FINDING AND FITTING BATTERIES FOR SMALL IOT DEVICES

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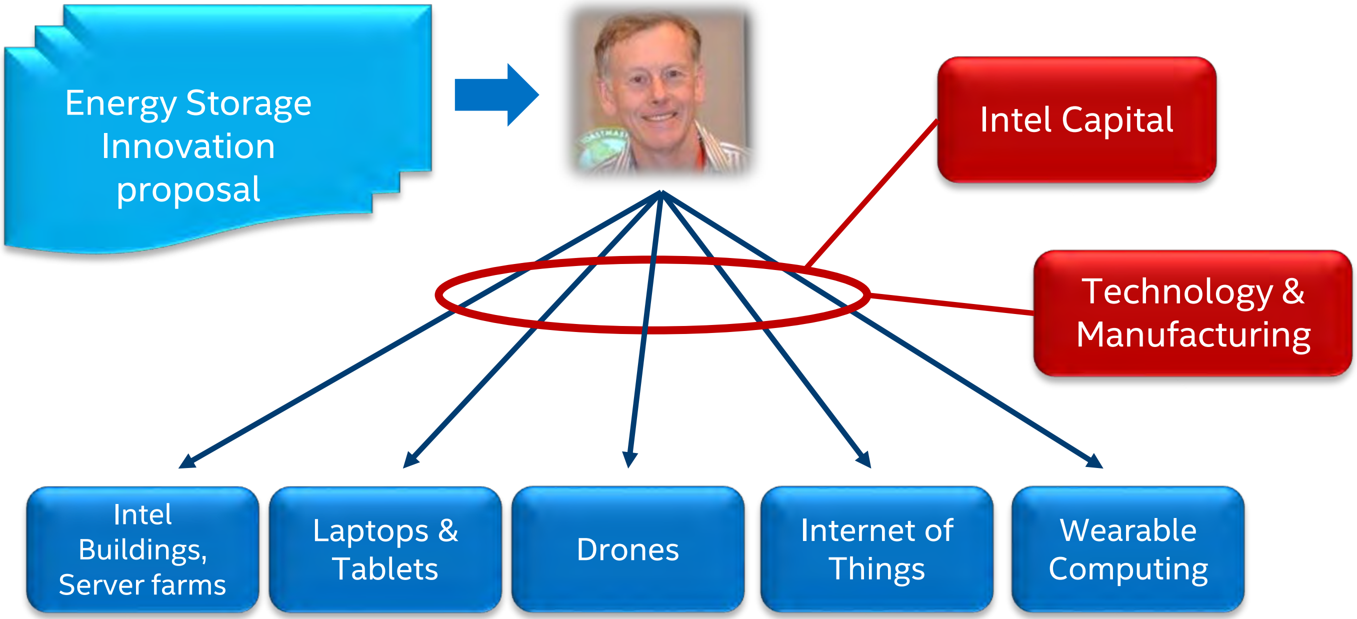
My job at Intel



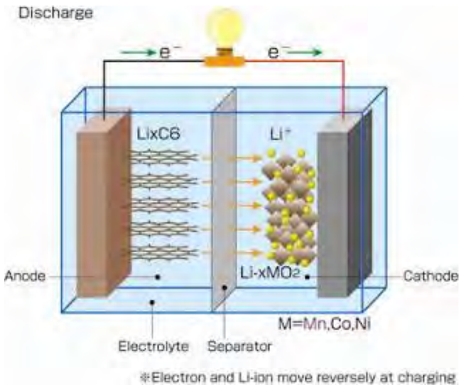
Key Requirements

Intel Buildings, Server farms	Big, low cost, longevity
Laptops & Tablets	High capacity, thin, enough power for turbo
Drones	Light, high power
Internet of Things	***Small, low self-discharge, enough power to transmit a signal***
Wearable Computing	Small, odd shapes, flexible … washable …

Battery Operation Review

A chemical reaction

- $LiCoO_2 + C_y = Li_{1-x}CoO_2 + Li_xC_y$
  Cathode Anode
  "x%" of ions moved during charge

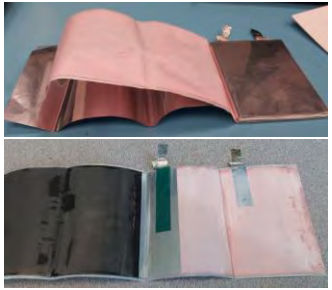


A structure

- Forces the electrons and ions to take different paths
- The electrons drive current outside the battery

