Lead–acid Batteries for Hybrid Electric Automobiles

What is a hybrid electric vehicle?

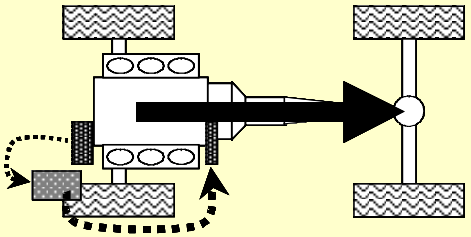
What does it do?

What does the battery have to do?

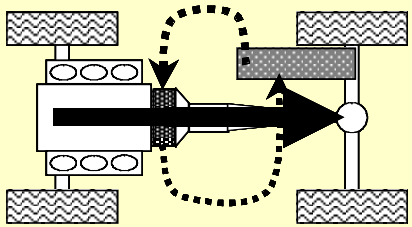
What are the candidate batteries?

How should we choose between them?

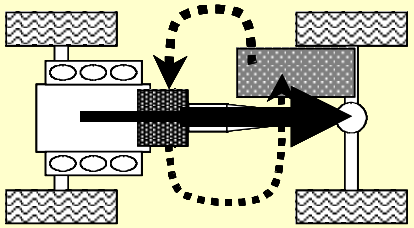
SLI only



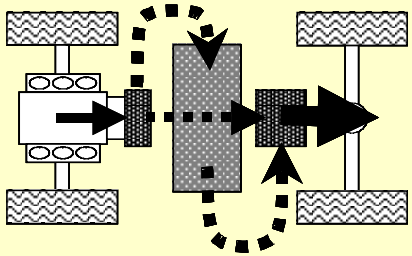
ISG



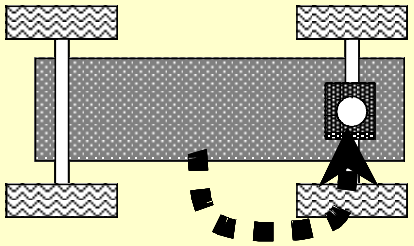
Parallel hybrid

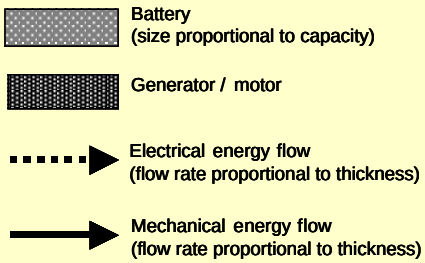


Series hybrid



Electric drive

