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CSIRO Energy Storage Projects:

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Low Emission Transport Theme Leader

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Energy Storage for Transport

Three projects

- Safe, High-Performance Lithium-Metal Batteries
- Supercapacitors
- Ultrabattery

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10 years ago we built two hybrid cars….

In partnership with Holden we built the ECOmmodore, a parallel hybrid vehicle**.**

With aXcess Australia, a series hybrid vehicle.

But with oil at $20/bbl, the technologies were not competitive

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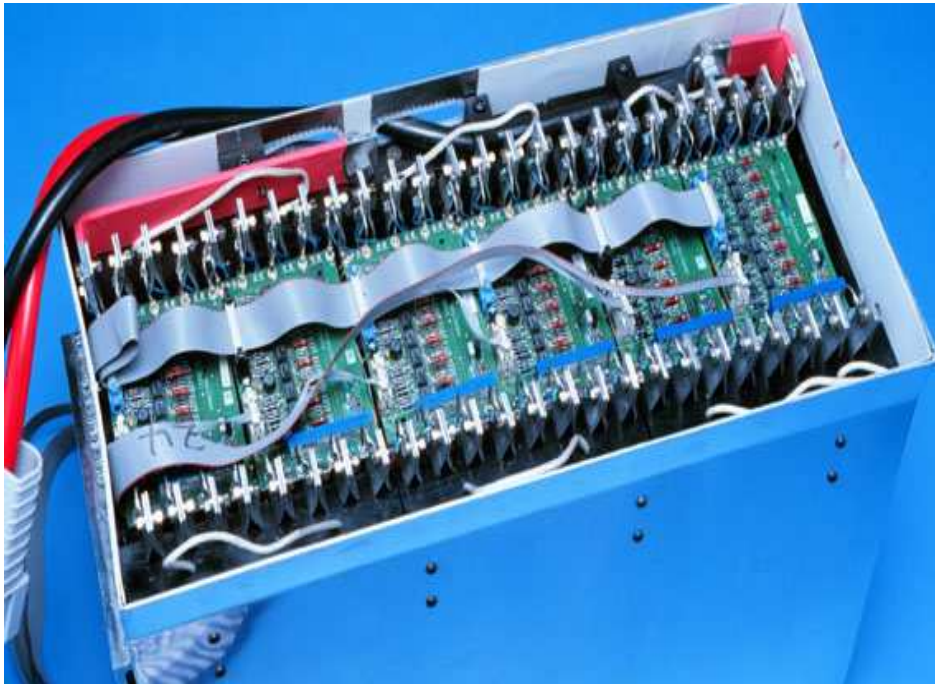
The energy storage system:

60 volt battery pack (VRLA, twin tab)

150 volt Supercapacitor



Sufficient power for good acceleration

Sufficient energy for ~15 km electric range

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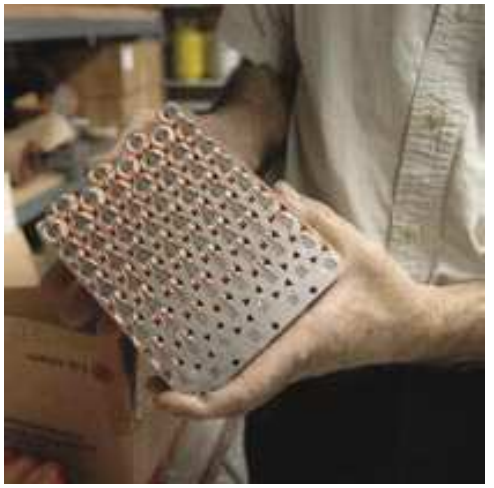
CSIRO Ultrabattery

longer life and low cost. It can be made in a conventional battery factory

Project 1. Li-Metal batteries

Safe, High-Performance Lithium-Metal Batteries

Li-ion powered t-zero
- 0 - 60 mph in 3.6s
- 300 mi range (@ 65 mph)



part of Li-ion battery pack:
7000 18650 cells!