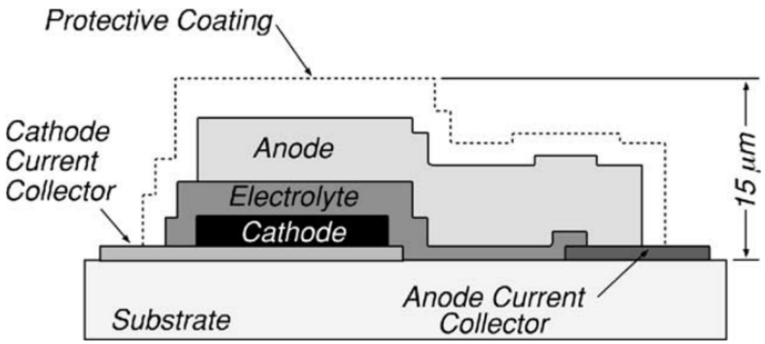
A Package

- Keeps chemicals in, moisture out.



[Animation]

Thin-Film solid-state cells



Is Lithium “it”?

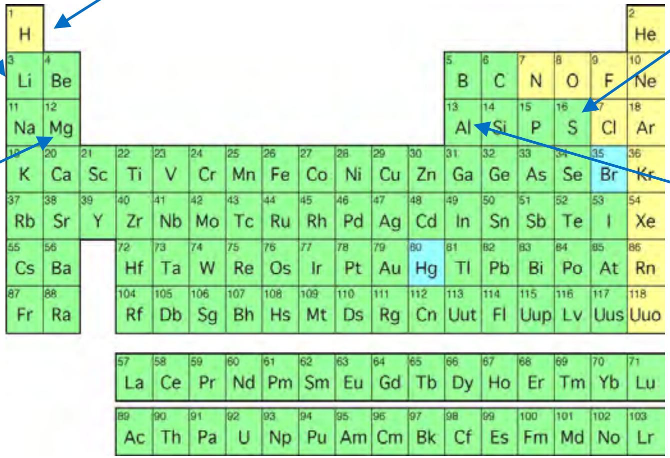
Light, operates at ~ 3.8V, is a solid metal at room temp

Hydrogen stored in a metal hydride (NiMh AA cells) is heavy, operates at ~ 1.5V

Li- Sulfur; light but less energy density, poor cycle life

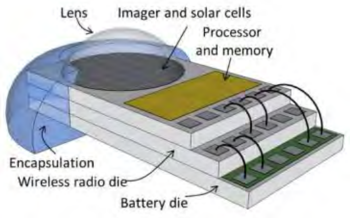
Mg++ better than Li+ if you could make it work

Al+++ better than Li+ if you could make it work, but low voltage.



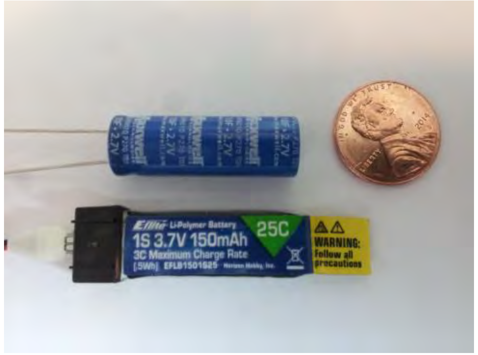
Battery challenges for the IoT

1. Recharge cycle count (cycle life)
   - Can be increased by under-charging cells at the expense of run-time
2. Power capability
   - Peak power (transmit) needs may be 1000 x idle power
3. Self-discharge
   - Can make supercapacitors impractical
4. Low temperature operation
   - Esp. solid electrolytes – it gets cold in some places!
5. Fitting into small spaces
   - Cell packaging diminishes the active material volume inside



