DOE Merit Review

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A123Systems

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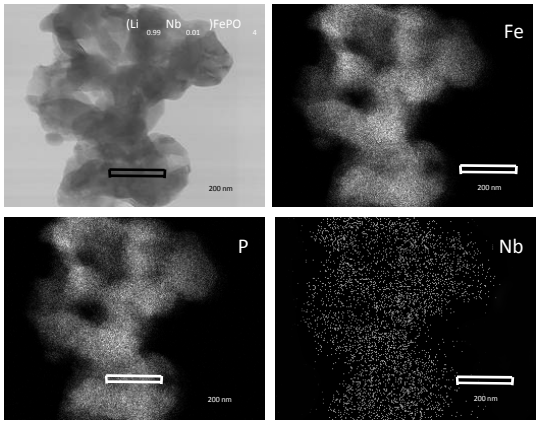
About A123Systems

Leading manufacturer of high power Li ion batteries and systems

- +2200 employees (aprox. 100 PhDs and 300 engineers)
- +$320M of private capital invested (General Electric is largest shareholder)
- Mass producing millions of cells per year (worlds largest maker of phosphate Li Ion)

Better battery enabled by new nano-materials (Nature Materials)



Nano particle size = extremely fast diffusion

Dopant significantly increases rate capability (8 orders of magnitude higher conductivity)

Broad portfolio of automotive cells funded through two USABC 50:50 cost share programs

- Prismatic cells

20Ah M1HD (PHEV and EV)
Vehicle SOP 2009/2010

4Ah M1Ultra (Passenger HEV)
Vehicle SOP 2011/2012

6Ah M1Ultra (Passenger and Heavy Duty HEV)
Vehicle SOP 2011/2012

8Ah M1Ultra (Passenger and Heavy Duty HEV)
Vehicle SOP 2011/2012

- Cylindrical cells

2.3Ah M1 (Heavy Duty HEV)
Vehicle SOP 2008

4.4Ah M1Ultra (Passenger and Heavy Duty HEV)
Vehicle SOP 2009

HEV Program Overview

Goal: Meet all FreedomCar requirements for a 25kW HEV pack

- Focus on barriers to commercialization

HEV development program

- 3-year contract, starting December 1, 2006
- $15M, with a 50-50 cost-share

Key Accomplishments in Past Year (HEV)

- Improved price-performance and validated design
  - Increased power >15% through new electrode design
  - Increased energy in existing form factor (3.6 to 4.4Ah)
  - Lowered 32113 cell cost by >40% in past year
  - Result: commercial production programs awarded to A123
- Cylindrical HEV (32113) cell entering high-volume production with major European OEM in ’09.
  - 32113 passed Process Sign Off (PSO) in February 2009
  - Vehicle Start of Production (SOP): Summer 2009
  - Demonstrates A123’s readiness to serve automotive market
- Technical progress in new areas
  - HEV prismatic products under development show high power capability
  - Passenger automotive and heavy-duty commercial vehicle
- Diversified customer base for 32113 cell
  - North American, European and Asian automakers using this cell in new vehicles
  - Passenger automotive and heavy-duty commercial vehicle

HEV Program Summary

- Program Duration – 36 months
- Program Timing – December 2006 to December 06, 2009
- Battery System – Doped Nanophosphate Chemistry
- Program Objective: Develop Nanophosphate cell and system with the following characteristics:
  - Improved Calendar Life (15 Years)
  - Increased Cycle Life Capability
  - Increased Power
  - Abuse Tolerance at Cell Level
- Total Program Value – $15M at 50%/50% cost share

HEV Gap Analysis

Characteristics	Units	A123 Q2 2008	A123 Q1 2009	A123 Q1 2009	A123 EOP Goal	FreedomCar 25 kW goal
Present Discharge Pulse Power (10s)	kW	**31**	**29**	**32**	25	25
EOL Discharge Pulse Power (10s)	kW	25	26	26		
Present Regenerative Pulse Power (10s)	kW	**25**	**23**	**26**	20	20
Total BOL available energy	kWh	**0.44**	**0.51**	**0.51**	0.30	0.30
Round trip energy efficiency	%	**95**	**95**	**95**	>90	>90
Cycle Life number of 25Wh cycles		0 (Gen 1)	Under test (Gen-1) March '09	Under test (Gen-2) Q2 '09 B0.1	300k	300k
Cold Cranking Power @ -30 *C	kW	**3.1**	**3.2**	**3.2**	**5**	5
Maximum System Weight	kg	**27**	**24**	**24**	21	40
Maximum System Volume	liters	**19**	**18**	**18**	15	32
Operating Voltage Limits (max, min)	V	**229**	**215**	**215**	185	400
Operating Voltage Limits (max, min)	V	**126**	**118**	**118**	102	0.55 Vmax
Maximum allowable self-discharge rate	Wh/day	**0.7**	**0.8**	**0.8**	<3.3	50
Equipment operation	*C	**-30 to +52**	**-30 to +52**	**-30 to +52**	-30 to +52	-30 to +52
Equipment survival	*C	**-46 to +66**	**-46 to +66**	**-46 to +66**	-46 to +66	-46 to +66
Cell type		32113 Gen-1	32113 Gen-1	32113 Gen-2		
Capacity	Ah	3.6	3.6	4.4		