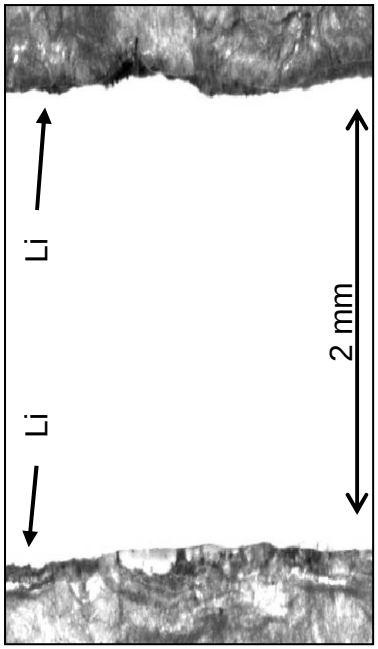
Safe Rechargeable Lithium-Metal Battery

- *Long-standing industry goal has been to replace the carbon-based anode with metallic lithium*
  - access 10-fold increase in electrode specific energy
  - device specific energy ↑ by 25%
  - targeting 200 Wh kg^{-1} (depending on cathode material)

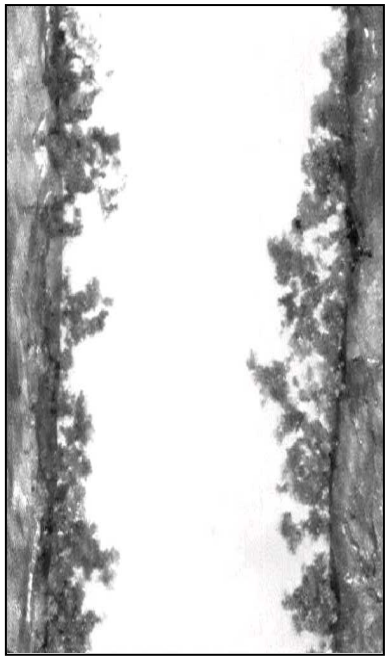
made possible by Room-Temperature Ionic Liquid Electrolyte

Why do we use ionic liquids?

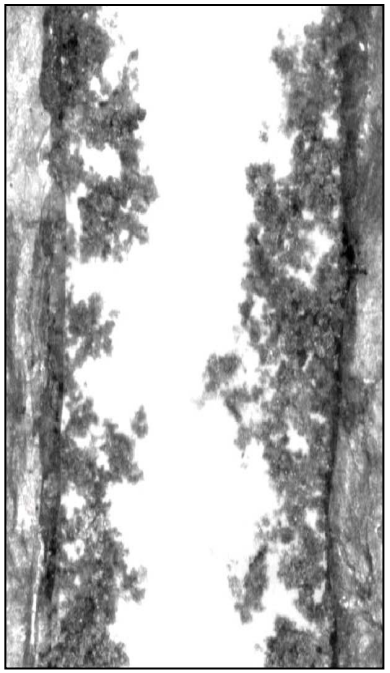
- ***……because in conventional electrolytes, the lithium electrode is not able to form a stable interphase at the electrode-electrolyte boundary….***
- ***……with the result that dendrites grow → short circuits***