Michigan Micro Mote

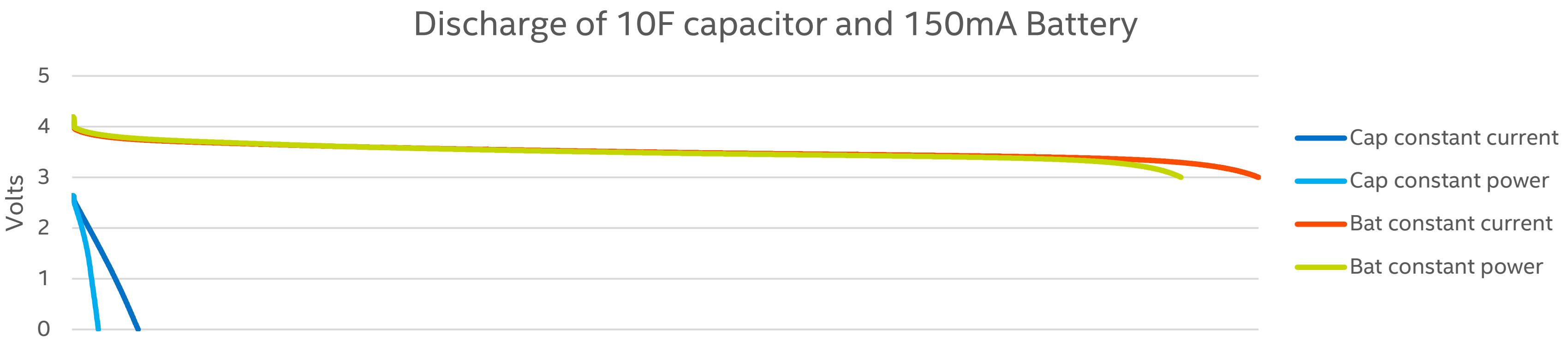
Capacitors Alternative



Great! ; High power, fast charge, high cycle life

Unfortunate:

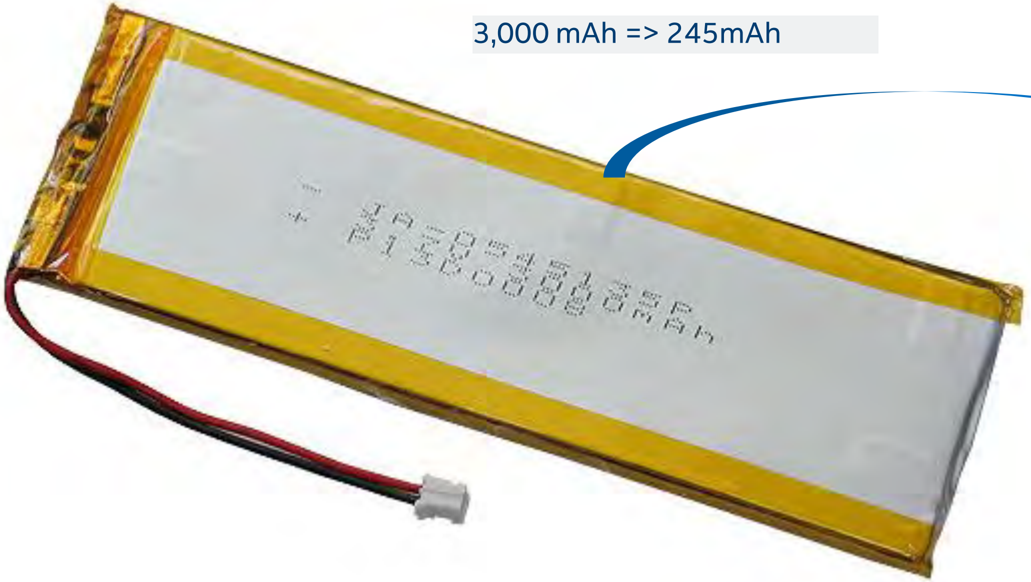
- Capacitor has <5% of the stored energy with a steep voltage drop
- Self-discharges in ~ 4 days vs ~4 years



THE CHALLENGE OF SMALL

IoTG, Wearables want smaller cells …

3,000 mAh => 245mAh



Key Inhibitor – the Package

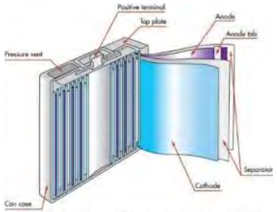
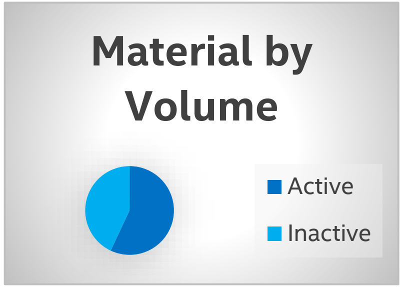


Fig 2. Prismatic or brick-shaped Li-ion cells often are cost-effective and come in a large variety of sizes.