32113 Product Line Progression

ANL testing

	Gen-0	Gen-1	Gen-2
Capacity (Ah)	3.4 - 3.6	3.8	4.4 - 4.6
Timing	Up to Q4 2007	Late Q1 2008 Early Q2 2008	First results received DVP&R – Q3'09
Notes	Pre-DV, with original anode material	New Anode - DVP&R 90% complete PV – Q3'09	Using higher-power and lower cost electrode design
	Cells delivered to ANL	Design freeze, this cell validated **(taken to production)**	Development continuing **Cells delivered to ANL & NREL**
Mass Production Start		Q2 '09 with Major European OEM	2010 with multiple OEM's (American, Asian, and European)

2009 Cell/Module Delivery Schedule

Delivery Tasks	2009											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deliver Gen-2 32113 cells to ANL		★										
Deliver Gen-2 32113 cells to NREL		★										
Deliver 6Ah prismatic cells to ANL											★	
Deliver 6Ah prismatic cells to NREL											★	
Deliver Gen-2 32113 modules to ANL											★	
Deliver 6Ah prismatic modules to ANL											★	
Deliver Pack Study to USABC											★	

SOW compliance

- Completed most of the materials, electrode and cylindrical cell development tasks on the program.
  - Still underway: Long term cycle and calendar life testing of Gen-1 32113, additional development of Gen-2 32113 (cost to be absorbed by A123)
- 32113 cell offers industry leading price performance but average power density. Focusing on prismatic cells for premium power density applications.
  - Looking to offer a broad product portfolio of cylindrical and prismatic HEV cells to cover most hybrid passenger and heavy duty requirements.
- We are spending more effort in the remainder of the program on module development and system issues
  - Still developing different concepts for 32113 module development

SOW compliance checklist

Materials Development		Notes	Jan-09
Cathode	Gen-1 cathode development (M1)	Powder manufacturing has been scaled-up	✔
	Gen-2 cathode development (lower cost, higher power M1)	Testing underway	✔
	Gen-3 cathode development (M1x)	Under development	✔
Anode	Next generation Anode	Ongoing, but 32113 Gen-1 design frozen	✔
Separator	Evaluate commercially-available separator	Ongoing, but 32113 Gen-1 design frozen	✔
	Nanocomposite separator (NCS)	Moved to PHEV program	✔
Electrolyte	Improve low temperature cold crank	Low T performance improved, but still working on additional improvements	✔
	Chemical shuttles (low-rate overcharge)	Shuttles proven effective	✔
	Chemical shuttles (cell balancing, HEV)	Shuttles not effective for cell balancing at mid-SOC	✘
	Flame-suppressing additives	FSAs demonstrate improved safety	✔

Electrode Development		Notes	Jan-09
	Ultra electrode development	Ultra electrode being used in 32113 and HEV prismatic	→
	Cell testing using Ultra electrodes	Completed	→
	Identify sources/mechanisms of impedance	Ongoing	✔

✔ **Achieved**

✔ **Under Development**

✘ **Not achieved**

SOW compliance checklist

Cell Development		Notes	Jan-09
26650	Design, fabricate, and test 26650 Ultra cells		✔
Infinitab	Design, fabricate, and test Infinitab cells	Infinitab approach abandoned in favor of better cell designs	✘
Gen-1 32113	Design, fabricate and deliver cylindrical HEV cells	Cells delivered to ANL and NRL Dec 2007	✔
	Conduct reference performance testing of HEV cells	32113 cells on cycle and calendar life testing	✔
	Conduct safety and abuse testing of HEV cells	Completed. Cells pass all safety/abuse tests.	✔
Gen-2 32113	Design and fabricate Gen-2 HEV cells	Completed	✔
	Conduct reference performance testing of Gen-2 cells	Ongoing	✔
	Conduct safety and abuse testing of Gen-2 HEV cells	Completed. Cells pass all safety/abuse tests.	✔
HEV prismatic	Design and fabricate prismatic HEV cells	Effort underway.	✔
	Conduct reference performance testing of prismatic cells		
	Conduct safety and abuse testing of prismatic HEV cells		