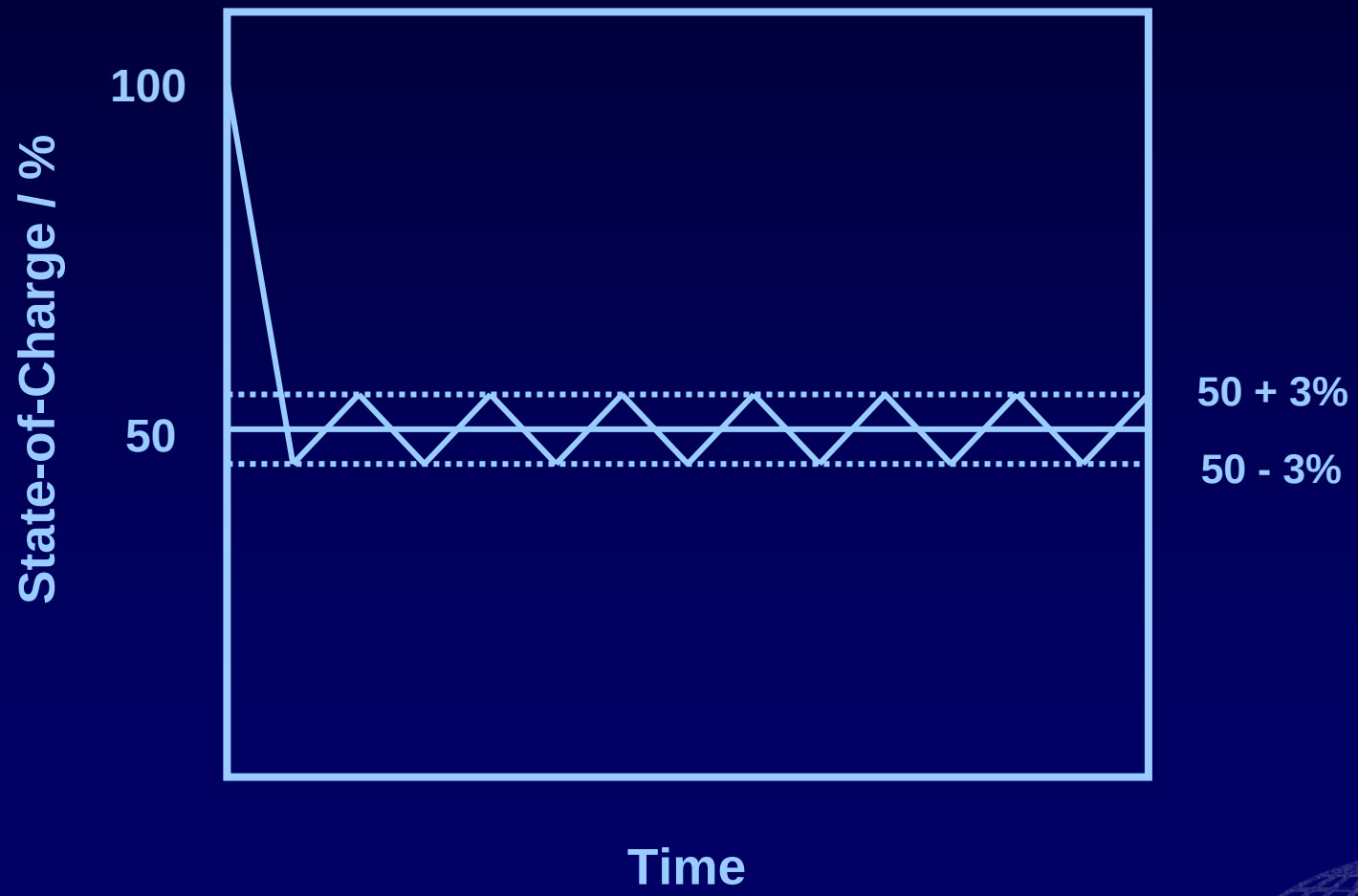




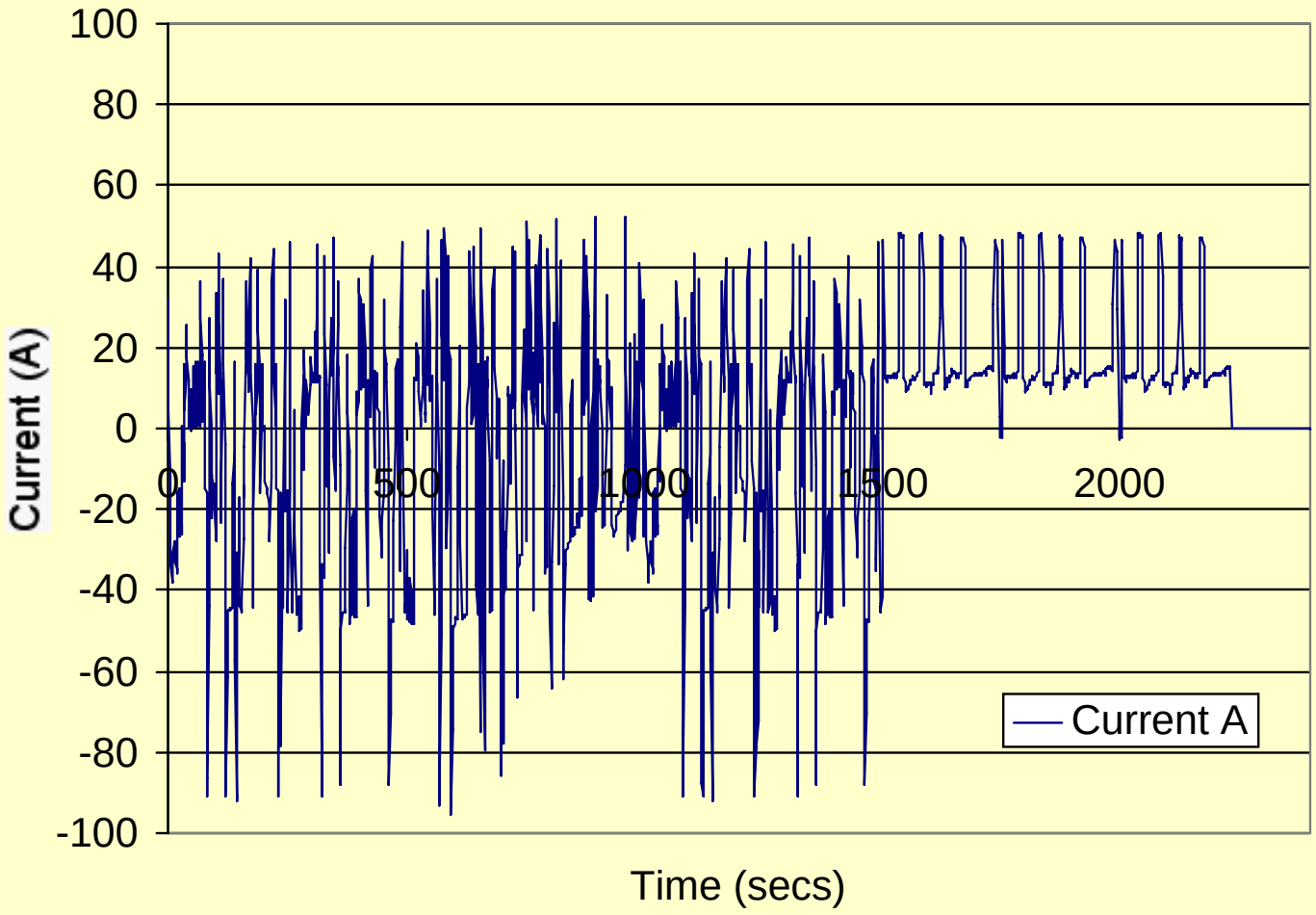
Types of Hybrid Electric Automobile

	Micro-	Mild-	Medium	Full
EV Drive				☆
Motor assist		☆	☆ ☆	☆ ☆ ☆
Regen. braking	☆	☆	☆ ☆	☆ ☆ ☆
Engine stop	☆	☆	☆	☆
Battery voltage	12	36	144	>200
Battery capacity (Ah)	50 - 60	15 - 20	6 - 8	6

State-of-charge of battery



Charge and discharge currents experienced by ‘Insight’ battery during hard driving



Typical range of state-of-charge, rates of discharge and recharge and failure modes