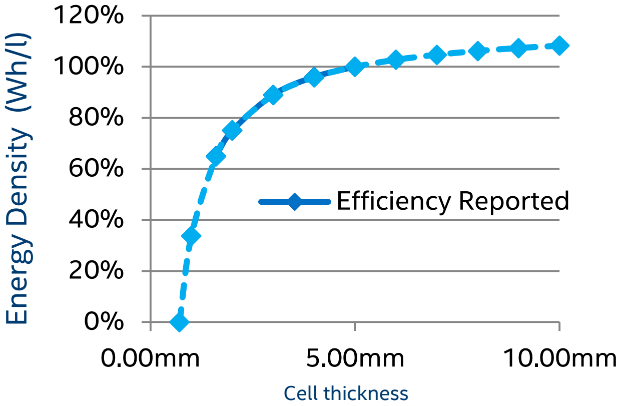
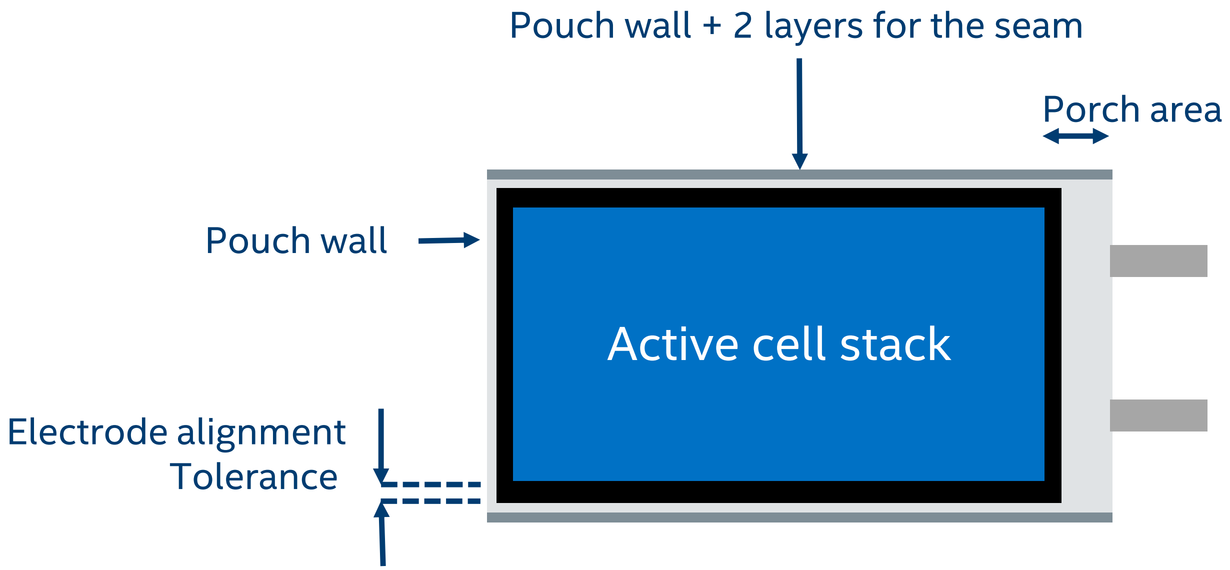
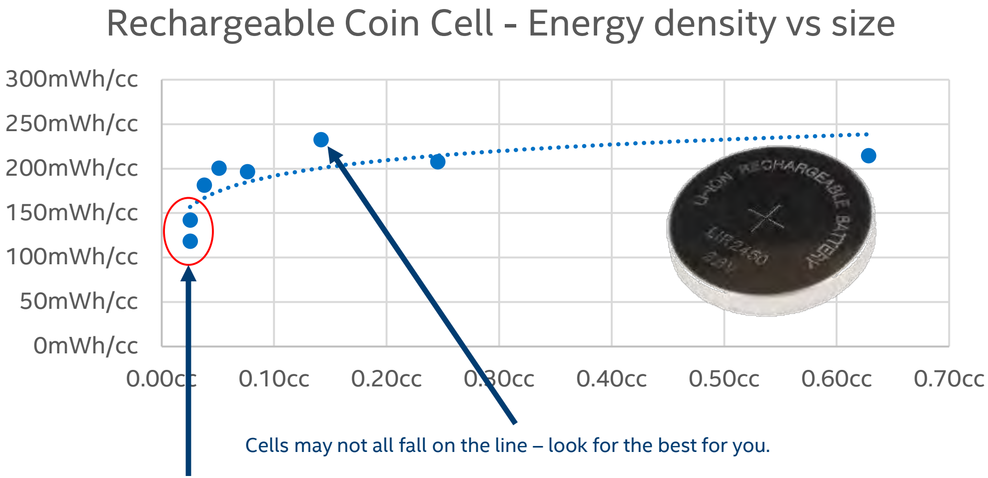