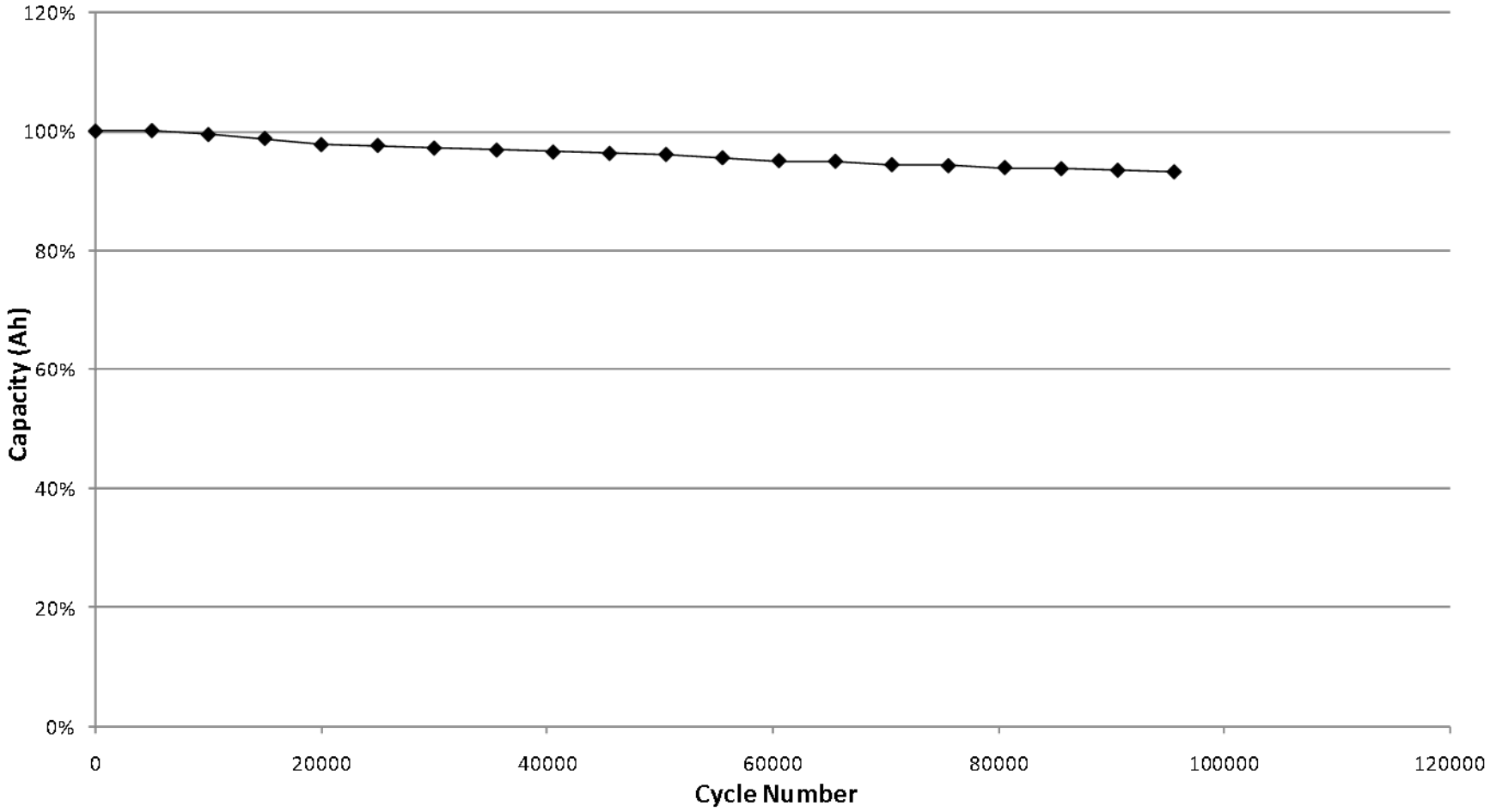
SOW compliance checklist

Module Development		Notes	Jan-09
SOC	Develop SOC algorithm	First generation algorithm developed and in commercial operation in HEV busses. Next generation algorithms under development	✔
SOF, SOH	Develop SOF, SOH indicators	First generation algorithm developed and in commercial operation in HEV busses. Next generation algorithms under development	✔
fast-track	Fast-track modules using 26650s		✔
32113 HEV module	Design and fabricate Gen-1 32113 HEV module		✔
	Conduct reference performance testing of 32113 module		
	Conduct safety and abuse testing of 32113 module		
	Deliver 32113 module to national labs		
Prismatic HEV module	Design and fabricate prismatic HEV module		✔
	Conduct reference performance testing of HEV module		
	Conduct safety and abuse testing of HEV module		
	Deliver HEV module to national labs		

Pack Development		Notes	Jan-09
	Task eliminated.	Funding used to develop HEV prismatic cell	✘

Cycle Life Testing on 32113

USABC Cycle (25Wh, 40-50% SOC, -100A/+75A HPPC, 50% SOC) at 30°C



32113 passes all USABC abuse tests

Test	Methodology	DVP&R Gen 1 Status	Results	Gen 2 Status	Results
Short Circuit	USABC	Complete	(4 cells EUCAR 2, 1 cell EUCAR 4)	Complete	(5 cells, EUCAR 2)
Overcharge	USABC (4.7V/32A)	Complete	(5 cells, EUCAR 2)	Complete	(5 cells = EUCAR 2)
Overdischarge	USABC	Complete	(5 cells, EUCAR 2)	-	-
Thermal Stability (Modified Hot Box)	USABC Methodology (Modified Temp to 150'C)	Complete	(5 cells, EUCAR 2)	-	-
Nail Penetration (RT)	USABC (w/ blunt steel nail, diameter = 8mm, at 8 +/- 1 cm/s) at RT (23°C +/- 3°C)	Complete	(5 cells, EUCAR 3)	Complete	(3 cells = EUCAR 4 & 2 Cells = EUCAR 3)
Nail Penetration (55°C)	USABC (w/ blunt steel nail, diameter = 8mm, at 8 +/- 1 cm/s) at 55°C	-	-	Complete	Results Forthcoming
Controlled Crush	USABC	Complete	(5 cells, EUCAR 2)	-	-
Mechanical Shock	USABC	Complete	(5 cells, EUCAR 2)	-	-
Thermal Shock	USABC	Complete	(20cells, EUCAR 0)	-	-