0 cycles



100 cycles



250 cycles

500 cycles

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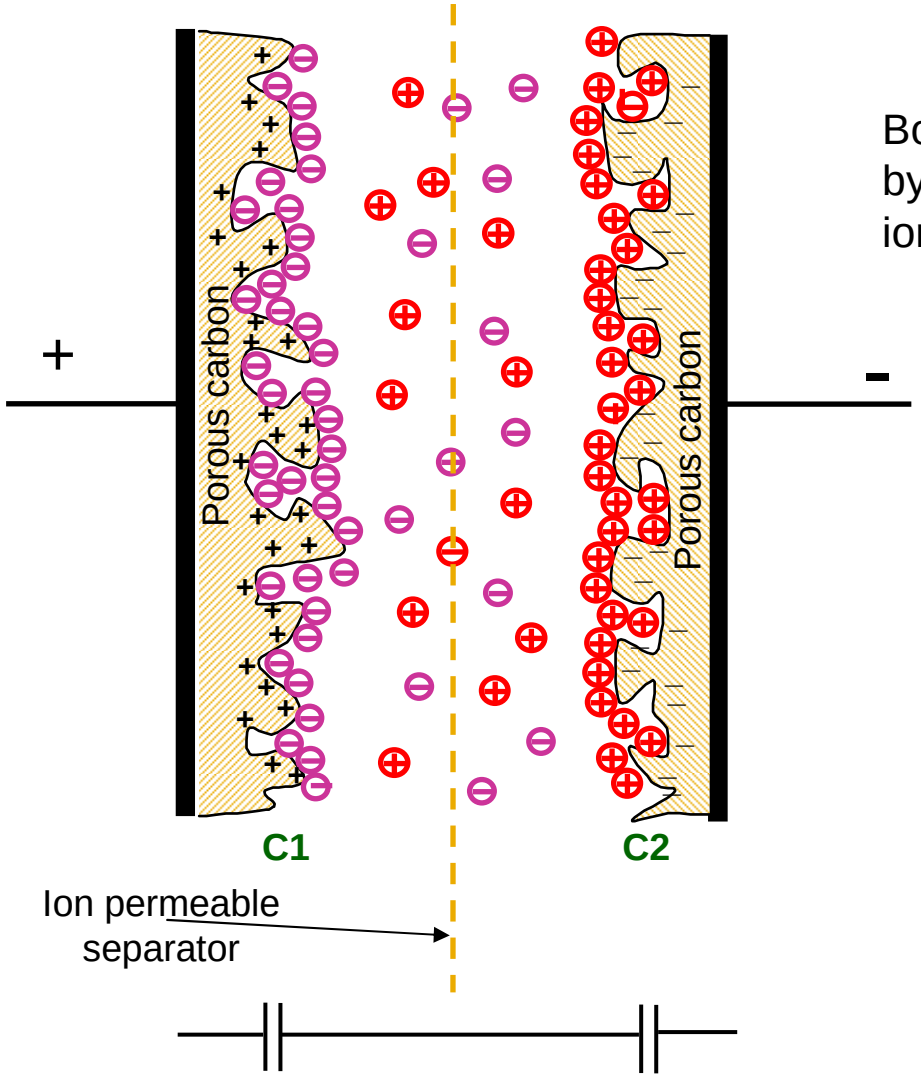
Project 2: Supercapacitors

High Energy Supercapacitors

- **Advantages**
  - ✓high power density ***(>>2kW/kg***)
  - ✓rapid charge/recharge (**Seconds**)
  - ✓environmentally friendly (well, not harmful!)
  - ✓energy storage, not conversion
  - ✓almost unlimited change/discharge cycles (***millions of cycles***)
  - ✓No maintenance

- **Current Limitations**
  - ✗low energy density **(~5Wh/kg)** relative to batteries
  - ✗voltage drops with energy use *(can be accommodated)*

Carbon Supercapacitor *(symmetric)*



Both electrodes charged and discharged by ***reversible adsorption/desorption*** of ions

$$1/C_T = 1/C_1 + 1/C_2$$

if C1 = C2, then

$$C_T = ½.\ C_2$$

(Energy = ½CV²)

