

The image features the Delphi logo in a bold, black, sans-serif font on the left side of a light blue background. To the right, there is a vertical strip of abstract digital imagery, including binary code (0s and 1s) and glowing, circular patterns that suggest data flow or network connectivity.

DELPHI

Low-Cost U.S. Manufacturing of Power Electronics for Electric Drive Vehicles

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Delphi Automotive Systems, LLC

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Project Overview

Timeline

- ◆ Start: January 2010
- ◆ Finish: December 2012
- ◆ Approx. 78% complete

(through Feb 2012)

Budget

- ◆ Total project funding
 - DOE: \$89.3M
 - Contractor: \$89.3M
- ◆ DOE funding to date
 - As of Feb/12: \$69.6M

Barriers

- ◆ Limited supply of technical resources
 - Technical training and experience with high-voltage, high-current (power) electronics
- ◆ Market demand for EDVs sensitive to:
 - Unstable/unpredictable fuel prices
 - U.S. policy incentives for EDVs and U.S. sourcing

Collaborators

- ◆ Project Lead: Delphi
- ◆ Vehicle OEMs: GM, Coda, Fisker, others
- ◆ Powertrain OEM Customers: Allison
- ◆ Suppliers: power silicon, capacitors, etc.
 - 145 qualified for power electronics (68 U.S.)

Collaborators

◆ Vehicle and Powertrain OEM Customers

- GM®, Allison Transmission®, Coda Automotive™, Fisker, others

◆ Suppliers

- Silicon, capacitors, circuit boards, castings, magnetics, etc.
- 2012 total qualified suppliers to Delphi
- 145 currently in use for Power Electronics (68 U.S. based)