HEV Prismatic Cell Technologies Quarterly Review

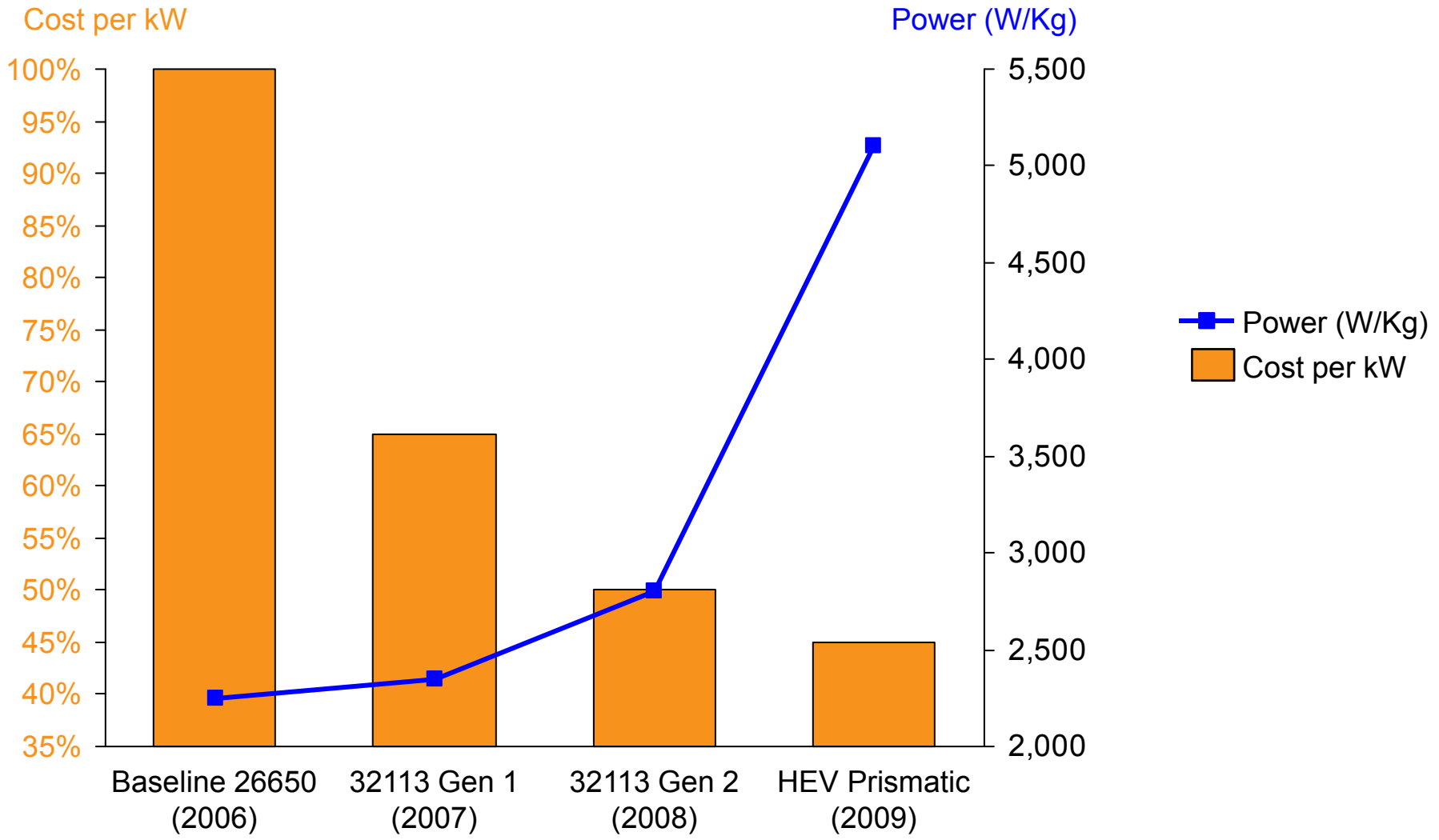
Mild HEV

Full HEV

Heavy Duty HEV

50%SOC		M1*Ultra* Prismatic Cell		
		4Ah	6Ah	8Ah
10 Sec. HPPC	225A	**4,590 W/kg**	**5,250 W/kg**	**5,300 W/kg**
		8060 W/L	**9320 W/L**	**9390 W/L**

M1 Ultra HEV Prismatic Cells Offer Industry Leading Price/Performance and Power



PHEV Program Overview

PHEV development program

- 3-year contract, started March 2008
- $12.5M, with a 50-50 cost-share

Major tasks

- 10-mile battery development
- 40-mile battery development

Key Accomplishments in Past Year (PHEV)

Developed 20Ah prismatic cell

- Designed for PHEV and Extended Range EV applications
- Leverages A123's technology
  - Higher energy density: Wh/liter, Wh/kg
  - Volume-efficient design
  - Low impedance = low waste heat
  - High power at low SOC
  - Excellent calendar life and safety at high SOC
  - Wide SOC range = higher useable energy

Key Accomplishments in Past Year (PHEV)

Developed flexible scalable modular design and architecture

- Can be liquid or air cooled
- Integrated electronics
- Voltage, temp sensing
- Advanced safety features