Typically ~5 Wh/kg

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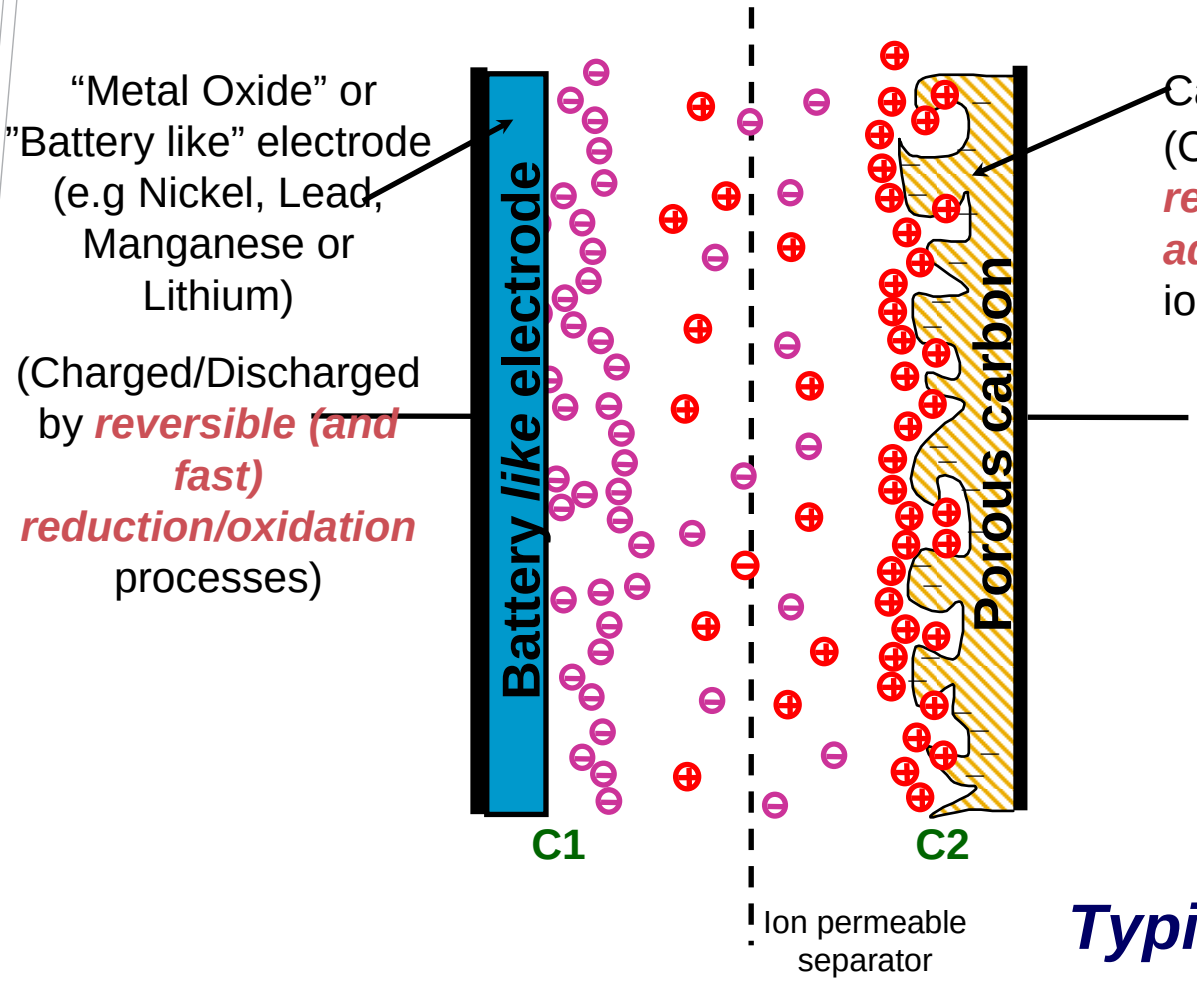
New *Asymmetric* Supercapacitor