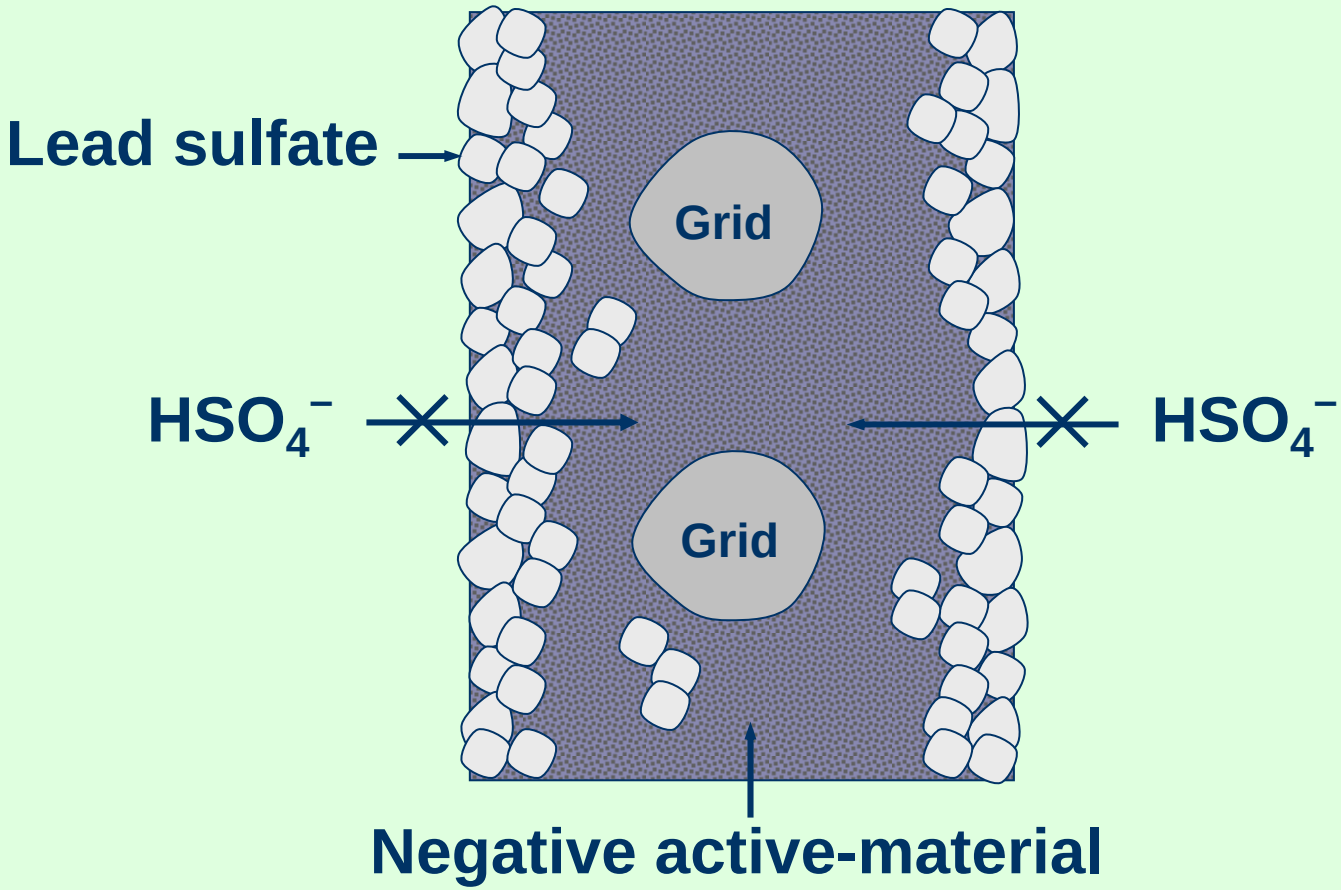
Duty	SLI	Deep cycle	High rate PSoC
Examples	12 V	EV	HEV , UPS, PV
Range of SoC	85 - 90 %	20 - 100 %	50 - 70, 70 - 90 %
Max. norm. disch. rate	10 C	4 C	15 C
Max. norm. charge rate	0.5 C	0.5 C	8 C
Life-limiting mechanisms	Corrosion, shedding	PCL 1, PCL 2	**?**

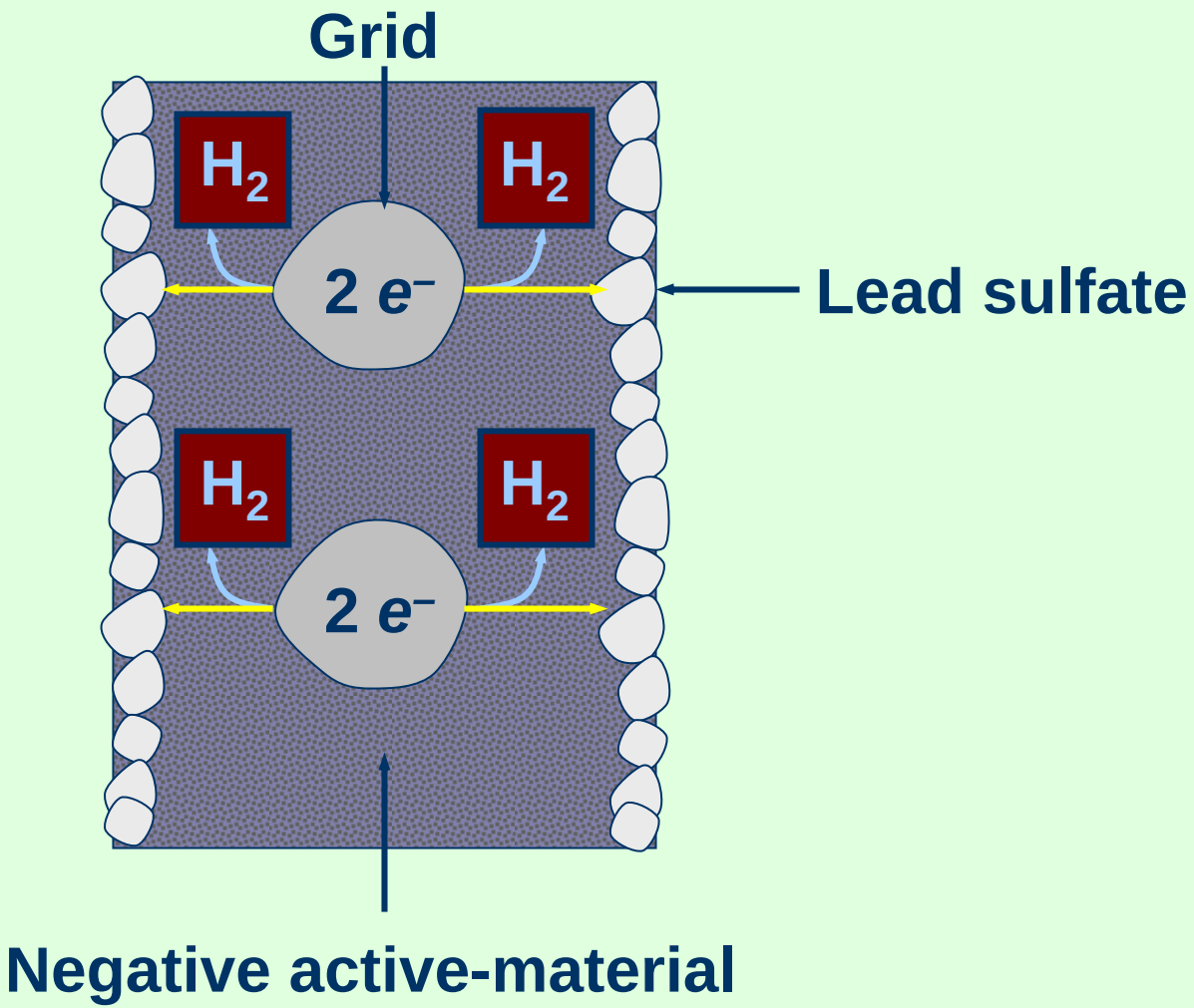
What factors should be considered when selecting a battery for an HEV?