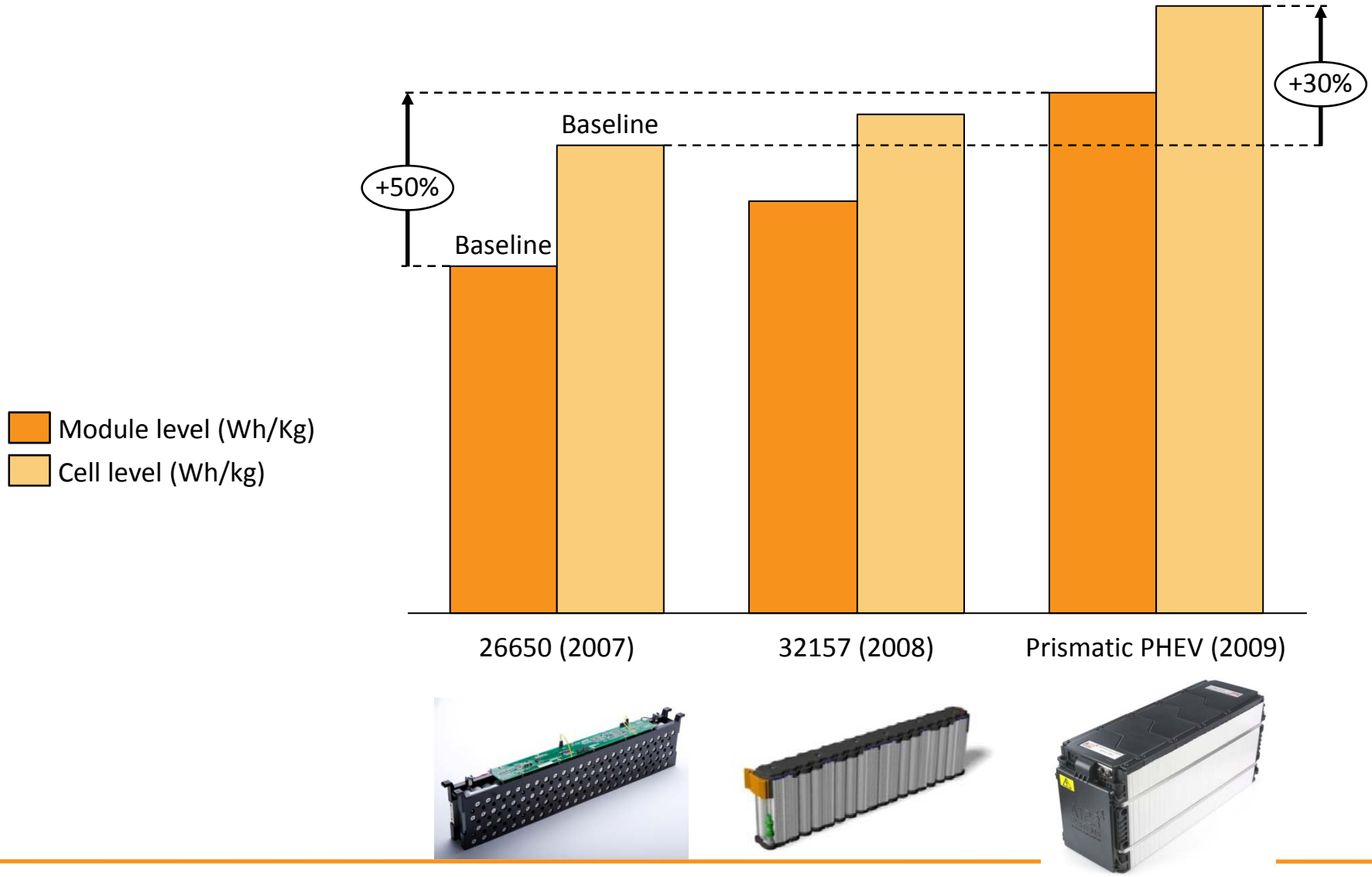
Digest of Progress

PHEV Program

In Q4 2008:

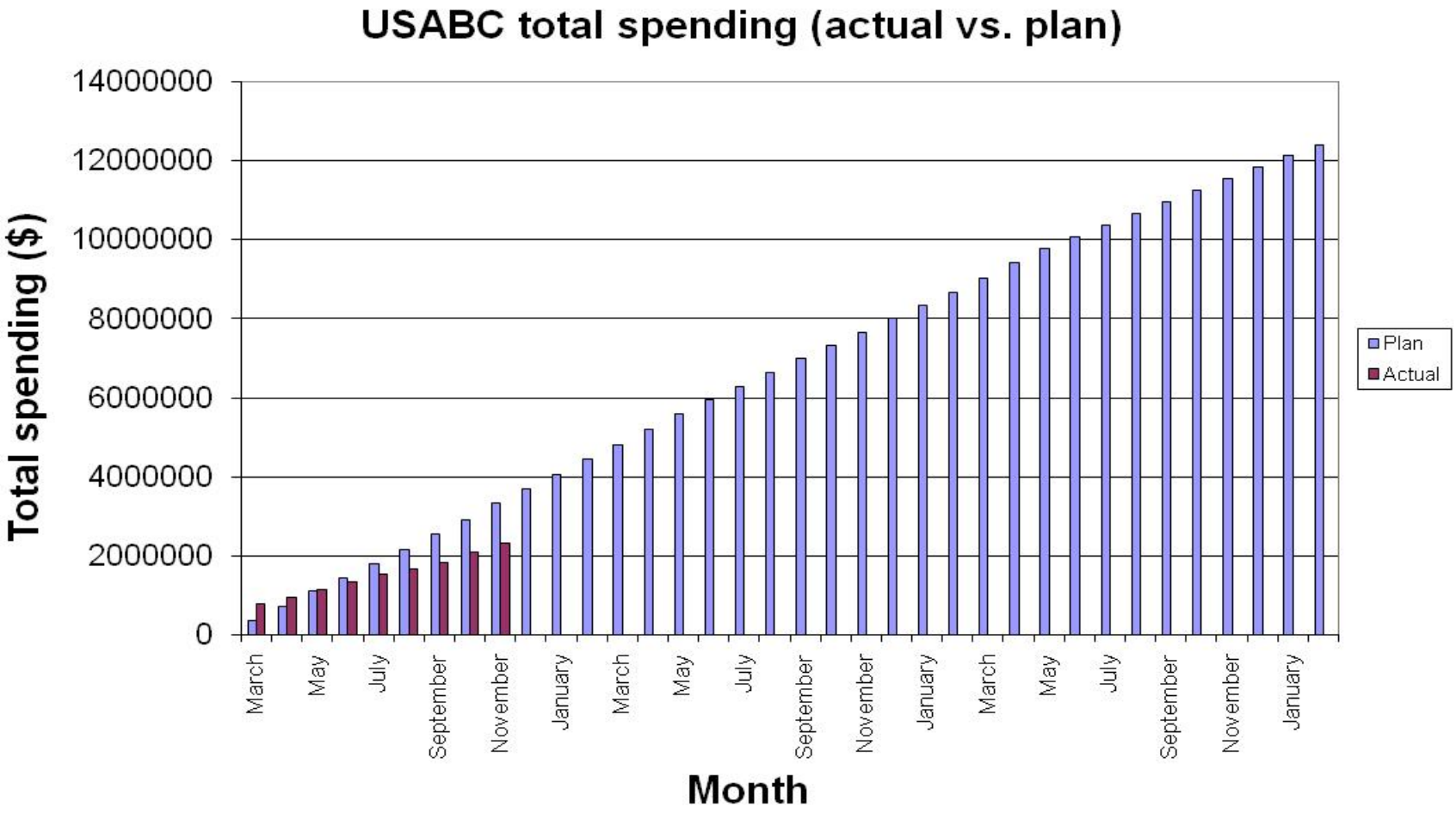
- Cathode Powder
  - Scaled up efforts to reduce cathode costs through improved and more efficient processes
  - Continue to expand cathode development to improve both capacity and energy
- Nanocomposite Separator
  - Improved throughput with new process
  - Developing scale up process
- Prismatic Cell Development
  - Increased energy density through new anode and cell designs : AP4
  - Increased cycle life and energy density with new materials
  - Confirmed safety for unit pack level cell (cells in parallel-AP3 cell design)
- PHEV Module Development
  - Expanded operations, and moved into new facility
  - Developed family of module solutions with 20 Ah prismatic cell, and improved design for optimal performance and robustness
  - Developed advanced system architecture
  - Multiple commercial design wins with major North American and European OEM's
  - Commercial mass production start in 2010