$1/C_T = 1/C_1 + 1/C_2$

Since $C_1 >> C_2$, then

$$C_T = C_2$$

Typically ~5 - 25 Wh/kg

Asymmetric has twice the capacitance of symmetric capacitors

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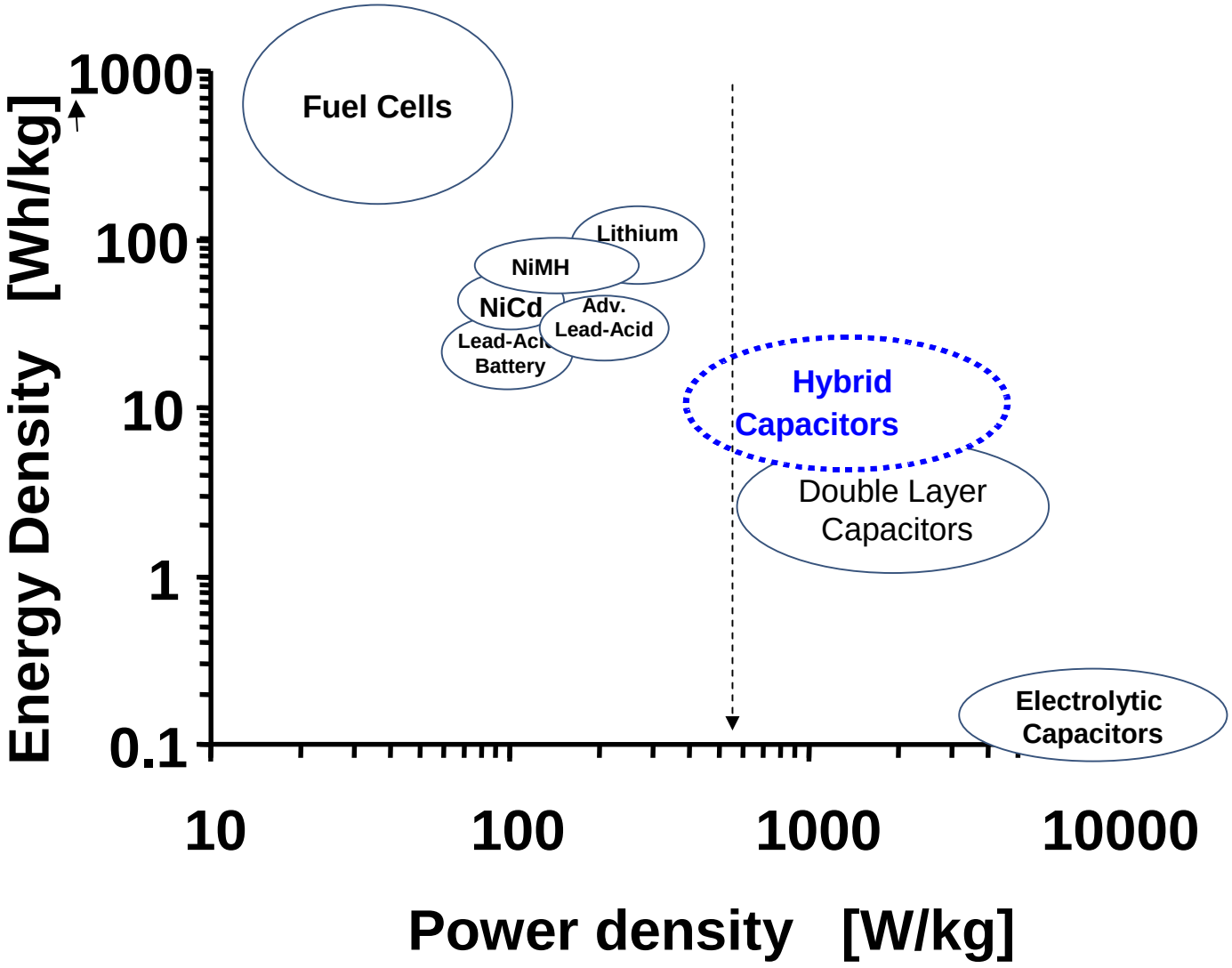
Energy vs. Power



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CSIRO $Ni(OH)_2$/C Asymmetric Supercapacitors
- *Performance to date*

Prototype	Capacitance **[Farads]**	Energy **Wh/kg**	Max. Power **W/kg**	ESR **[m.Ω]**	Cycle Efficiency
06-01 (45 mL)	1980	12.1	4430	2.3	0.99
06-02 (45 mL)	2250	5.8	1670	3.5	0.99
06-03 (90 mL)	1770	5.1	1540	2.3	0.99
06-04 (90 mL)	4740	7.8	1410	2.9	0.96
06-05 (90 mL)	**8540**	**14.8**	**2740**	**1.0**	**0.99**