Cost

Weight

Life


Lead sulfate
Grid
HSO_4^-
HSO_4^-
Grid
Negative active-material


Grid
H_2
H_2
2 e^-
Lead sulfate
H_2
H_2
2 e^-
Negative active-material

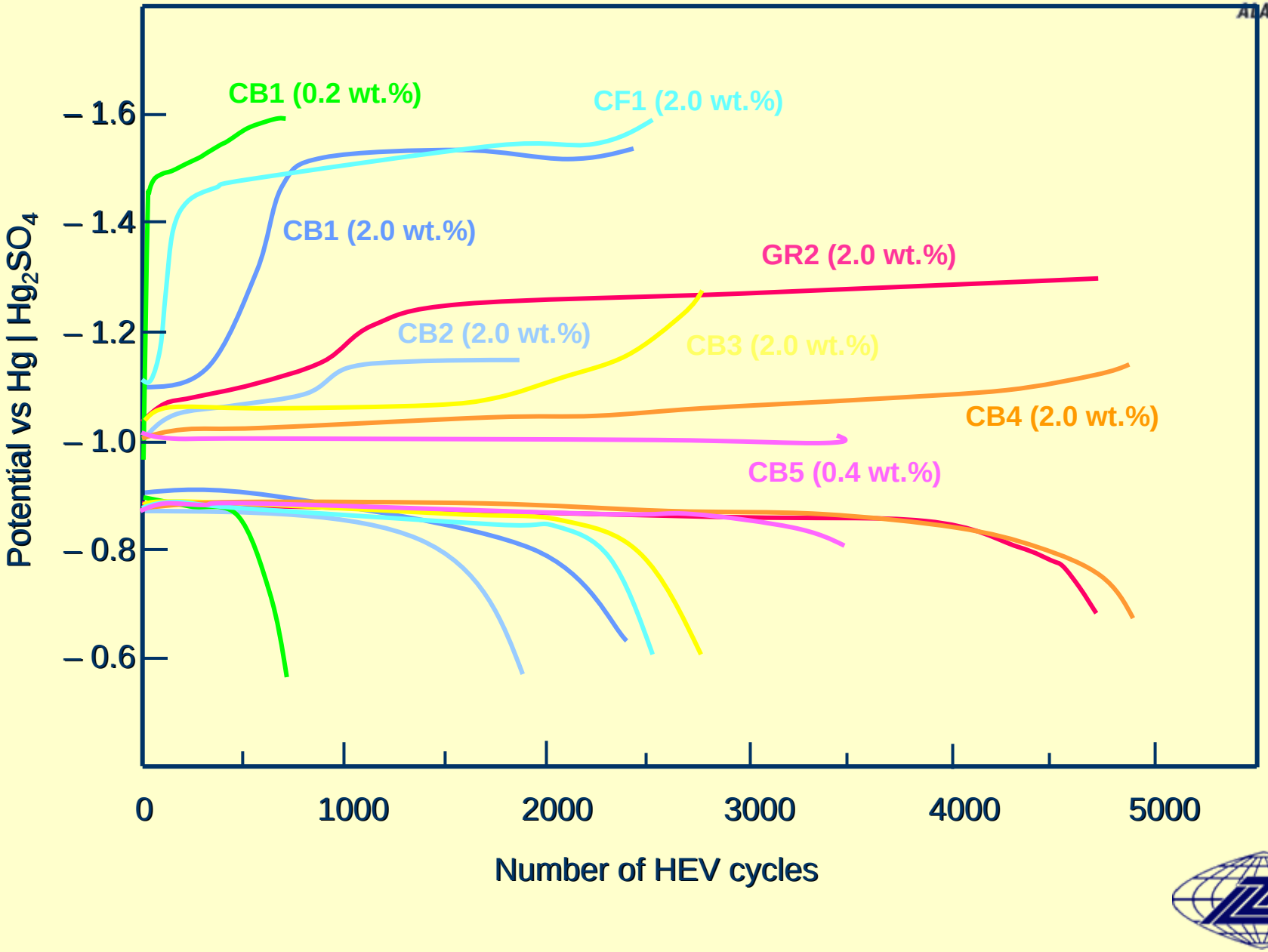
Characteristics of high-rate partial-state-of-charge operation