Continuous improvement in module and cell level energy density



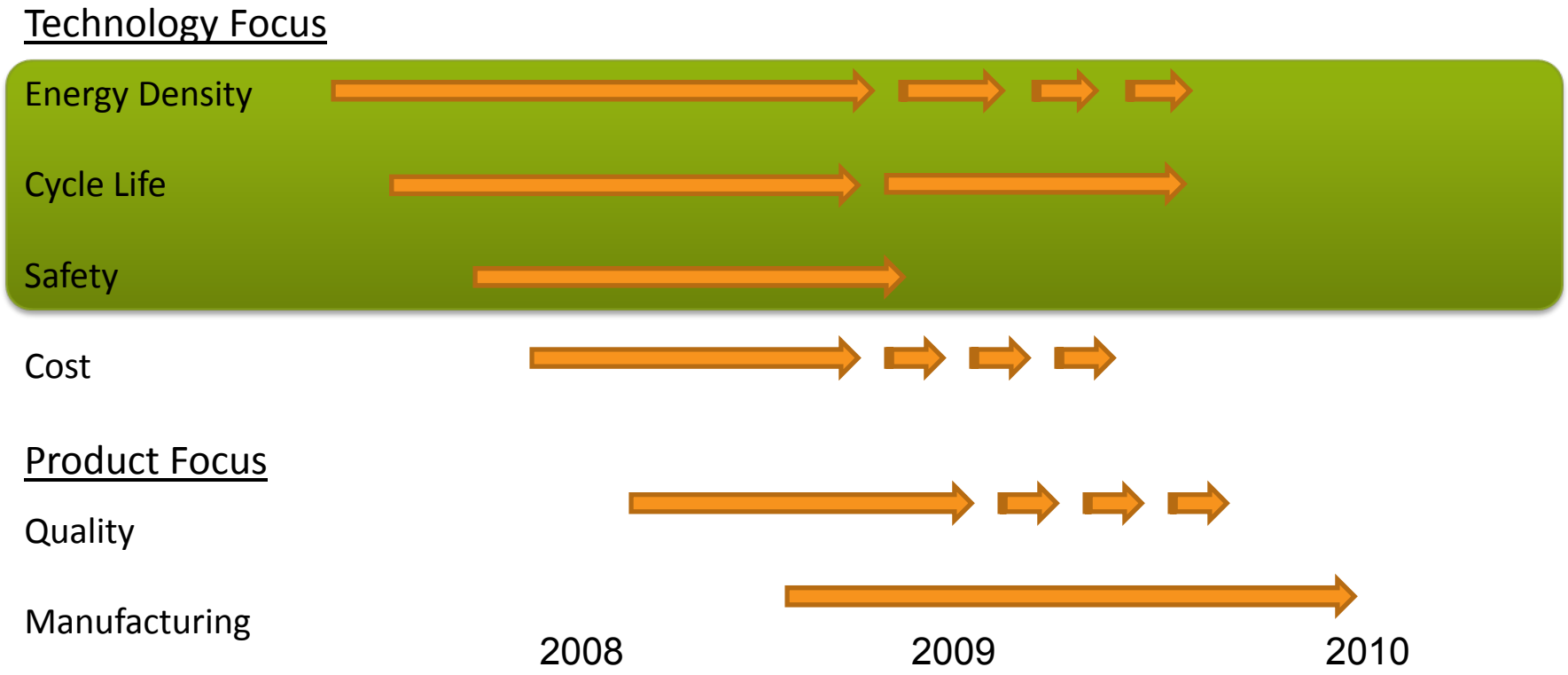
PHEV Program Total Spending

Actual vs. Plan



Prismatic Cell Focus

- A123 has developed 4 spiral generations of prismatic PHEV cells. Currently focus is on key PHEV objectives of energy and life (new anode and separator development)
- Safety performance evaluation at pack level complete
- Fully automated mass production process developed in parallel