Chart: 105 x 95mm footprint cell, Z=5mm,4mm, 3mm, 2.8mm,1.6mm

Package XY Penalties



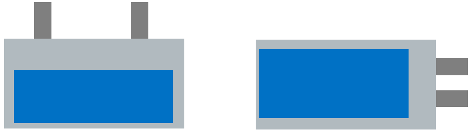
True for all cell types



Cells may not all fall on the line – look for the best for you.

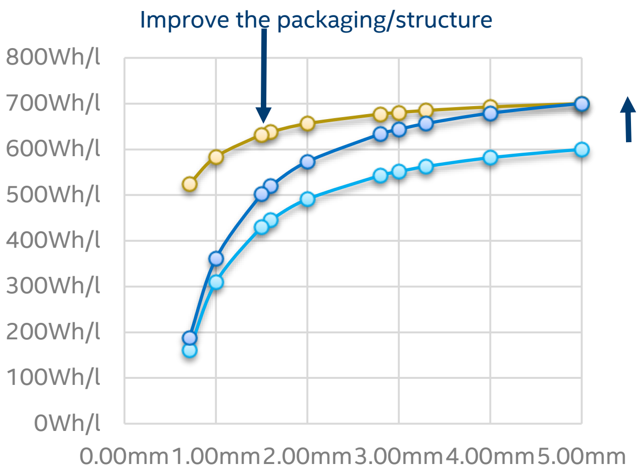
Same size – energy lost to achieve reflow-solder cell

Even XY ratio matters:

