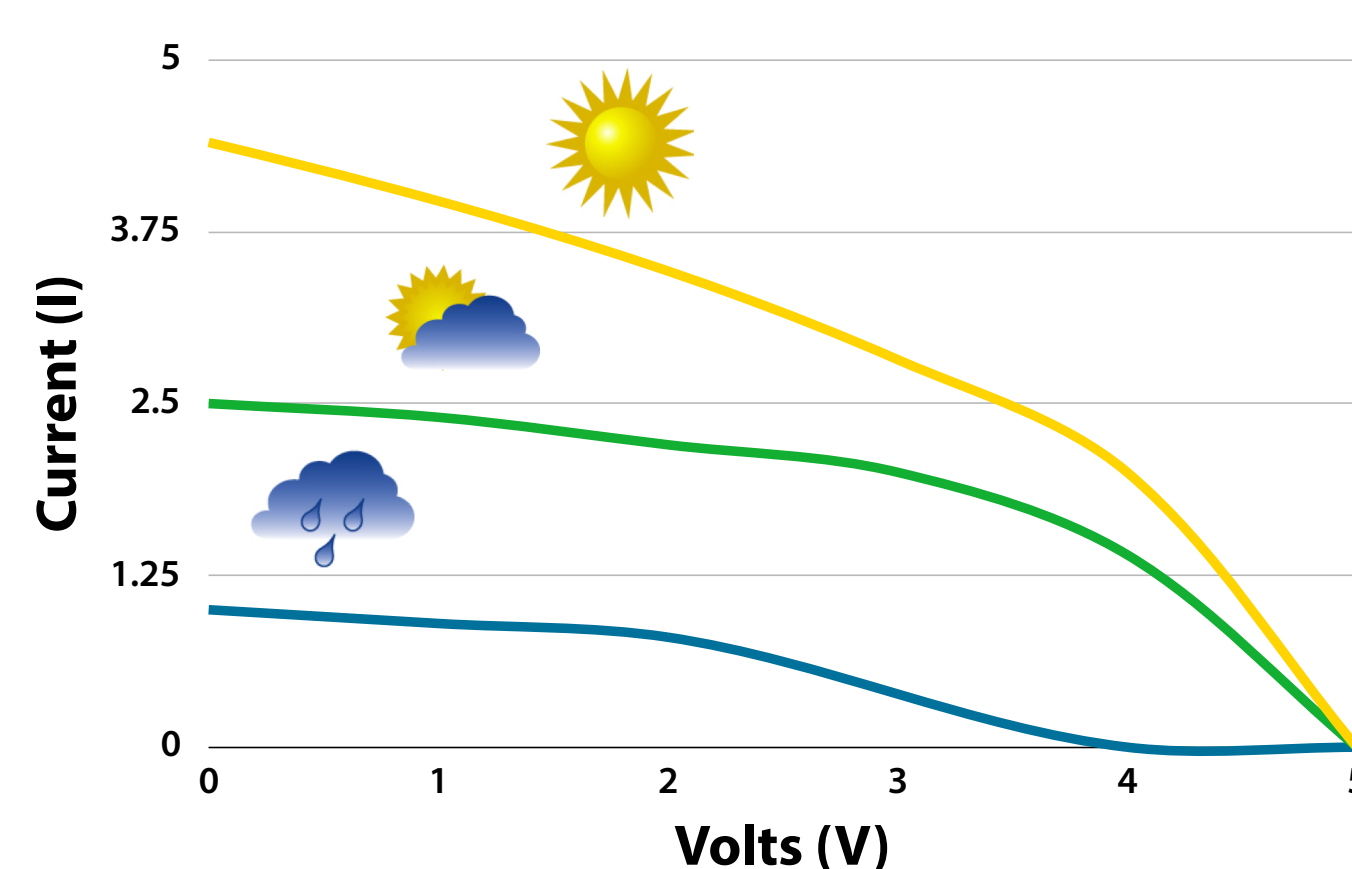
```
1.  NV int w, t, l, m
2.  main() {
3.      while(1)
4.          t = temp()
5.          l = light()
6.          m = moist()
7.          w = wet(t,l,m)
8.          send(w)
9.          sleep(1)
10. }
```

w = wet(t,l,m)

How long?
1s? 1hr?

send(w)