◆ State of Indiana – incentives offered

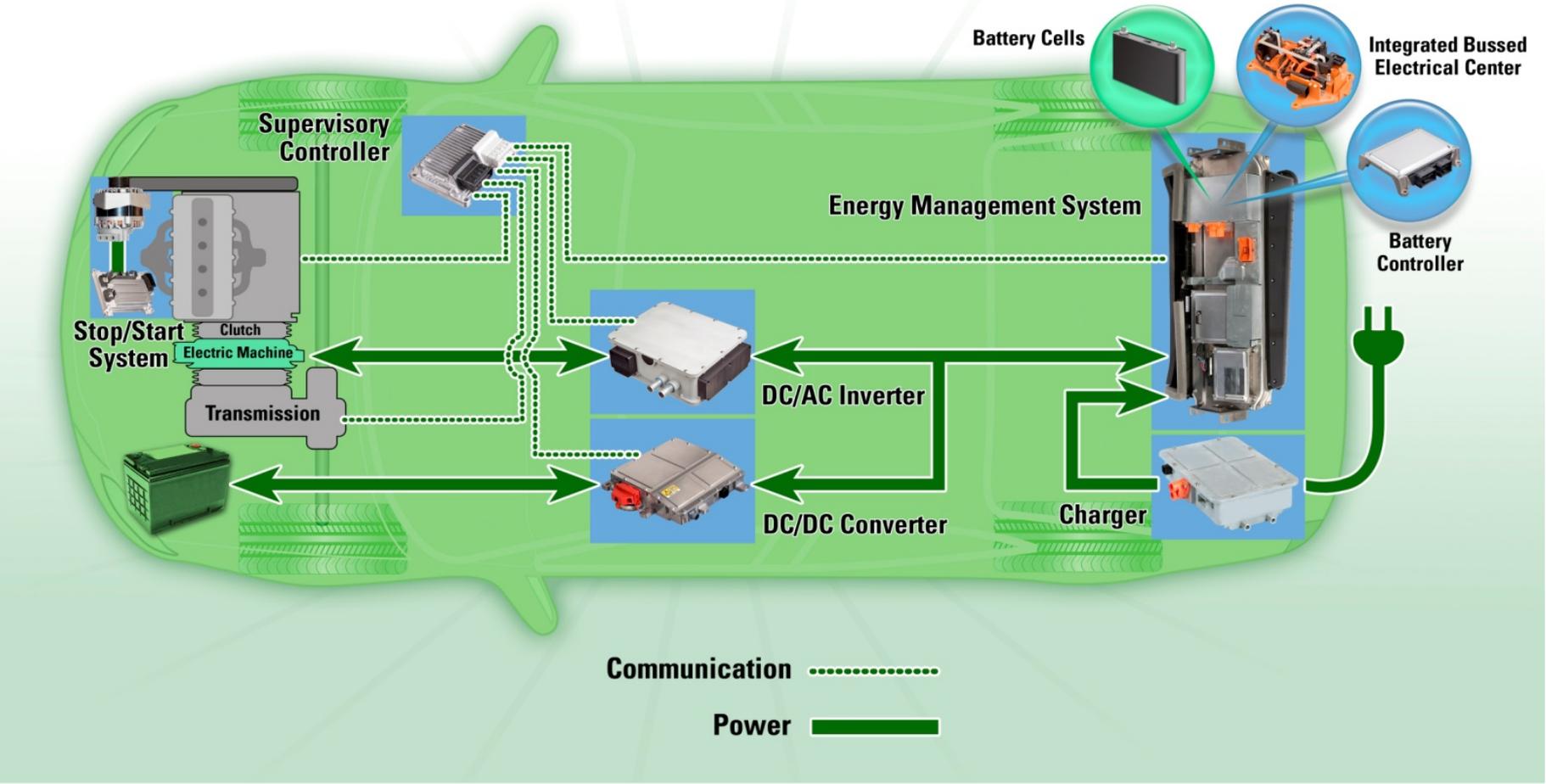
- EDGE Tax Credit over ten-year period

◆ City of Kokomo, Indiana – incentives offered

- Personal property tax abatement – five years on manufacturing equipment and special tooling – approved by City Council on 26Apr2010
- Revolving loan fund
- Workforce development support (w/ Purdue University & State of Indiana)

Delphi has in place the customers, suppliers and community foundation to succeed

Relevance: Lower-cost power electronic products enable expansion of U.S. demand for EDVs



Market Drivers: Performance - Emissions - Fuel Economy



Relevance: Establishes U.S. power electronics production capacity

◆ Build upon Delphi's core capabilities

- Rapid, concurrent product/process design optimization for production
- Based on power electronics building blocks
- Testing for validation
- Power electronics product line
 - » Inverters, converters, chargers, controllers, energy storage systems