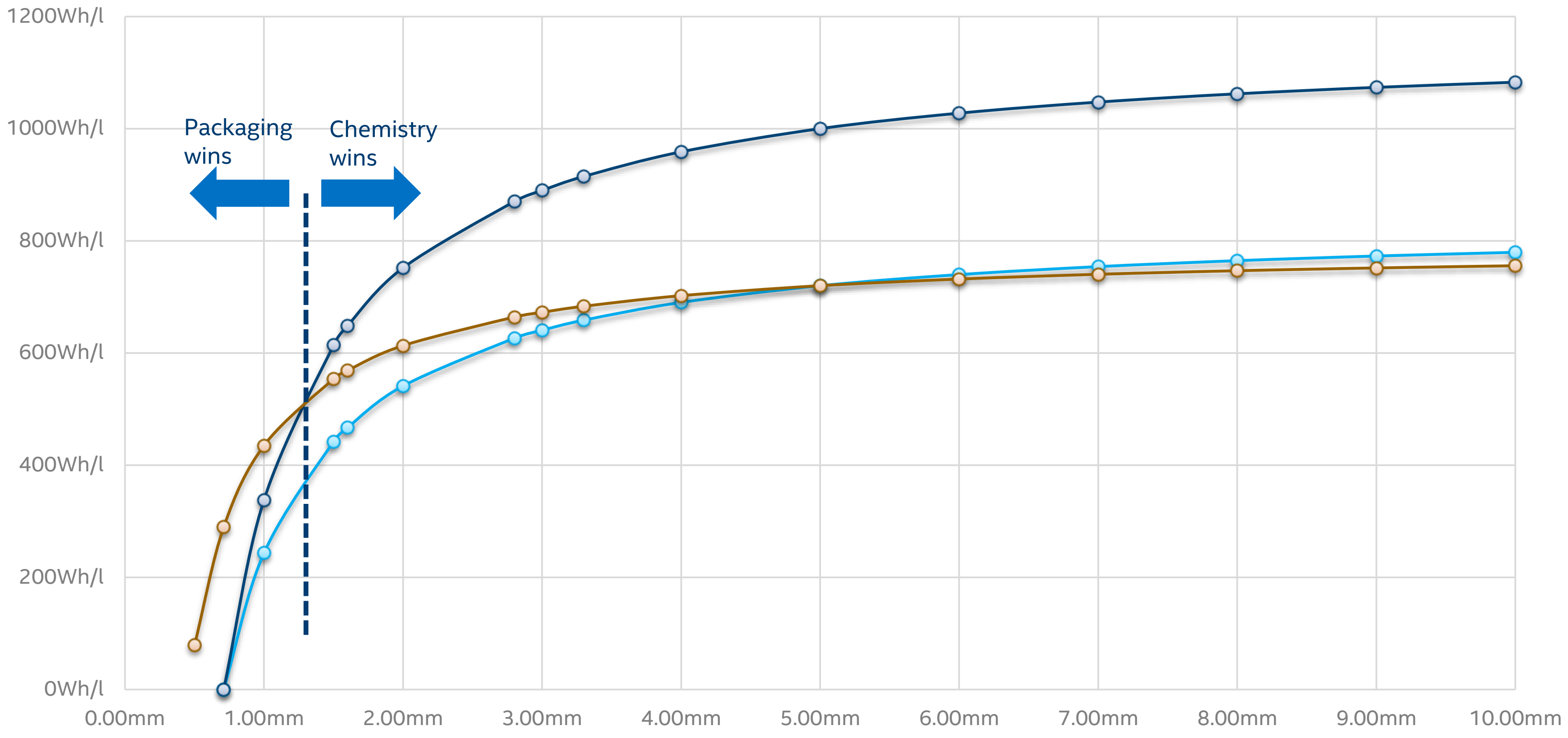


Source: OEM short-form data sheet

Improvement Vectors



Package Z penalties (PC, phone, tablet size)



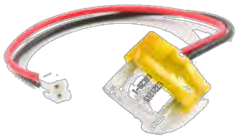
THE POWER CHALLENGE

Do only traditional watches actually consume average power ?

Intended applications & power capability

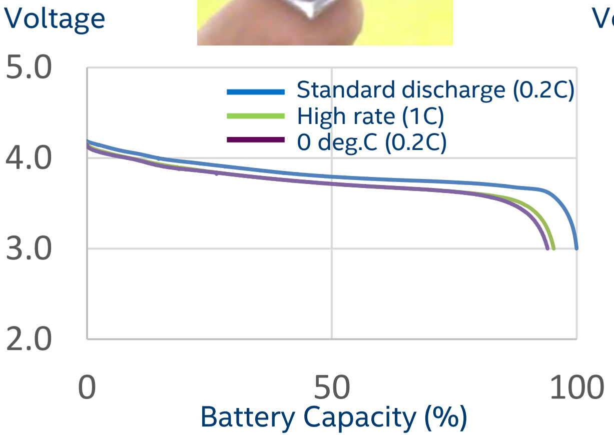
- Batteries use "C-rate" … the current that will drain them in 1 hour.
  - Non-rechargeable coin cells intended for watches etc.
    - Expect to last months – *cannot deliver energy quickly*
  - Rechargeable coin cells have ~ ½ the energy content
    - Charge and discharge in hours

  - Li-polymer batteries (1C – 25C+) can charge and discharge quickly.