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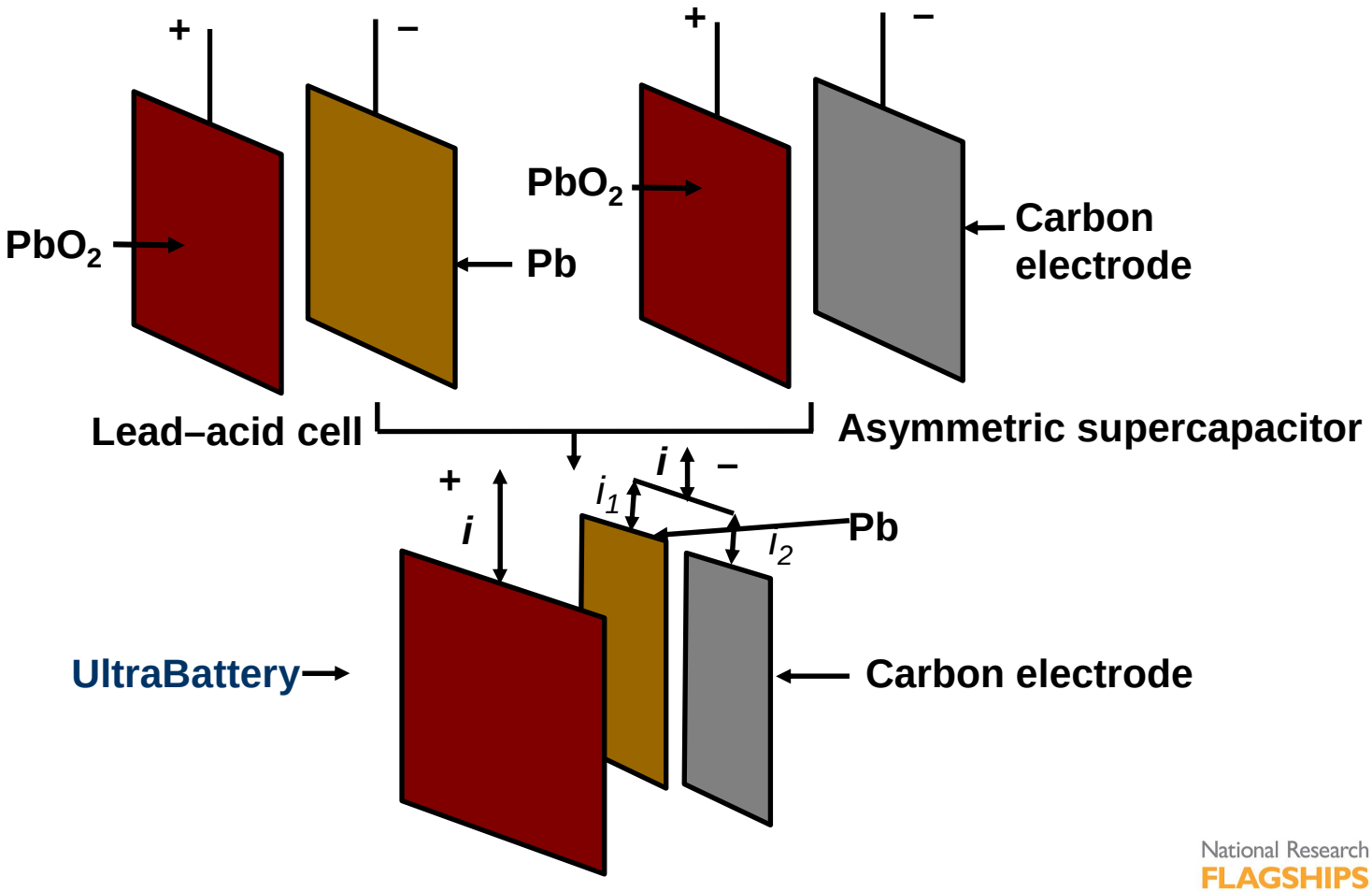
Project 3: Ultrabattery

Low cost vs high tech batteries

Absorbs energy quicker, lasts longer, suitable for hybrids

Configuration of UltraBattery

- UltraBattery combines an asymmetric capacitor and a lead-acid battery in one unit cell, without extra electronic control.