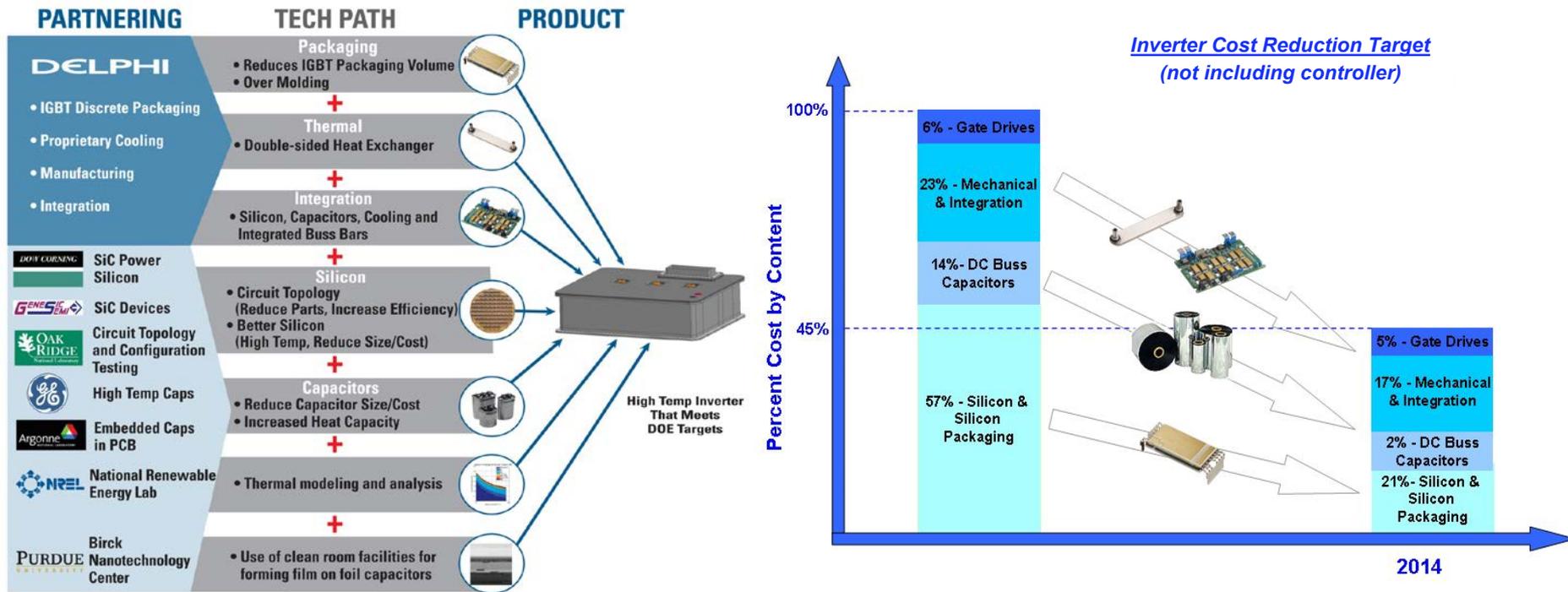


**Delphi's Power Electronics
Manufacturing Site
Kokomo, Indiana**

◆ Establish a globally competitive, U.S.-based production source for power electronics

- Automobiles
- Commercial vehicles
- Off-road / industrial equipment

Relevance: Provides a commercial path for future power electronics technology



– October 2007 –

Delphi Awarded \$8.2M DOE program for Development, Test and Demonstration of a Cost-Effective, Compact, Light-Weight, and Scalable High Temperature Propulsion Inverter

– November 2009 –

Delphi Awarded \$8.4M DOE program to develop GaN devices for HEV/PHEV/EV/FCV

Approach: Apply more than 20 years of Delphi experience with EV and HEV technology

- ◆ Largest North American supplier for HEV power electronics components and energy management systems
- ◆ HEV propulsion architects for multiple vehicles
- ◆ More than 100 relevant patents issued since 2000
- ◆ Focusing on aggressively lowering the cost of powertrain electrification
 - System design and architecture
 - Component design and development
 - Controls and algorithm development
 - Design for manufacturability

**The Result – Expanding Use of Energy-saving
EV and HEV Technology in Transportation**

Approach: Focus on three major areas

- ◆ Optimizing Delphi's power electronics component and system designs for volume production for a broad range of applications
 - Automotive vehicle manufacturers
 - Commercial vehicle manufacturers
 - Off-road vehicle manufacturers
 - Industrial equipment manufacturers
- ◆ Retrofitting existing and install required new equipment and tools
- ◆ Validating the readiness of Delphi's component and system designs for production

Approach: Apply Delphi's value-add

◆ Cost Efficiency

- Delphi understands automotive cost challenges and price competition
- Delphi leverages a large supplier base and technology building blocks to create affordable products, through volume production with economies of scale

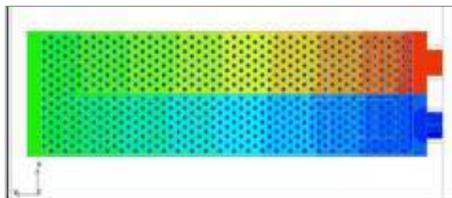
◆ Innovation

- Invention applied to high-volume production
- Proprietary power semiconductor packaging technology
- Solving the problems of thermal management and packaging for transportation

◆ Proven Reliability

- Delphi track record of single-digit PPM production of automotive power electronics and energy storage systems

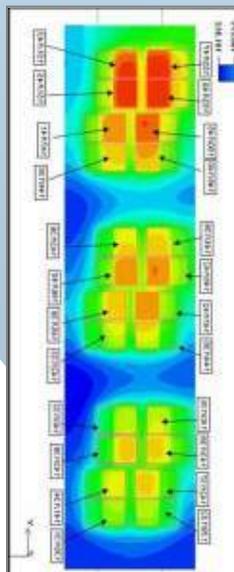
Approach: Apply a wide array of Delphi EV/HEV component and system development tools