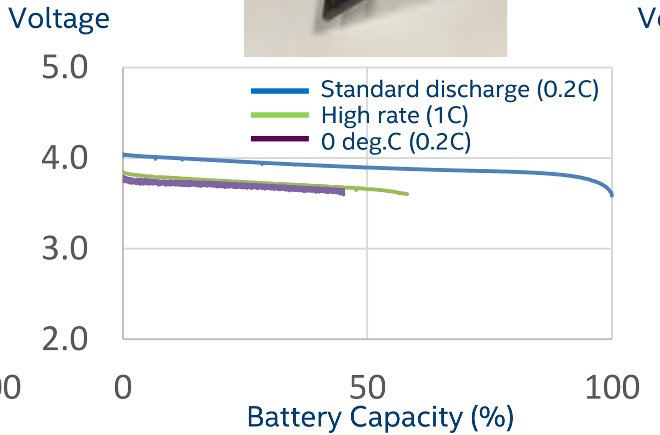


High current & low temperature

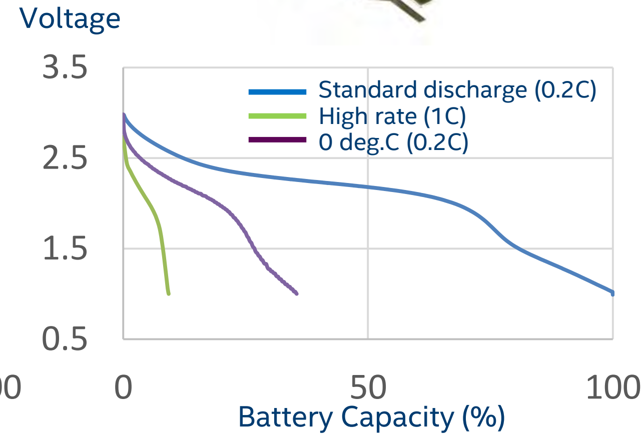
Li-ion battery



Thin-film battery



Rechargeable Coin battery



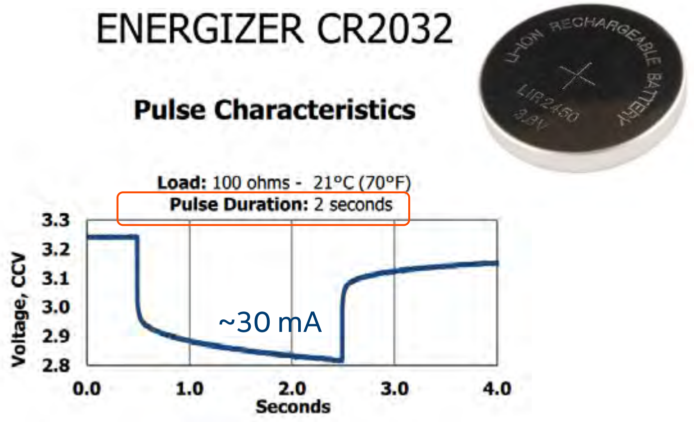
Effective capacity considering impedance is important.

Power is managed …

Transmit power ~5mA?

Compute power ~ 1mA?

Idle power µA



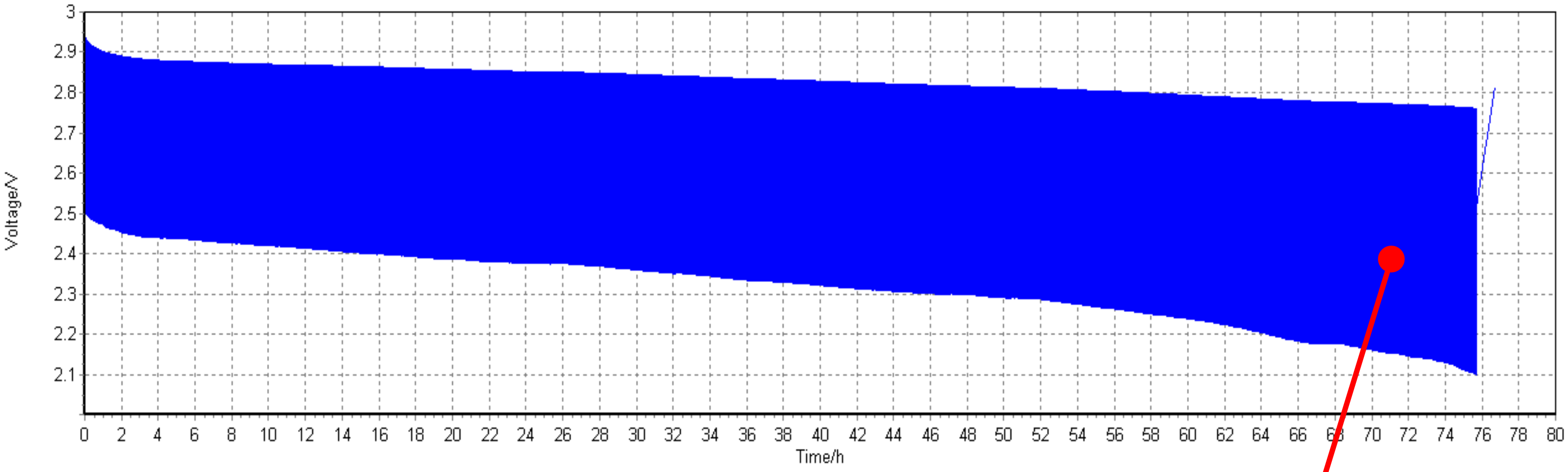
* Random data sheet – check for current values.