1. High rate - up to 15 C discharge and 8 C charge

2. Long periods without approaching top-of-ch.

3. Very large number of (small) cycles - 300,000 rather than < 1,000.

EoC and EoD potentials of negative plates in HRPSoC operation



Medium Hybrids

Key FreedomCAR Performance Goals

Characteristic	Units	Min. Power-assist	Max. Power-assist
10 s Disch. power	kW	25	40
10 s charge power	kW	20	35
Available energy	kWh	0.3	0.5
Weight	kg	40	60
Cycle life	cycles	300,000	300,000
Derived parameters			
Specific disch. power	$W\ kg^{-1}$	625	667
Specific ch. power	$W\ kg^{-1}$	500	583
Specific energy	$Wh\ kg^{-1}$	7.5	8.3

VRLA Batteries designed for power-assist operation

Battery type, manufacturer	Design elements	Specific power ($W\ kg^{-1}$)
'RHOLAB' (8Ah) Enersys	Twin-tab to boost Power, spiral	600
Bipolar (8Ah) Effpower	Bipolar plate Pb-Impreg ceramic	1000
Ultra (8.5Ah) Furukawa/CSIRO	Additional carbon Capacitive element	500 - 600

The First Test Vehicle

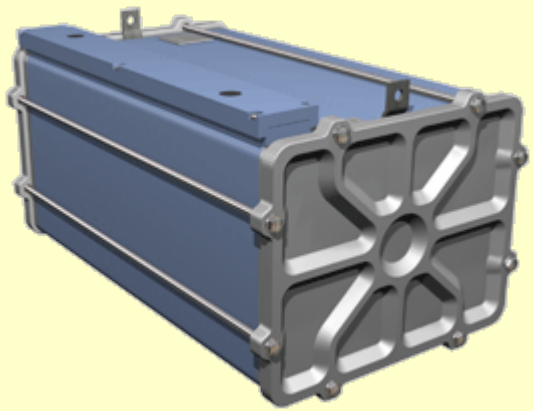
Project Effpower

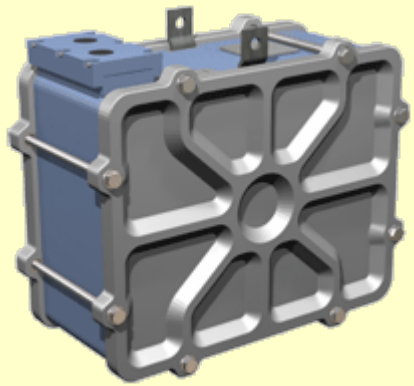
ALABC Identifier: Effpower

Battery type: Bipolar, 8 Ah, 144V

Vehicle: Honda Insight

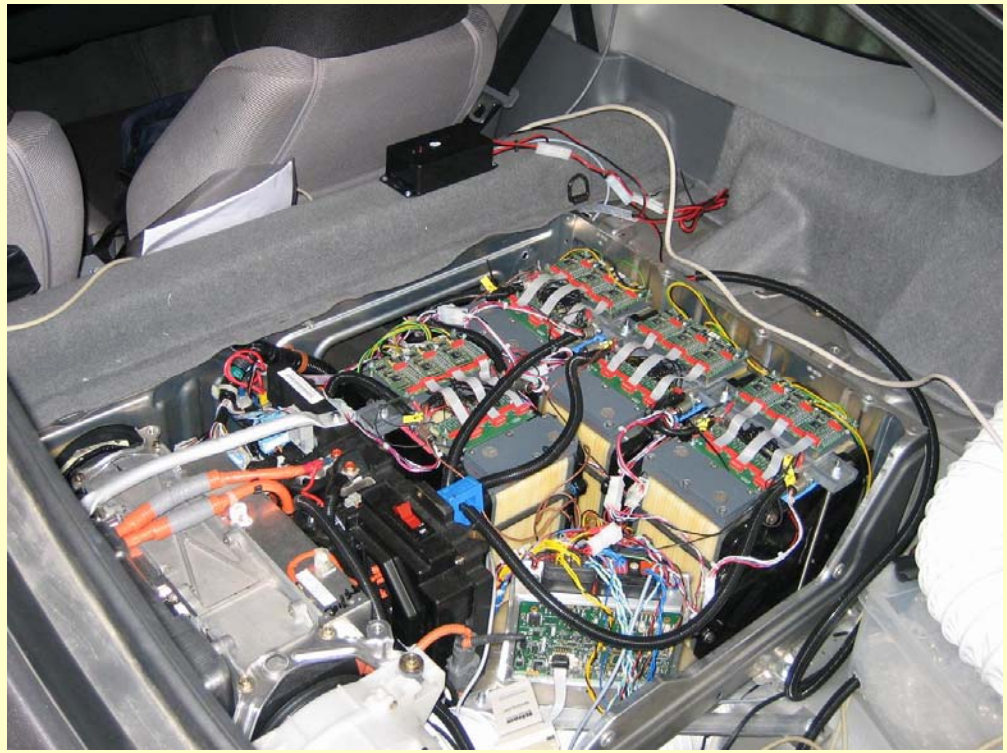
Voltage: 144V





BATTERY MANAGEMENT

- Honda Insight Battery Management System supplied and installed by PROVECTOR
- Add-ons including CAN interface, OBD2 module and GPS module
- Effpower cell monitoring system



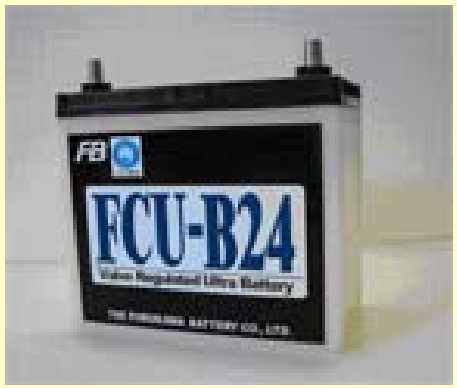
Project ‘Ultra’