**Heat Exchanger
Fluid Dynamics Modeling**



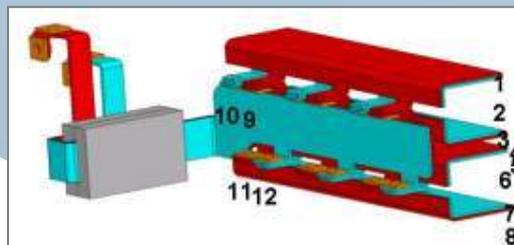
**Vehicle
Integration**



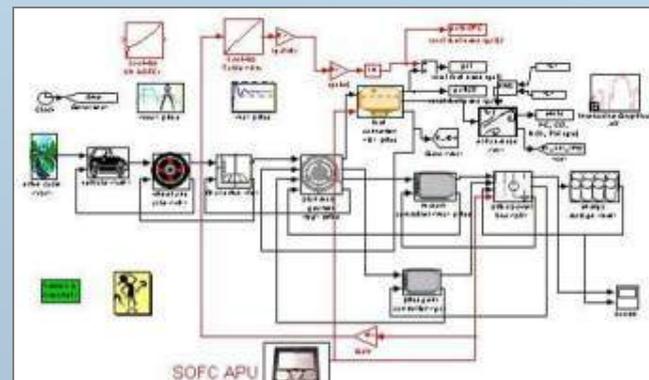
**Power Module
Thermal FEA**



System Dynamometers



**DC Bus Structure
Q3D Inductance Modeling**



**Vehicle Modeling and
Simulation**

Approach:

