Battery Integration Workshop

SmartBatt: „Technical Slot 2“ – Cell Selection

Presented by Dr. Peter Miller, Ricardo

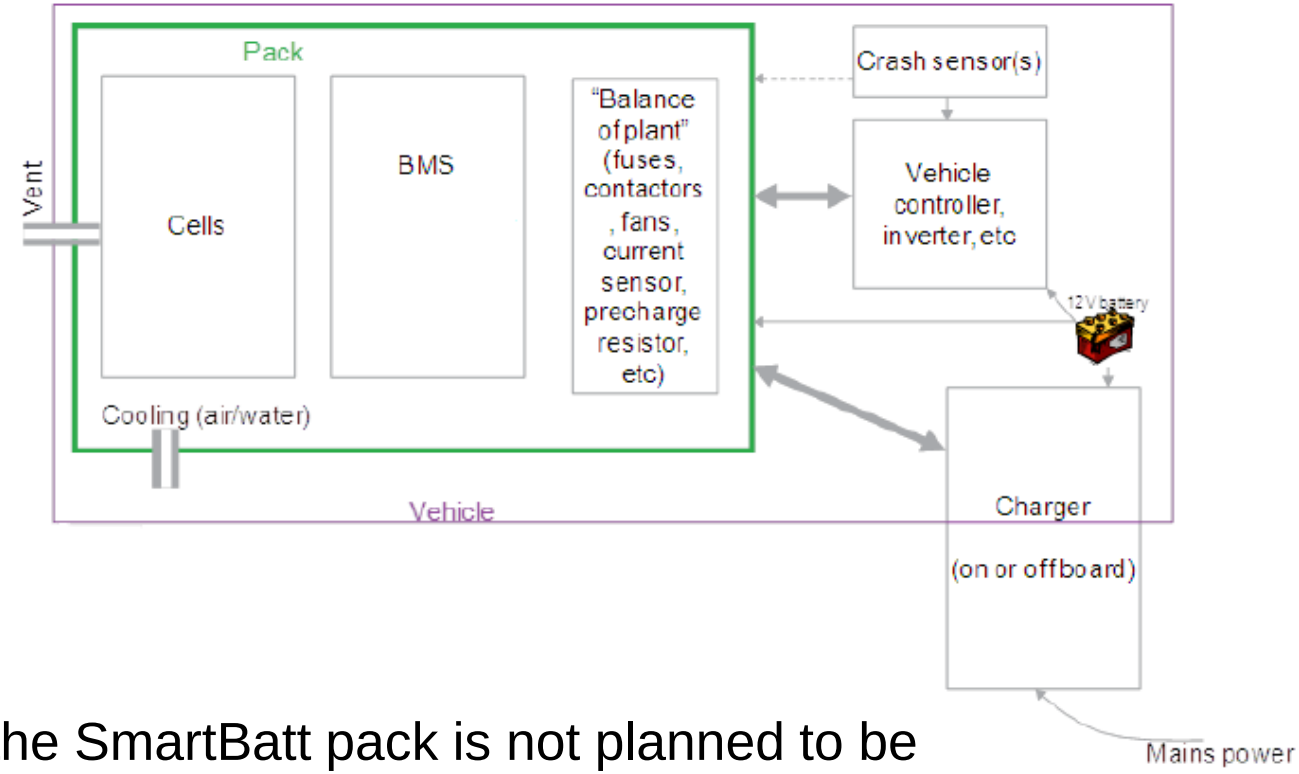
SmartBatt pack: Electrical requirements

Simulations based on the SLC assuming a "City EV application" showed the following were sensible requirements for the pack:

- >= 20kWh energy
- The power from the pack is 42kW continuous, 70kW for 30 secs.
  - –max charge power is 30kW.

It was also decided that the high voltage from the battery will be in the range 200-400V to allow the use of low cost power electronics.