Our Work: computing systems designed for volatile power and frequent failures

Tools

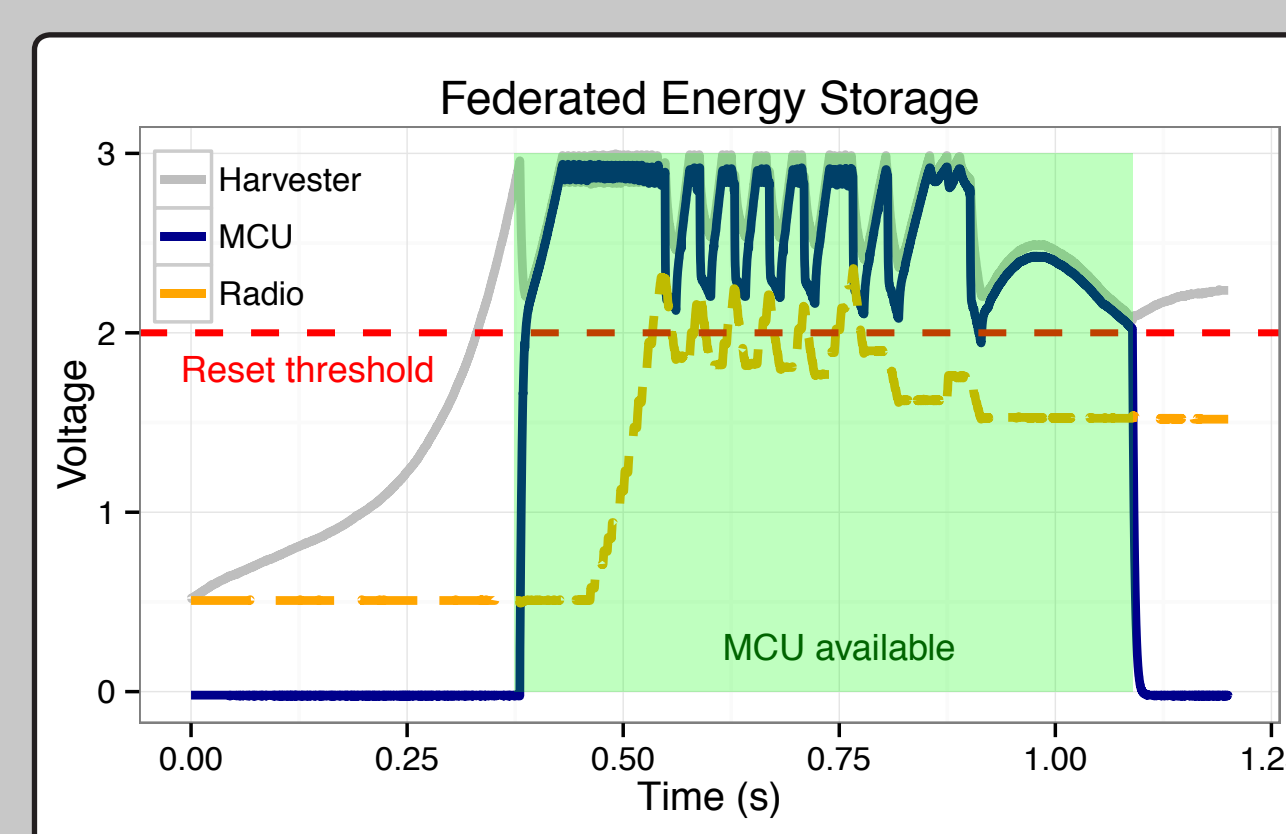Record and replay energy harvesting environments with **Ekho.**

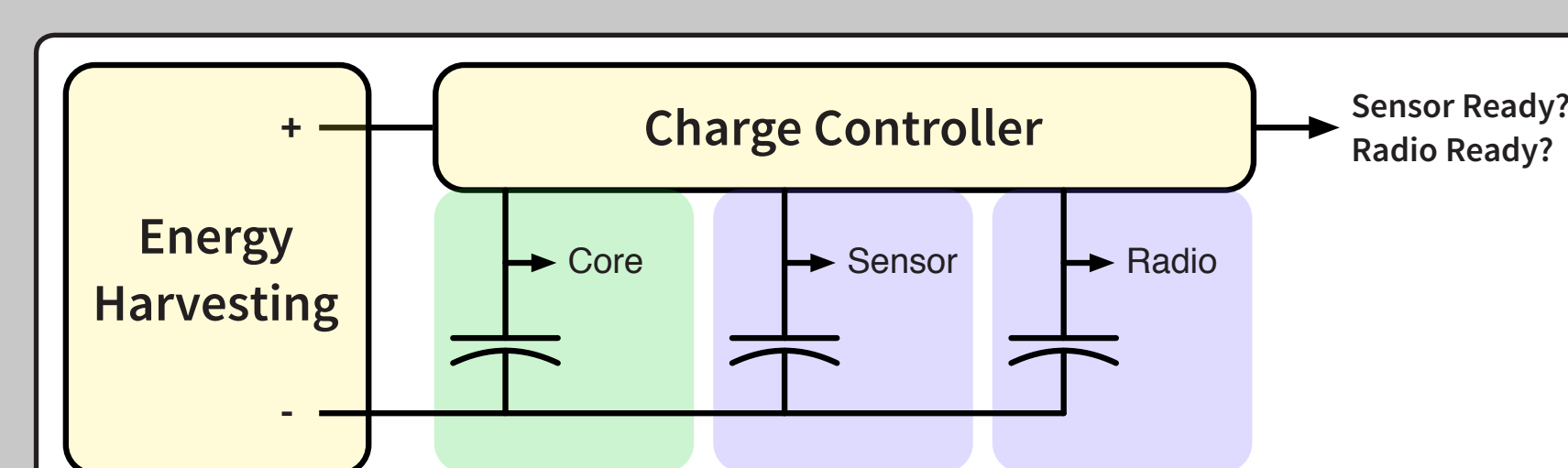I-V curves represent all possible harvester conditions at an instance of time.