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Project 3 - Ultrabattery

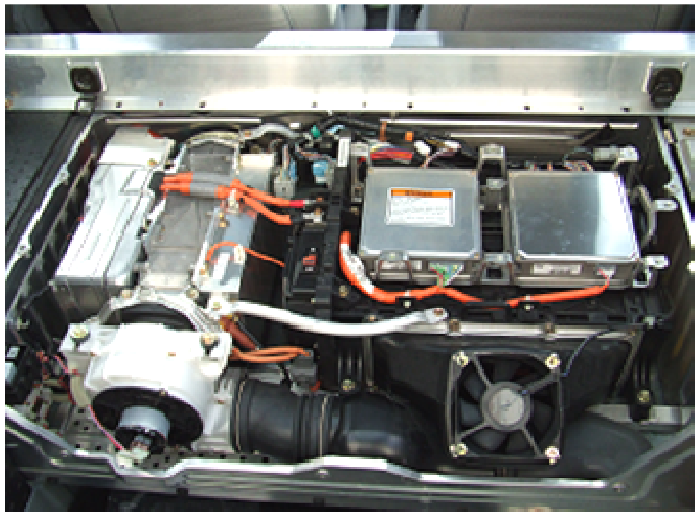
Laboratory evaluation

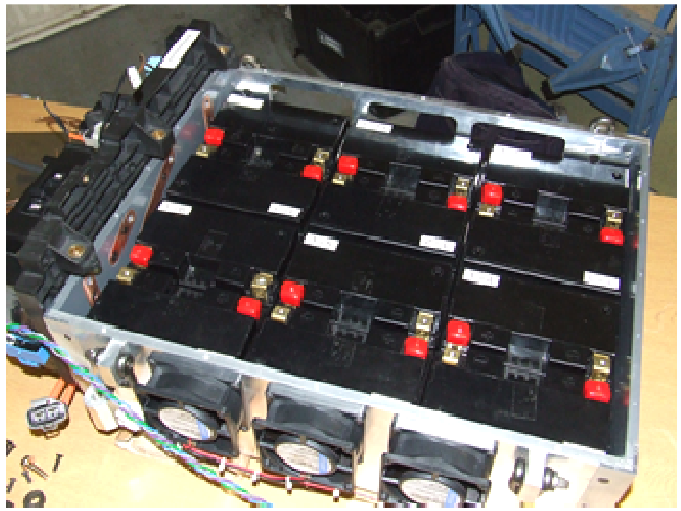
- **Ultrabattery meets or exceeds the targets of *power, available energy, cold cranking and self discharge* set by the US FreedomCar for both minimum and maximum power-assist HEV systems**
- **Cycling performance of UltraBattery is significantly longer than that of the state-of-the art lead-acid batteries and, *more importantly, is proven to be comparable or even better than that of the Ni-MH cells used in Honda Insight HEV***

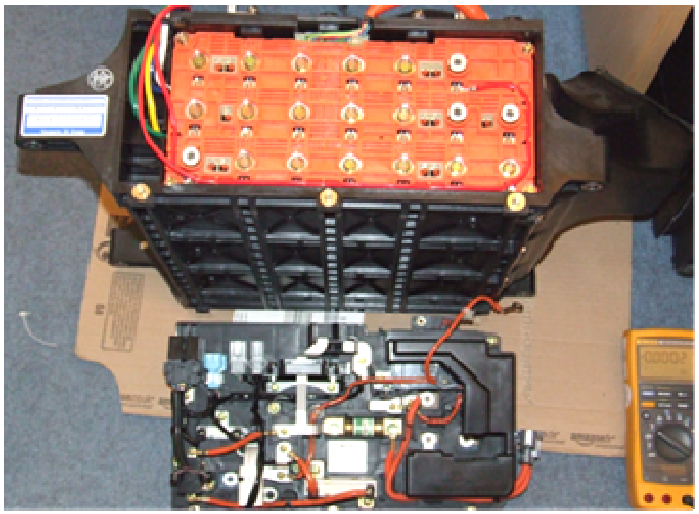
Field trial at Millbrook, UK

- ***In durability trials the UltraBattery pack achieved 100 000 miles and the battery pack is still in a strong and healthy condition.***

Replacement of Ni-MH pack with UltraBattery Pack







Ni-MH pack

UltraBattery pack

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Fuel, emissions and cost comparison

	Fuel consumption L/100km	CO^2 Emissions g/km	Battery cost $US
Ni-MH	4.05	96	$1500 to $2500
Ultrabattery	4.16	98.8	$350 to $400

The long service-life and reduced cost of the UltraBattery will promote the 'uptake rate' of HEVs.