"Definition of all interfaces"- Electrical



- As the SmartBatt pack is not planned to be installed in a physical vehicle a generic electrical interface was selected as shown above.
- A full FMEA has been completed based on this system boundary

Candidate cells

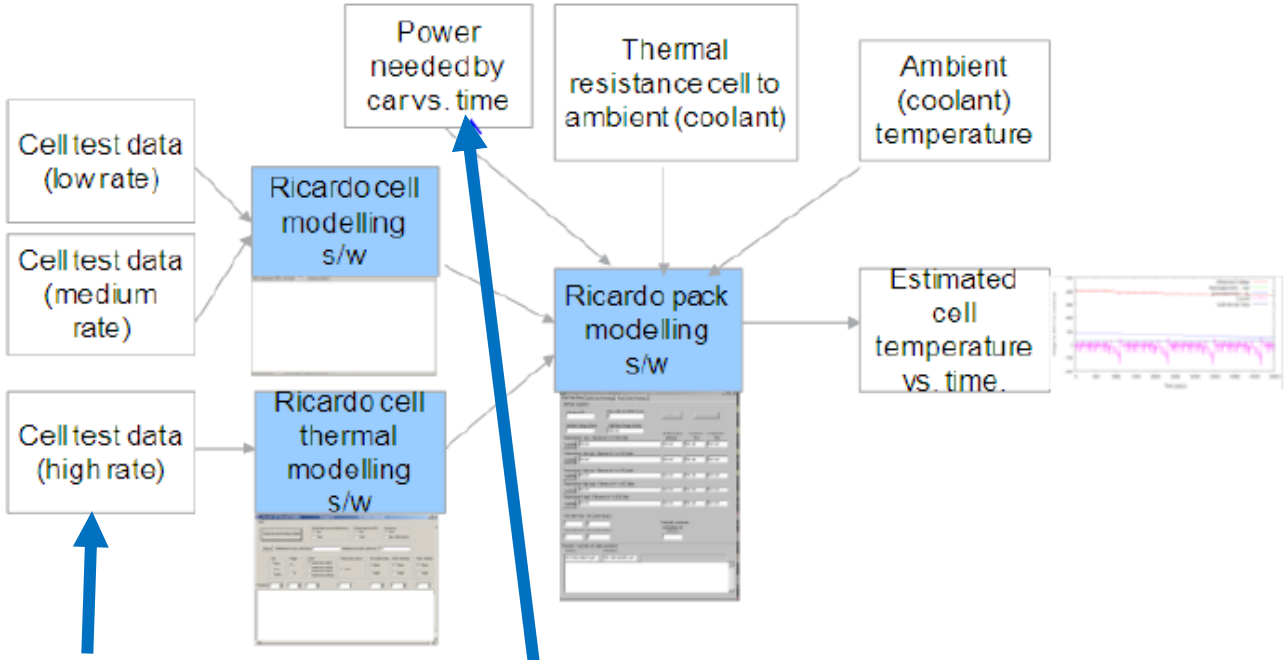
	Cell chemistry	Pack weight (kg)	Pack volume (L)	Pack energy (kWh)	Pack power (kW)	Pack regen power (kW)	Pack nominal voltage (V)	Total cell number	Cycle life to 80% DOD
C1:	LFP	180.544	95.732	24.024	96.096	96.096	300.3	364 (91s4p)	>5000
C2:	NCM	143.2	71.1	25.752	77.256	51.504	296	80 (80s)	>1000
C3:	LFP	219.84	108.864	25.344	101.376	50.688	307.2	480 (96s5p)	>1500
C4:	LCMO	136.8	67.6	24.746	67.488	49.491	296	1520 (80s19p)	>2000

- An initial review by Axeon resulted in 4 candidate cells that appeared to meet the requirements .