ALABC Identifier: DP 1.1

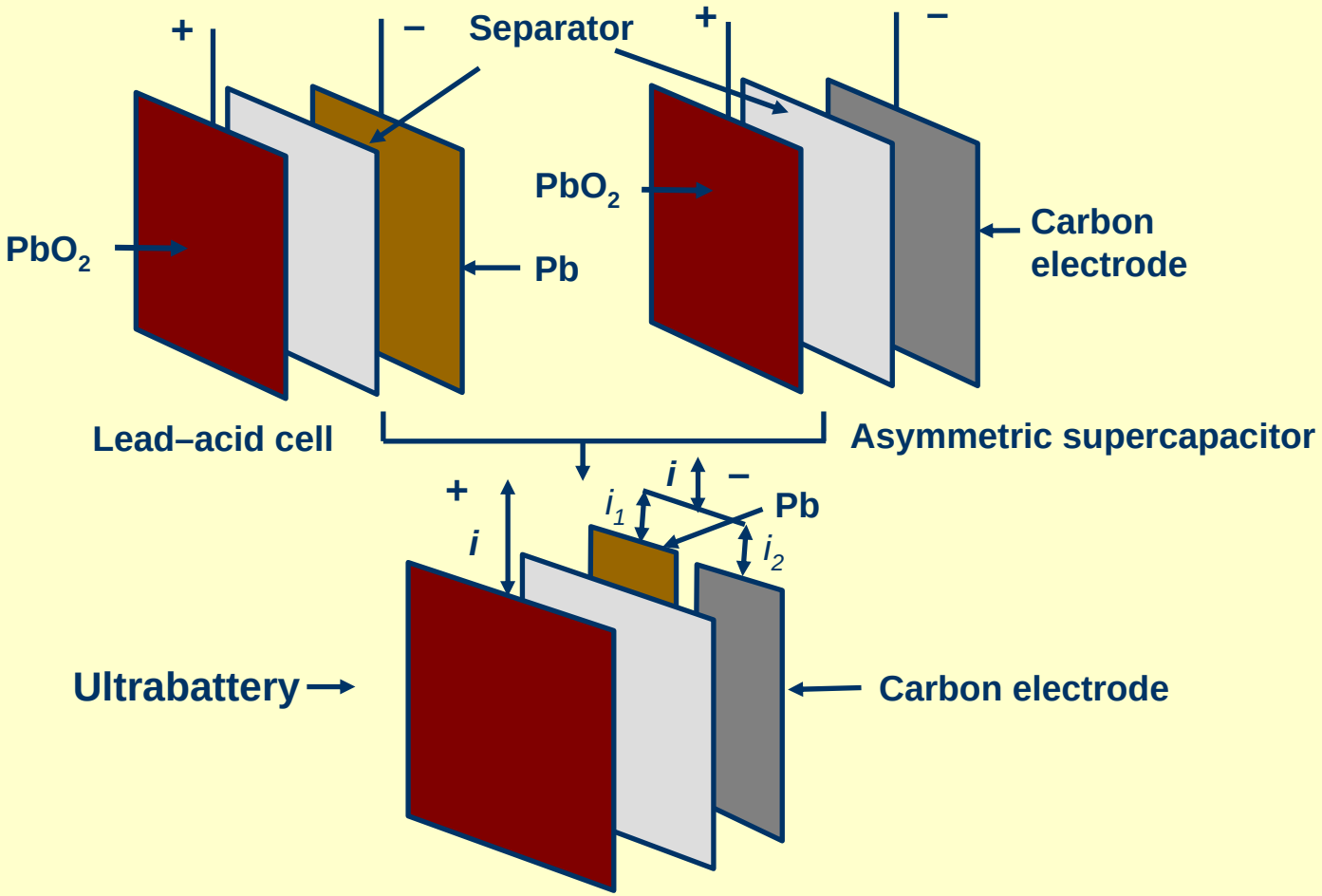
Battery type: Furukawa/CSIRO flat, 7 Ah, 12V