Build upon Delphi's extensive validation test capability



**Performance / Temperature
Tri-Temperature
Thermal Shock**



**Mechanical
Test**



**Vibration +
Thermal Shock**



EMI / EMC
• Emissions
• Susceptibility
• Immunity

Environmental
• Humidity
• Dust
• Corrosion
• Humidity



Powered Temperature Cycling

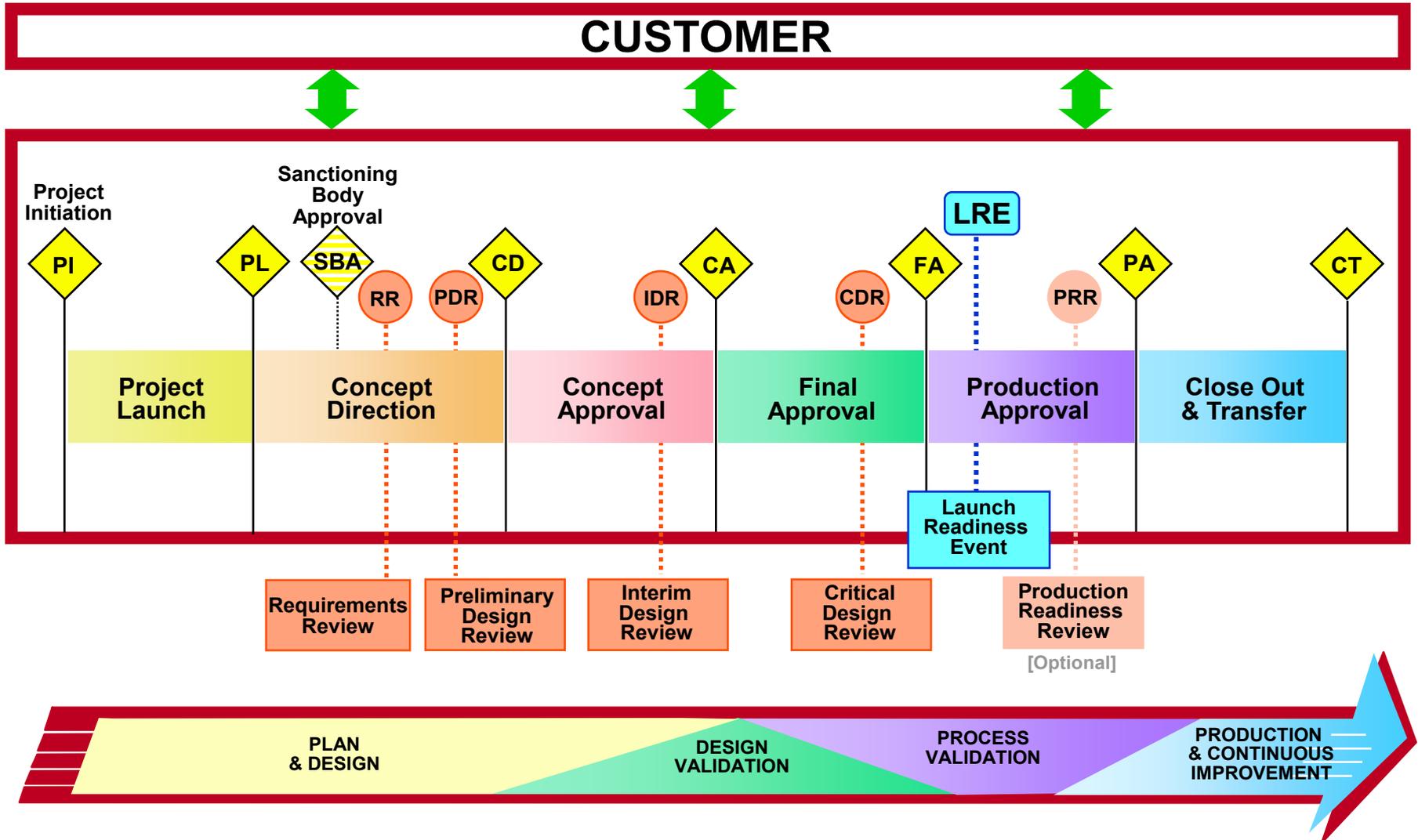


Highly Accelerated Life Test



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Approach: Utilize Delphi's Product Development Process



Accomplishments: New Power Electronics Production and Validation Facilities

- ◆ Feb 2010: First surface mount test boards completed
 - ◆ July 2010: First production started (for 1st export customer)
 - ◆ Sep 2010: Certification received for ISO/TS 16949 Quality Management System
 - ◆ Nov 2010: ISO 14001 Environmental Certification
 - ◆ Dec 2010: Completed installation of validation equipment at Kokomo Morgan Street (KMS) facility
 - ◆ Dec 2010: Groundbreaking for new validation facility at Kokomo Corporate Technology Center
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- ◆ Feb 2011: Successfully passed a new customer run-at-rate
 - ◆ Mar 2011: Low volume production initiated (for 2nd export customer)
 - ◆ Apr 2011: Energy Storage System test lab and proto build area completed
 - ◆ Apr 2011: Prep completed for validation and manufacturing areas for Energy Storage System
 - ◆ Sep 2011: Initial assembly and test equipment complement installed for Passenger Car Inverter
 - ◆ Oct 2011: New engineering/validation laboratory was completed, with DOE ribbon-cutting on Oct 17
 - ◆ Oct 2011: First pre-design proto builds scheduled for converters and inverters
 - ◆ Oct 2011: First flexible final assembly & test area installed
 - ◆ Dec 2011: Recertification of TS 16949 & ISO 14001
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- ◆ Mar 2012: Run-at-rate scheduled for next production launch product
 - ◆ Sep 2012: Start of production scheduled for lithium-ion battery controller



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Accomplishments: Chargers 100/220 AC to DC

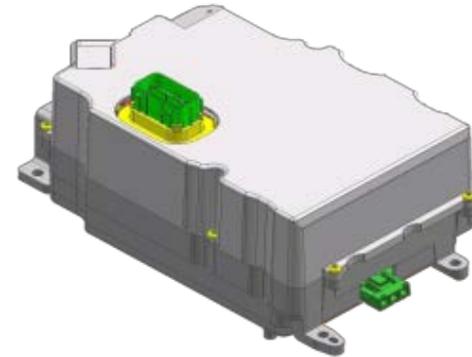
- ◆ Jan - Sep 2010: Engineering samples sent to OEM customers in North America and Europe
- ◆ July 2011: First low-volume samples produced in controlled process environment
- ◆ Oct 2011: Second generation prototype design development initiated
- ◆ Nov 2011: First prototype samples delivered to Asian customer
- ◆ Nov 2011: Award of production business for European customer
- ◆ Jan 2012: Long lead validation equipment ordered