Costs

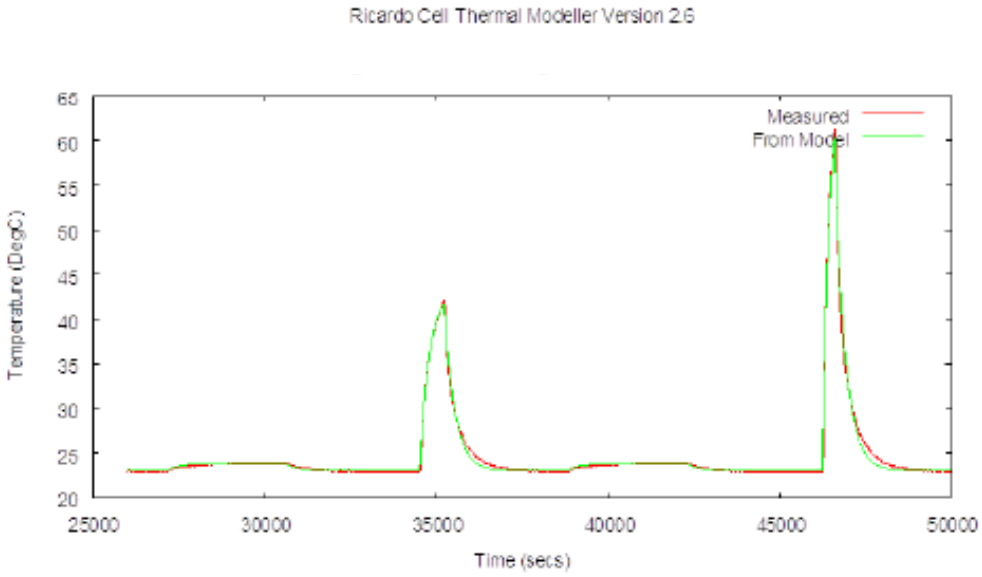
- An initial review of the cells rejected the C3 cells as they were about 35% more expensive than all the other solutions (which were all very similar in cost per Wh) leaving 3 candidates:
  - Two pouch cells (C1 and C2)
  - One metal case cell (C4)

Cooling requirements #1/3

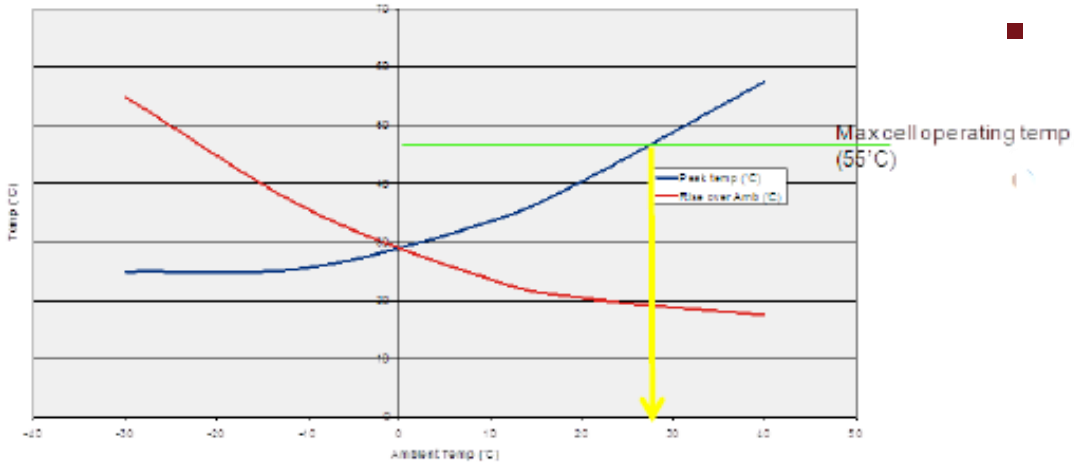


- Samples of each of the 3 candidate cells were purchased by Axeon and then tested to create the cell test data.
- VW did a simulation of the (virtual) vehicle over the artemis drive cycle to produce a corresponding Power vs. time profile.
- Ricardo used the test data to create cells models which they then simulated over the artemis drive cycle for 4 cooling scenarios (none, free air, forced air, water cooled) for a range of coolant temperatures