Vehicle: ALABC Honda Insight

Voltage: 144V



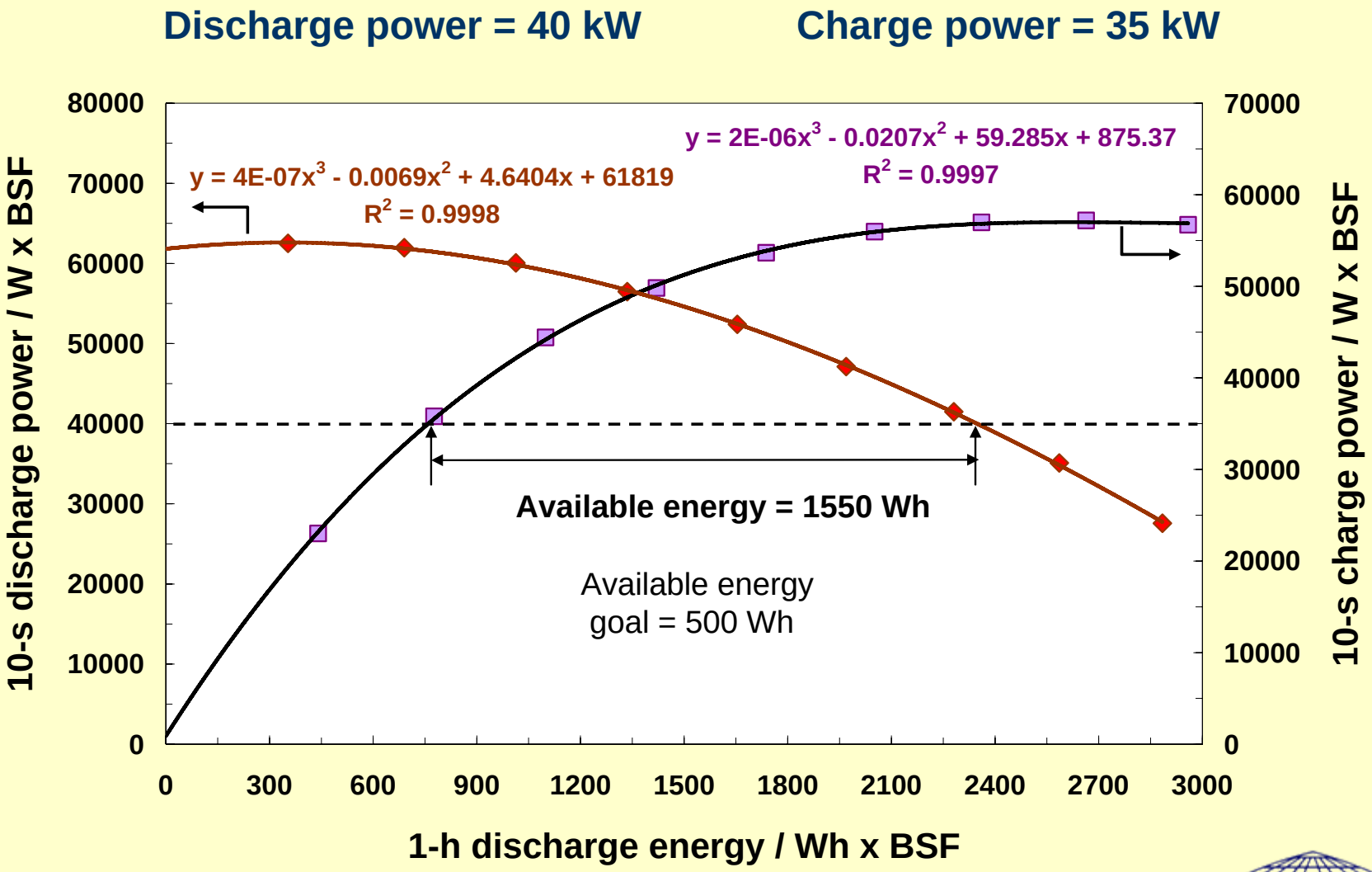
Configuration of the Ultrabattery



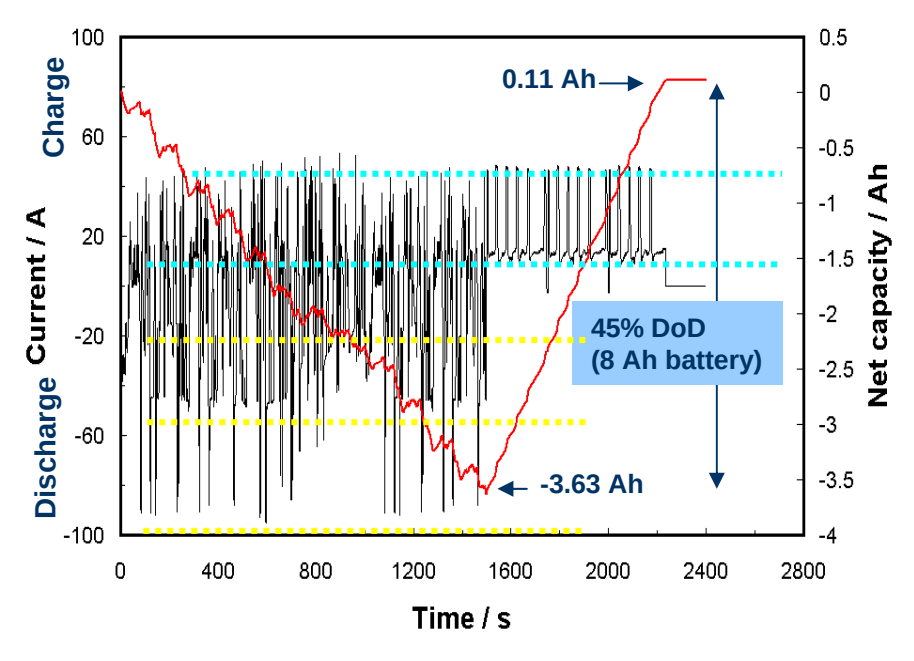
Ultrabattery is a hybrid energy-storage device, which combines an asymmetric capacitor and a lead-acid battery in one unit cell, without extra electronic control.