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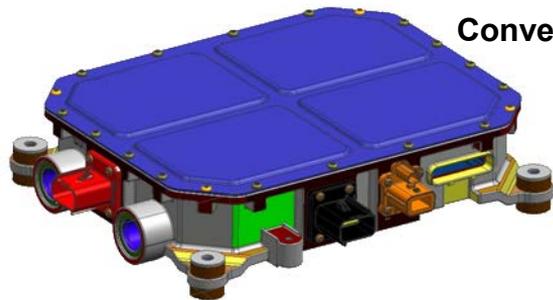
Accomplishments: Passenger Car Inverters

- ◆ Mar 2010: Received customer commitment
 - ◆ May 2010: First reliability evaluation completed
 - ◆ July 2010: First design confirmation units built
 - ◆ Aug 2010: First customer deliverables achieved
 - ◆ Sep 2010: Next design turn build completed
 - ◆ Nov 2010: Customer units delivered for motor calibration
-
- ◆ Jan 2011: First phase reliability successfully completed
 - ◆ Mar 2011: Validation equipment delivered and installed
 - ◆ Mar 2011: Second design turn build complete
 - ◆ July 2011: Second phase reliability testing started
 - ◆ Aug 2011: Vehicle testing started
 - ◆ Sep 2011: Initial complement of production equipment ordered / installation started
 - ◆ Dec 2011: Completed second phase customer deliveries
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- ◆ Jan 2012: Third design turn frozen

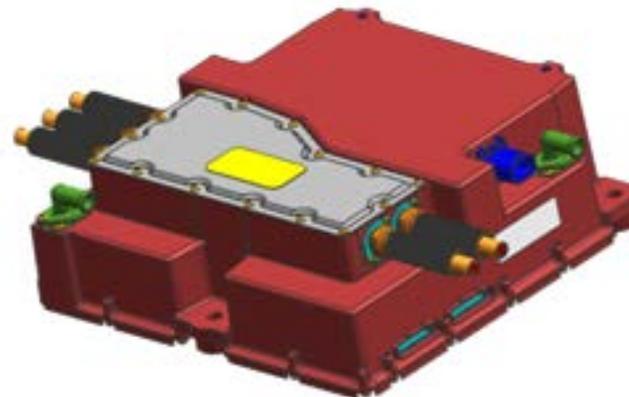


Accomplishments: Commercial Vehicle Systems

- ◆ May 2010: Populated inverter circuit boards at new manufacturing site
 - ◆ May 2010: Populated battery controller boards in engineering build facility
 - ◆ May 2010: First inverter drives a motor
 - ◆ July 2010: First complete customer system delivered
 - ◆ Aug 2010: First reliability evaluation completed
-
- ◆ Feb 2011: First vehicle test complete with inverter, converter and battery system
 - ◆ Aug 2011: Delivered second design turn hardware to customer
 - ◆ Aug 2011: Design validation testing initiated
 - ◆ Dec 2011: ESS Design validation testing completed
-
- ◆ Feb 2012: Converter design validation testing completed
 - ◆ Feb 2012: First customer reliability testing started for the battery controller, converter, inverter and energy storage system



Converter



Inverter

Accomplishments: Passenger Car DC/DC Converters

- ◆ Jan 2010: Project approved by Delphi for funding, initiating PDP process
 - ◆ Feb 2010: Manufacturing capital and tooling orders placed
 - ◆ Jun 2010: First process confirmation build
 - ◆ Sep 2010: Validation build and testing completed
 - ◆ Oct 2010: First production shipment to a China customer
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- ◆ Feb 2011: First production shipments to two European customers
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- ◆ Jan 2012: Validation build and testing begins for cost optimized production design



FY12 Summary of Achievements

(actual for Oct 2011 – Feb 2012 and planned)