Cooling requirements #2/3



- Example simulation compared to measured data for cell temperature rise



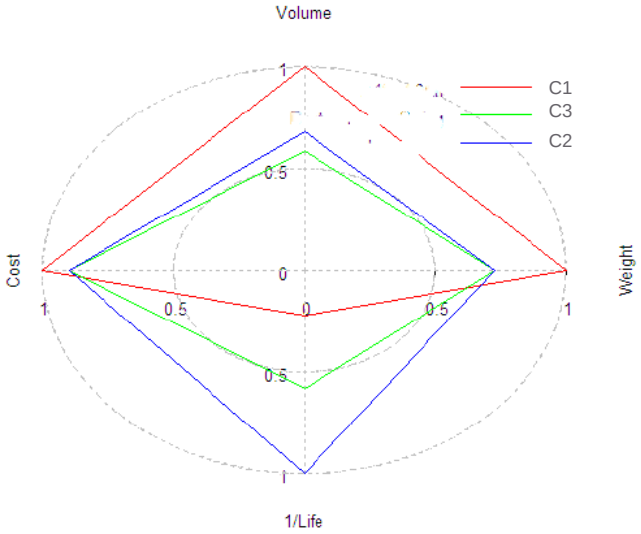
- This simulation shows peak cell temperature (blue curve) for a range of coolant temperatures
  - The max. coolant temperature in this case is 28'C

Cooling requirements #3/3

- The conclusions were
  - C4 based pack may not need heating or cooling
  - The C2 based pack would require heating and active cooling
  - The C1 based pack would require active cooling

- This is mainly due to the fact that the C4 cell is rated to a higher operating temperature (70oC) compared to the 55oC of the others.

Comparison of 3 cell options



Constraints:
20kWh
30kW charge
42kW discharge

- Radar chart above shows "SmartBatt" packs using the 3 different cells
  - 1 is worst, 0 is "perfect" on each axis (so the nearer the centre the better).
- C4 cells have the additional advantage they probably would not need any active thermal management to meet targets.
- As the C1 cell was worse on 3 viewpoints (and all had an acceptable life) it was decided to reject these and just do safety tests on the C4 and C2 cells.