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100+ MPG
CALCARS.ORG
AQMD
Energy CS
SUNPOWER
TOYOTA
PRIUS
PLUG OK
CALCARS.ORG
THIS PLUG-IN HYBRID GETS 100+ MPG

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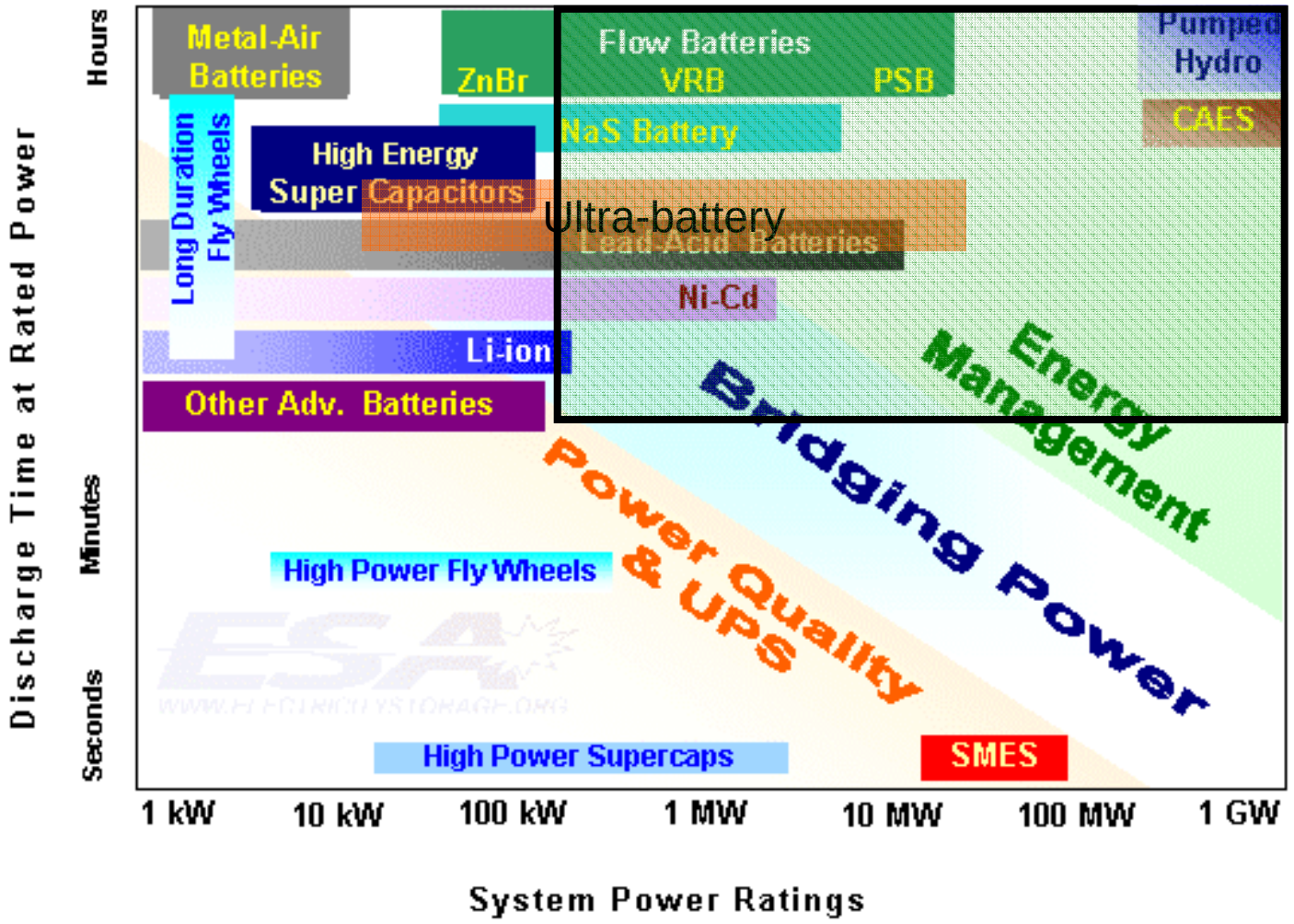
Ultrabattery: features and benefits

- Greater power
- Significant improvement in service-life
- Able to produce in smaller sizes, with sufficient power to drive the bigger engine capacity in conventional automobiles
- Applicable to a wide range of HEVs with greatly reduced cost compared with existing nickel/nickel-metal hydride technology
- Reconfigurable for a variety of applications (i.e., power tool, high-power UPS and renewable energy)
- Low cost

Power characteristics of different energy-storage devices



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