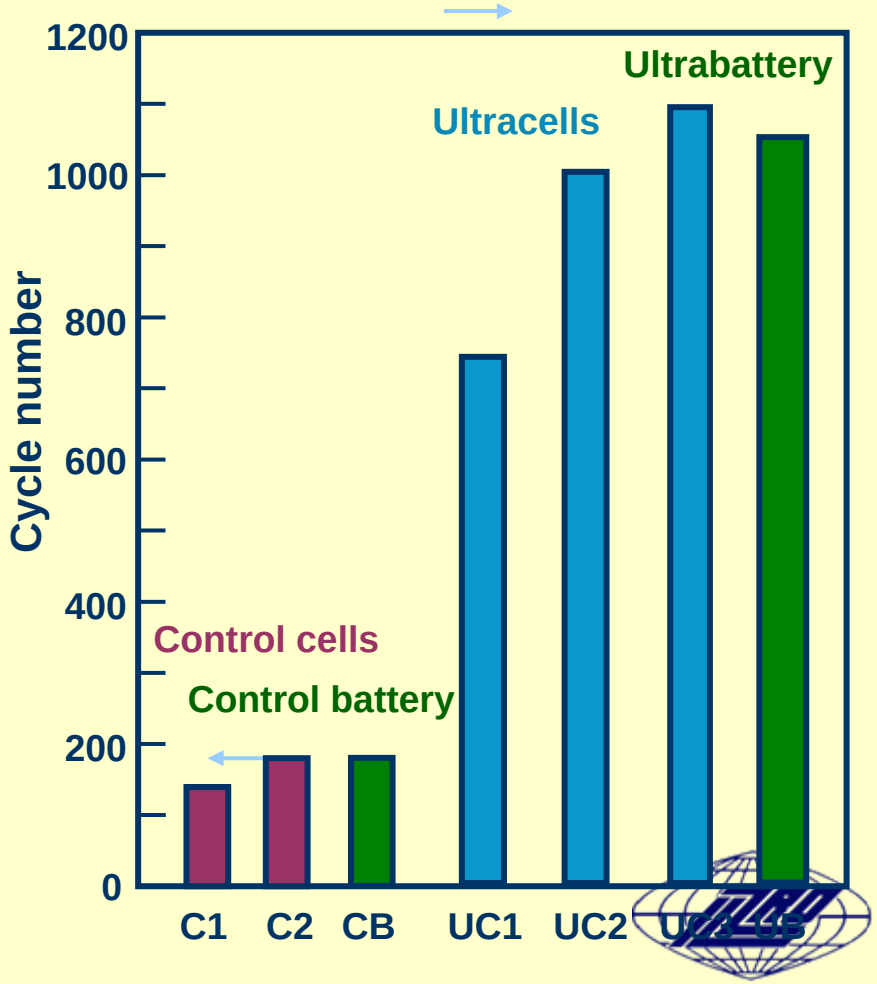
Hybrid pulse power characterisation

(maximum power assist, battery-size factor = 35)



High-speed and hill-climbing driving profile





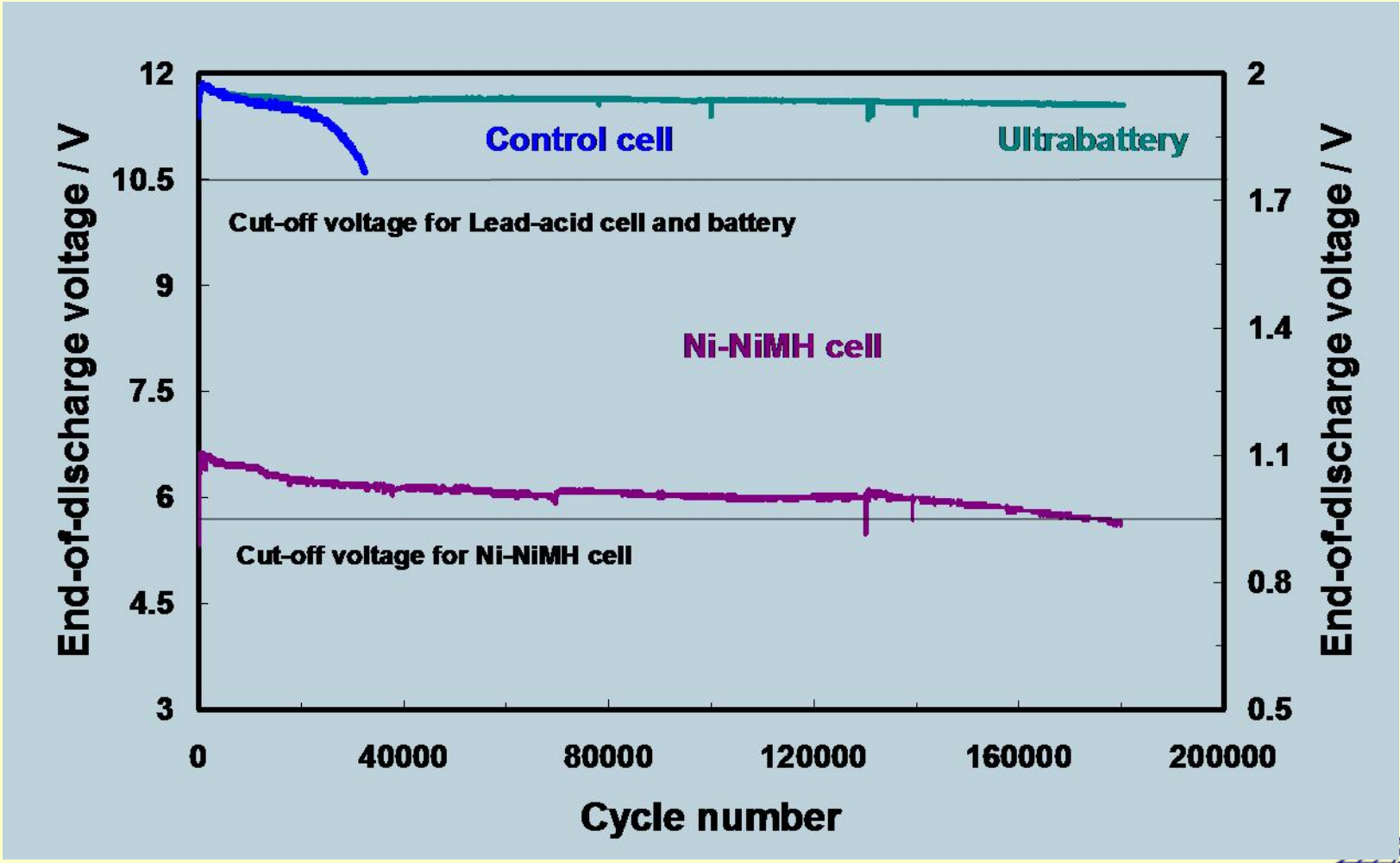
Cycling procedure:

discharge the cell/battery to 80% SoC and then subject to the above profile repetitively until the minimum voltage reaches 0 V.

Performance:

at least *four times* longer in cycle-life than the state-of-the art VRLA cells

Cycling Performance
(Under EUCAR Power Assist Profile)



Power-assist HEVs on Road Test with VRLA batteries

Battery for a Power-assist HEV (~1kWh)

	NiMH	Li-Ion	VRLA	Freed'car Min.Goals
Weight (kg) (excl. BMS)	23.26	12.5	33.3	40 (inc. BMS)
Cost, $ (raw materials)	349 Ni - lme	74 Li - USGS	58 Pb - lme	500 whole battery
Life - cycles	300,000	?	200,000+	300,000
Life - miles	100,000+	?	50,000++	100,000

If hybrid electric vehicles are to contribute meaningfully to reductions in pollution, in greenhouse gas emissions and to relieving the pressure on world oil supplies they must be adopted in very large numbers. In order for this to happen such vehicles must be affordable…