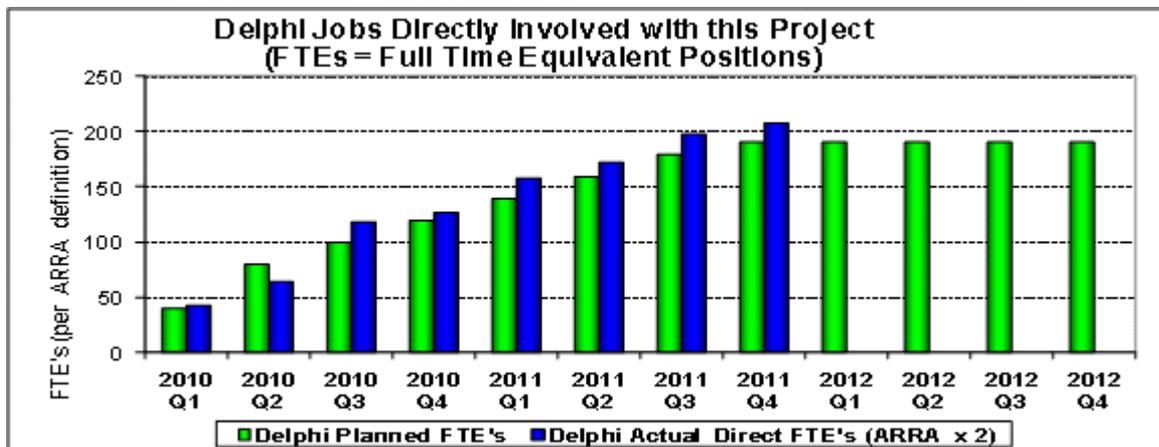
- ◆ Nov 2011: Charger low-volume samples sent to customers
- ◆ Nov 2011: Assembly and test equipment installation
 - Commercial Vehicle Hybrid System: started Nov 2011, completes May 2012
 - Passenger Car power electronics: started Dec 2011, completes July 2012
- ◆ Dec 2011: Re-certification to TS 16949 and ISO 14001 standards
- ◆ Jun 2012: Design validation testing completed for...
 - Commercial Vehicle Systems: testing started Aug/11, completes Jun/12
 - Passenger Car Inverter: testing started July/11, completes Jun/12
- ◆ Aug 2012: Production starts for Energy Storage System Control Module
- ◆ Dec 2012: Production process validation builds and testing
 - Passenger Car Inverter: build Aug/12 - Oct/12, testing Oct/12 - Dec/12

Accomplishments:

Project goal of 190 direct jobs has already been exceeded

<u>Estimated U.S. Jobs (as of 31Dec2011)</u>	DOE's 50% Cost-Share	Delphi's 50% Cost-Share	Total
Delphi Direct FTEs (ARRA Reported FTEs)	99.0	99.0	198.0
<u>Delphi Indirect/Support FTEs</u>	<u>49.5</u>	<u>49.5</u>	<u>99.0</u>
Subtotal Delphi	148.5	148.5	297.0
Est. Suppliers' FTEs (1.036 x Delphi) *	153.8	153.8	307.6
<u>Est. Indiana Community FTs (1.049 x Delphi) *</u>	<u>155.7</u>	<u>155.7</u>	<u>311.4</u>
Estimated Total U.S. Jobs Created / Retained by this project	458.0	458.0	916.0

* Multipliers based on State of Indiana Study: "What Indiana Makes, Makes Indiana: Analysis of the Indiana Manufacturing Sector," by Thomas P. Miller & Associates for the Central Indiana Corporate Partnership, January 17, 2005.



This project has directly resulted in 198 jobs at Delphi and many more U.S. jobs indirectly

Future Work

Beyond FY12 (by 31 Dec 2012)

- ✓ Complete implementation of scalable, lean and cost-effective manufacturing processes that can be rapidly expanded to meet increases in demand

Determination of Project Success

- ✓ An ISO/TS16949 quality certified U.S. power electronics production facility
- ✓ A world-class U.S. skilled workforce at Delphi and our suppliers, capable of meeting the needs of the emerging U.S. and global demand for power electronics components and systems for EDVs
- ✓ An established U.S. test and remanufacturing operation for power electronics components and systems associated with EDVs
- ✓ U.S. production capacity established for power electronics components and systems capable of supporting annual production of at least 200,000 EDVs

Summary

- ◆ Delphi is the largest North American supplier of power electronics components for EDVs
- ◆ Delphi is committed to the future of power electronics and the petroleum reduction benefits of EDVs
- ◆ This project will help ensure that vehicle OEMs and power system integrators have a globally competitive U.S. source for power electronics



**Delphi's
Power Electronics
Manufacturing Site
Kokomo, Indiana**

- ◆ Delphi has in place the customer base, strategic partnerships and supplier foundation necessary to achieve the goals of this project