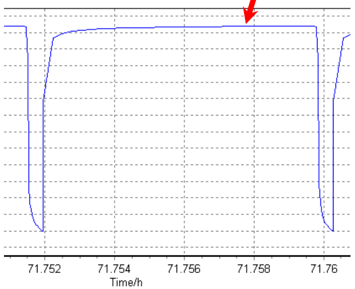
Radio power – module power may be ~10x this value. Eg class 2 Arduino shield 50mA @ 3.3V

Class	Max. permitted power (mW)	(dBm)	Typ. range[3] (m)
1	100	20	~100
2	2.5	4	~10
3	1	0	~1
4	0.5	-3	~0.5

Source: Wikipedia (Bluetooth)

Power Profile Example





Battery: CR2430 coin cell

Discharge profile:

2S pulse @ 30mA
28S idle @ 2µA

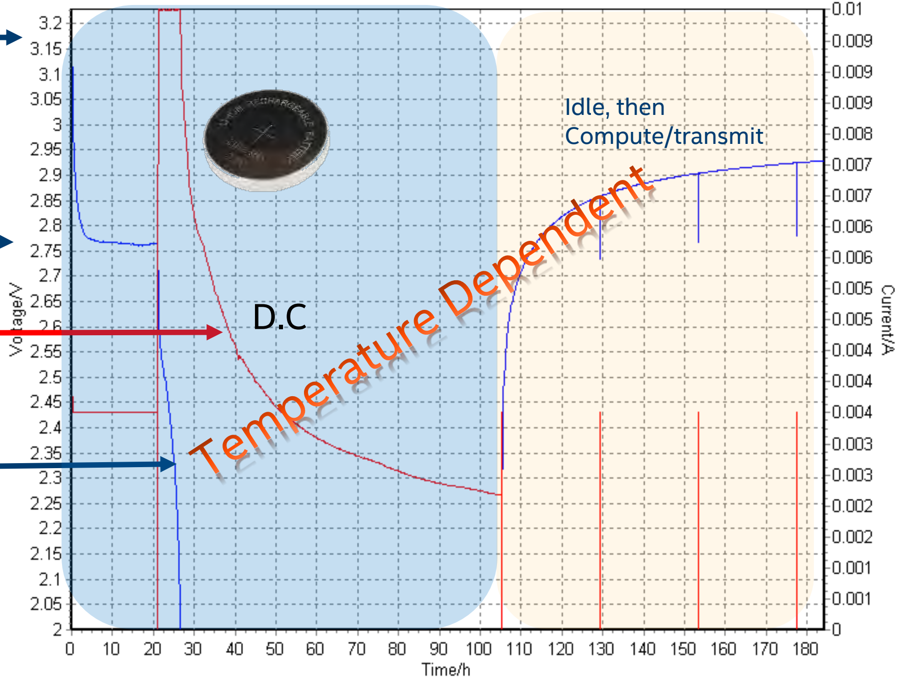
Power Delivery Example : Primary Coin Cells

Very low load voltage

Voltage with 4mA load

Maximum current to sustain 2V

Reaction to 10mA load



Choices we have for small cells

(not a complete list)

- Solid state (thin film) cells

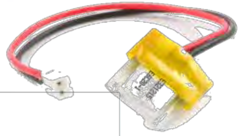
5-50uAh

500uAh – 50mAh

- Coin Cells

1mAh – 1Ah

- Small Li-ion cells

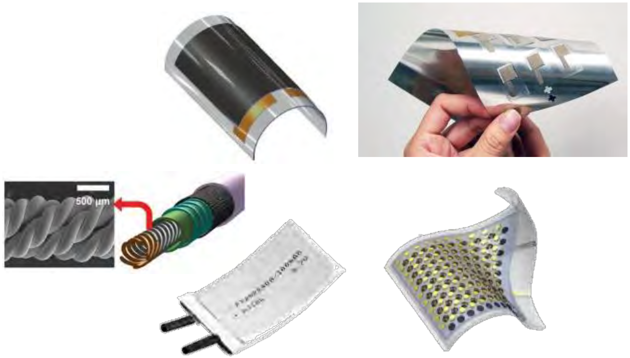


~ 10mAh +

- Pin cells

~ 15mAh

- … and a variety of interesting new formats …



Battery Selection Summary

- Find a battery that physically fits the device.
- Check that it can be recharged often enough.
  - … and remember that high-temp, high-charge degradation may be more significant.
- Check that peak currents will not cause the voltage to crash.
  - … and check that at the lowest operating temperature.
- Check that the self-discharge rate is low enough
  - … and check that at the highest operating temperature.

Summary

“You can’t always get what you want,
But if you try sometimes, you just might find
You get what you need.”

M. Jagger/K. Richards

THANK YOU!

Questions ??