PHEV Program: Executive Summary

- A123 prismatic cell efforts continue to be focused demonstrating a high energy, long life and robust PHEV cell

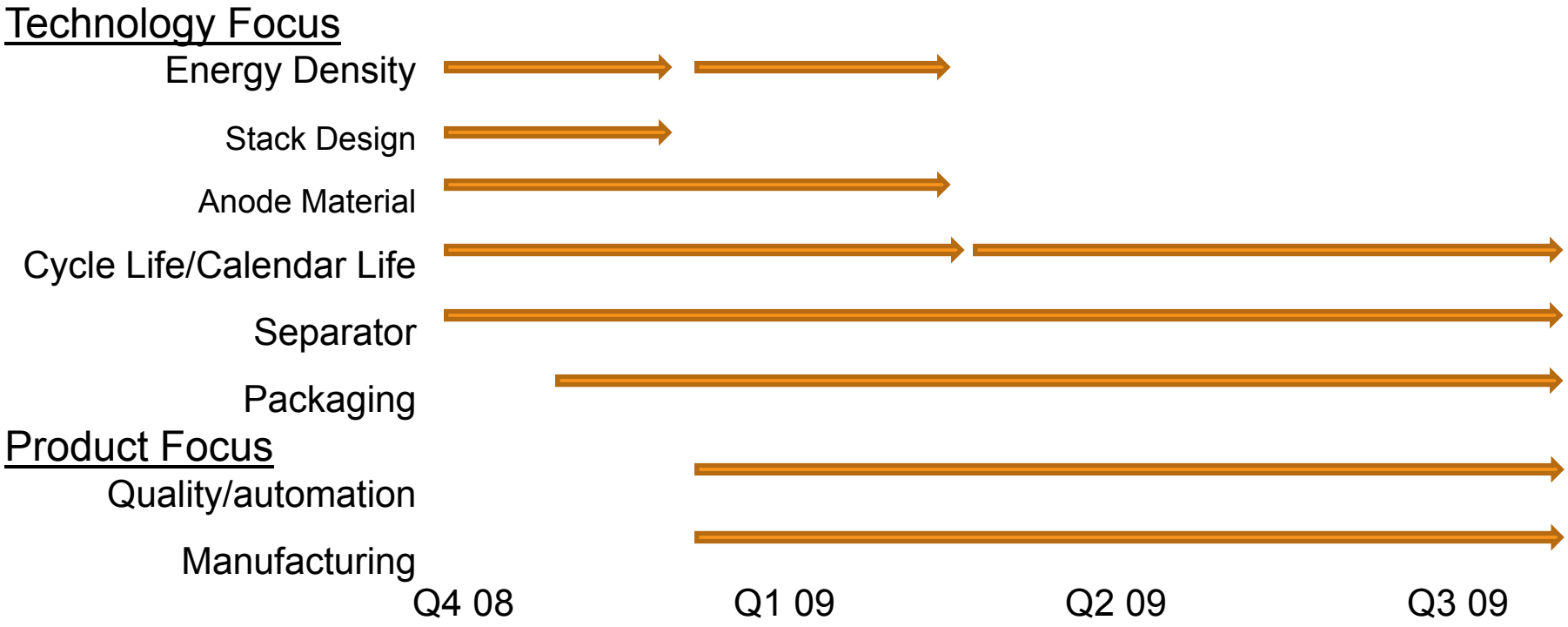
  - Increased energy density through new anode and cell designs : AP4
  - Increased cycle life & energy density through new anode
  - Increased robustness through new separator
  - Confirmed safety for unit pack level cell (cells in parallel)

Summary: Successful safety tests for cells in parallel

Test Items	Test Condition	Results	PASS	EUCAR Hazardous Levels
Overcharge Test	32A, 5.5V (16.2Ah, 100% SOC, 55°C)	Vented, Smoked, No Explosion, No fire	3/3	Hazard Level 3
Nail Penetration test	3mm did. Blunt with 1.5mm round tip, 8cm/sec speed (16.2Ah, 100% SOC, 55°C)	No Vented, Smoked, No Explosion, No fire	3/3	Hazard Level 3
Overdischarge Test	1C rate discharge for 1.5hr (16.2Ah, 100% SOC, 55°C)	No Vented, Smoked, No Explosion, No fire	3/3	Hazard Level 3
Hot Box Test	Up to 300°C, 5°C/min (16.2Ah 100% SOC)	Vented, Smoked, No Explosion, No fire	3/3	Hazard Level 4
Crush Test	75mm radius rod, 3 axis (x, y, z-axis) (16.2Ah, 100% SOC, 55°C)	Vented, Smoked, No Explosion, No fire	3/3, 3/3, 3/3	Hazard Level 3
External short circuit	0.1 mΩ resistance, 10min (16.2Ah, 100% SOC, 55°C)	Vented, Smoked, No Explosion, No fire	3/3	Hazard Level 3