"Standard" Cell Safety Tests

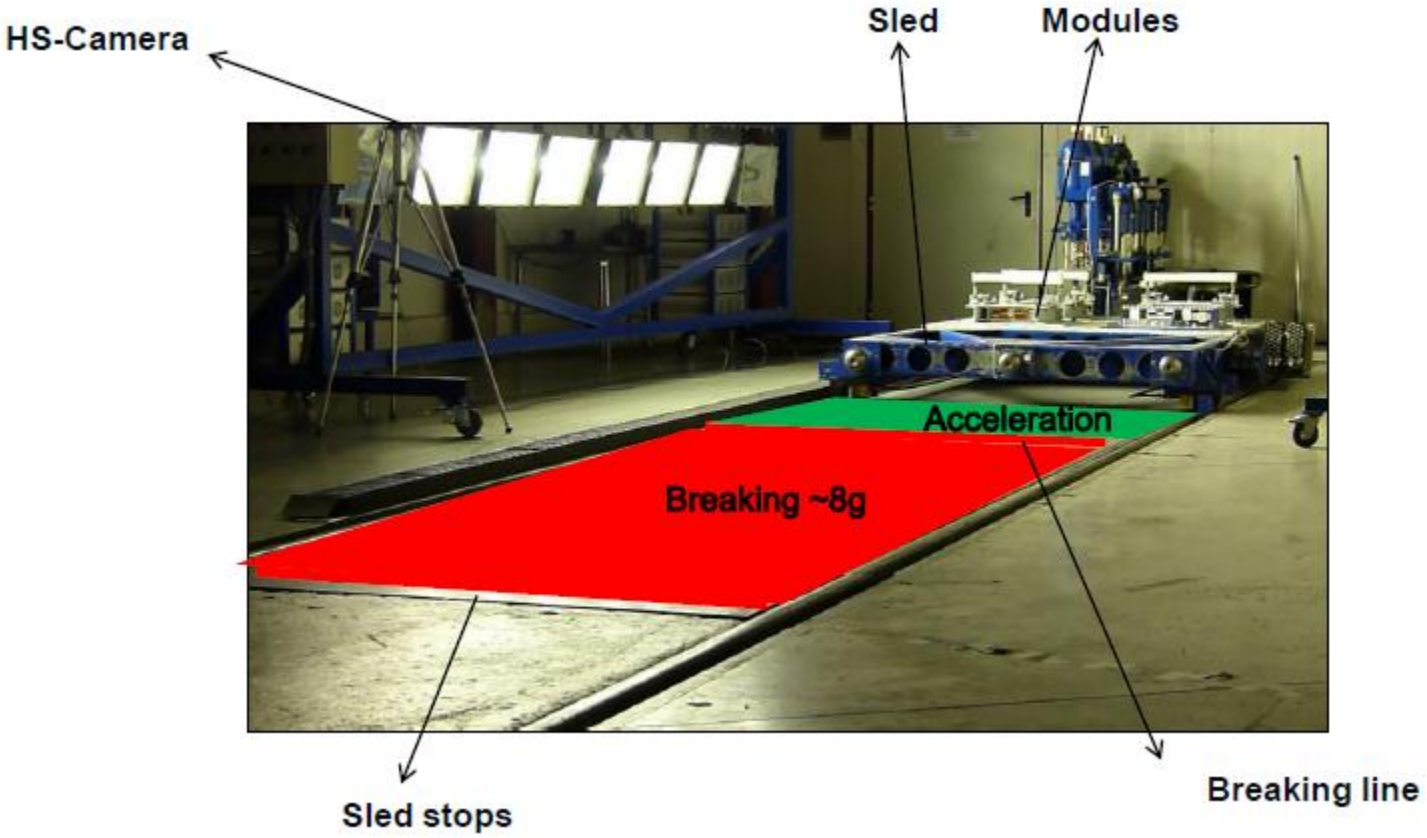
- 3 different tests conducted on C4 and C2 cells:
  - Thermal Shock Tests (according to SAEJ 2464)
    - 5 cycles from -40°C to 70°C
    - time of exposure at each temperature: 1h
  - Overcharge Test
    - Charging current: 1C for C2, C4
  - Nail Penetration Test

- C4 cells passed all tests
- C2 cells failed Overcharge and Nail penetration tests.
  - **Note:** testing was done in a way that would approximate a cell in a SmartBatt module, which is different from a "standard" cell test.