Ekho records and replays I-V surfaces.

Hardware Platforms

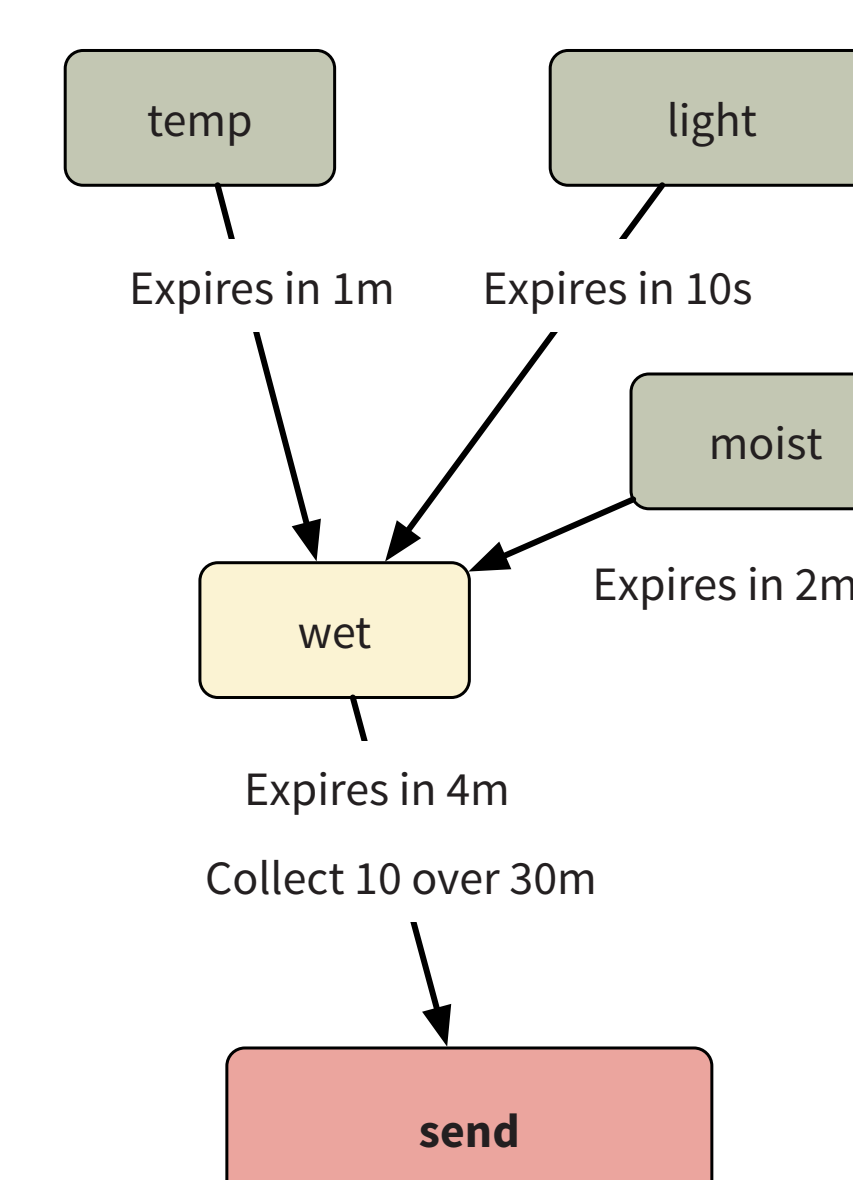**Federate energy storage** for more responsive, more efficient devices.

Physically separate energy stores to avoid a tragedy of the commons.

Language and Runtime

Data- and time-aware language provides runtime support for batteryless sensors.

temp — Expires in 1m
light — Expires in 10s
moist — Expires in 2m
wet — Expires in 4m
Collect 10 over 30m
send

Programs specify temporal constraints, and the runtime schedules tasks to maximize useful work.