Summary and Future work

- Prismatic cell development continue to focus on the cost reduction, quality and manufacturability in 2009
- New separator development will continue for AP4 technology in 2009 as major cost reduction opportunity



A123 Scalable Prismatic Module

- Scalable, modular architecture (20Ah to 120Ah)
- Modular Monitor Balance Board (MBB)
- Active Balance - extended life, fast balance
- Liquid or air cooled compatible
- Robust laser welded buss bars
- Uniform compliant compression system
- Redundant safety systems
- Durable protection skin

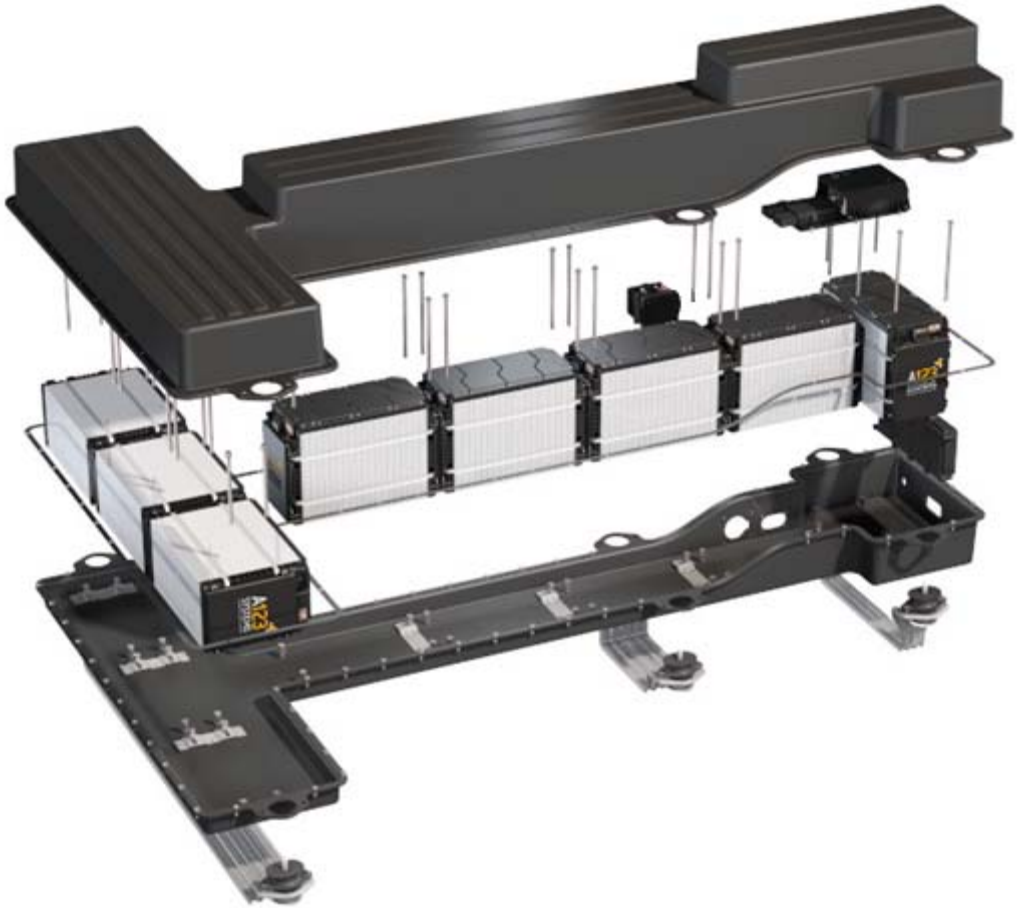
Reconfigurable for applications ranging from 1kWh to >100kWh

Scalable Modular Architecture Components

BCU

EDS

Modular scalable pack architecture allows common parts to be configured with liquid or air cooling for different pack designs



Videos of robotic cell and pack assembly

Prismatic Module Program Summary

- Module Design Freeze Accomplished Oct 2008
- UNDOT Certification Testing underway
- Abuse Testing (Nail Penetration, Overcharge, Short Circuit) achieved good results e.g. < EUCAR 4
- Cycle life testing showing good results
- Module thermal management system capable of high power performance
- Novel design approach allows for common bill of materials over wide range of PHEV and EV applications
- Phase A testing complete 2Q2009
- Module manufacturing plans underway for Pilot launch in 2009
- Mass production planned in 2010 with multiple North American and European OEM's

Successful commercialization of A123Systems USABC funded work

- Products developed through USABC funding are now designed into +19 vehicles from +7 major OEMs
  1. Multiple programs awarded with German OEMs using A123 cells
  2. Major North American companies, such as Chrysler and Delphi, have awarded A123 contracts
  3. First mass-produced HEV in China (Shanghai Automotive, largest OEM in China) to use A123 cells

Video: USABC synergy with Smart Grid: win-win dual use

Using HEV and PHEV battery technology to improve the electric grid!

Summary

- A123 has leveraged USABC funding to:
  - Accelerate development of HEV and PHEV products
  - Add to A123's systems' capability
  - Win production programs in both HEV and PHEV
  - Find new dual use markets for HEV and PHEV batteries in the grid

- HEV program extremely successful
  - Process sign off (PSO) for 32113
  - High-volume HEV production in 2009

- Only completed first year of PHEV program, but significant progress already made

Acknowledgments

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USABC
UNITED STATES ADVANCED BATTERY CONSORTIUM