Example test results – C2 overcharge test

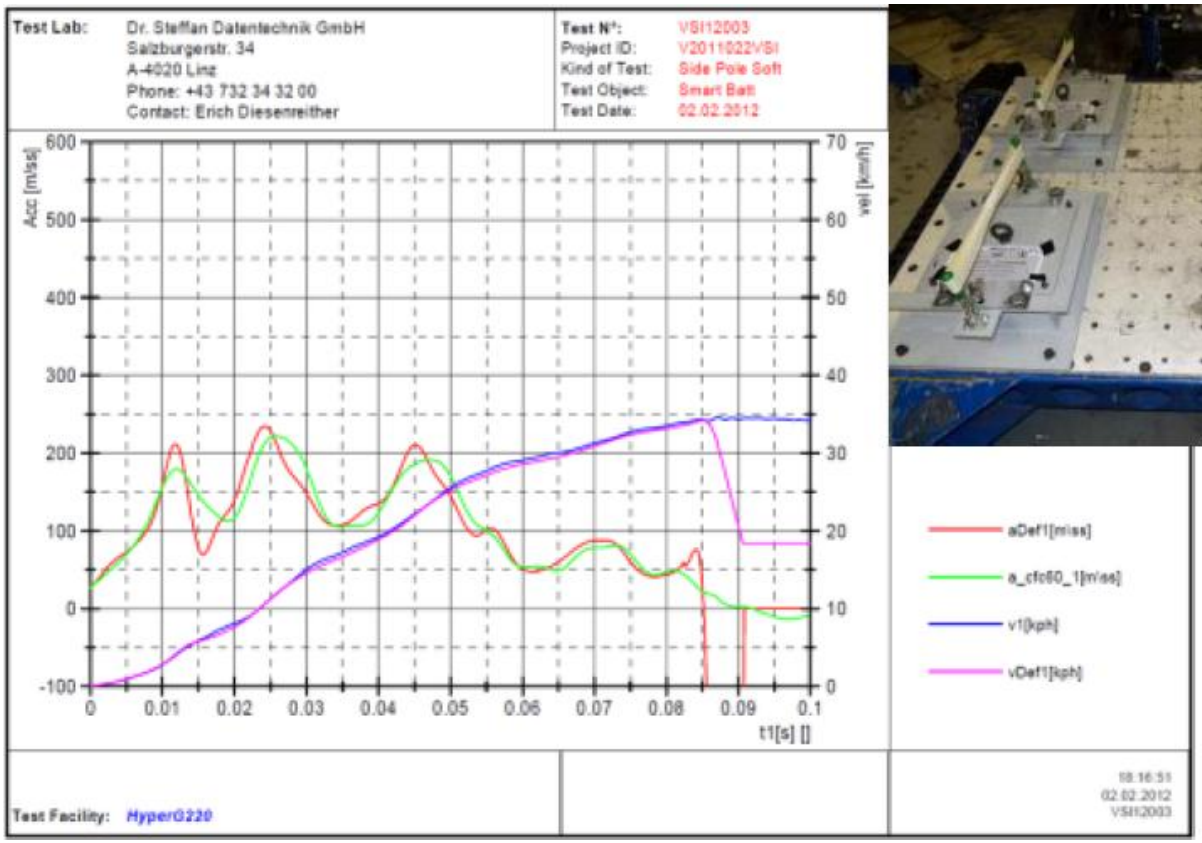
- Severe reaction and temperature rise up to 800° C
- Note testing was done in a way that would approximate a cell in a SmartBatt module, which is different from a "standard" cell test.

Crash simulations - Test Setup



- Tests were designed to give acceleration profiles that closely matched what the packs/cells would see in actual whole vehicle crash tests.

Crash simulations - Example test results



- Acceleration profile is close to the target (and velocity almost perfect)
- All tests passed by both cells.

"Assessment of the impact of future cell developments"

			New Concept 1	New Concept 2	New Concept 3
Timeline	now	Now	~2-3 years	~5 years	>10 years
Cell chemistry	LCO-LMO	NCM	Advanced TMO/ Si-alloy	Li-S	Li-air
Energy density per cell (Wh/kg)	180	180	235	550	1000
Energy	23kWh	27kWh	~25kWh	~25kWh	~25kWh
Estimated total Cell cost	~6720€	~9640€	~6000€	~4500€	~3000€
Estimated pack Cost (€/kWh)	~€500/kWh (Now - low volume)	~€600/kWh Now low volume	~€400/kWh 2013	~€300/kWh 2016	€200/kWh 2020

- New concept 1 and 2 are likely to physically be very similar to today's cells (but smaller) so the SmartBatt results would be applicable to them
  - Packing is likely to be hard cased Prismatic (like C4 but probably larger) for high volume cells.
- New concept 3 may require different packaging, but its really too early to say.

Conclusions

- The initial selection process resulted in 4 candidate cells
- Selection based on cost reduced this to 3
- Weight & volume considerations reduced this to 2 cells
- Safety tests (helped by the thermal simulations) resulted in the final selection
  - C4
  - crash simulations were passed by the 2 cells / preliminary module designs that were tested.
- Looking forward to the future it is felt that the SmartBatt concepts will be applicable for at least the next 2 generations of cells.
- Note this and the proceeding SmartBatt presentations can only give only a brief overview of portions of the SmartBatt program that have been completed in the last 17 months.