Electric Drive Component Manufacturing -Magna E-Car Systems

2012 DOE Vehicle Technologies Program Annual Merit Review

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Magna E-Car Systems

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Project ID: AARAVT027

Overview

Timeline

- Start Date: July 1, 2010
- End Date: June 30, 2013
- More than 50% Complete

Budget

- Total Project Funding
  - DOE $40,000,000
  - Magna E-Car - $47,402,116
- DOE Funding
  - FY2010: $7,131,124
  - FY2011: $11,992,153
  - FY2012: $3,635,526

Barriers

- Unexpected changes in program timing
  - OEM customer design and software changes
  - Reduction in OEM volumes
- Increased cost and timing for low-volume components
  - Maintaining cost position at reduced volume forecasts for 2012

Partners

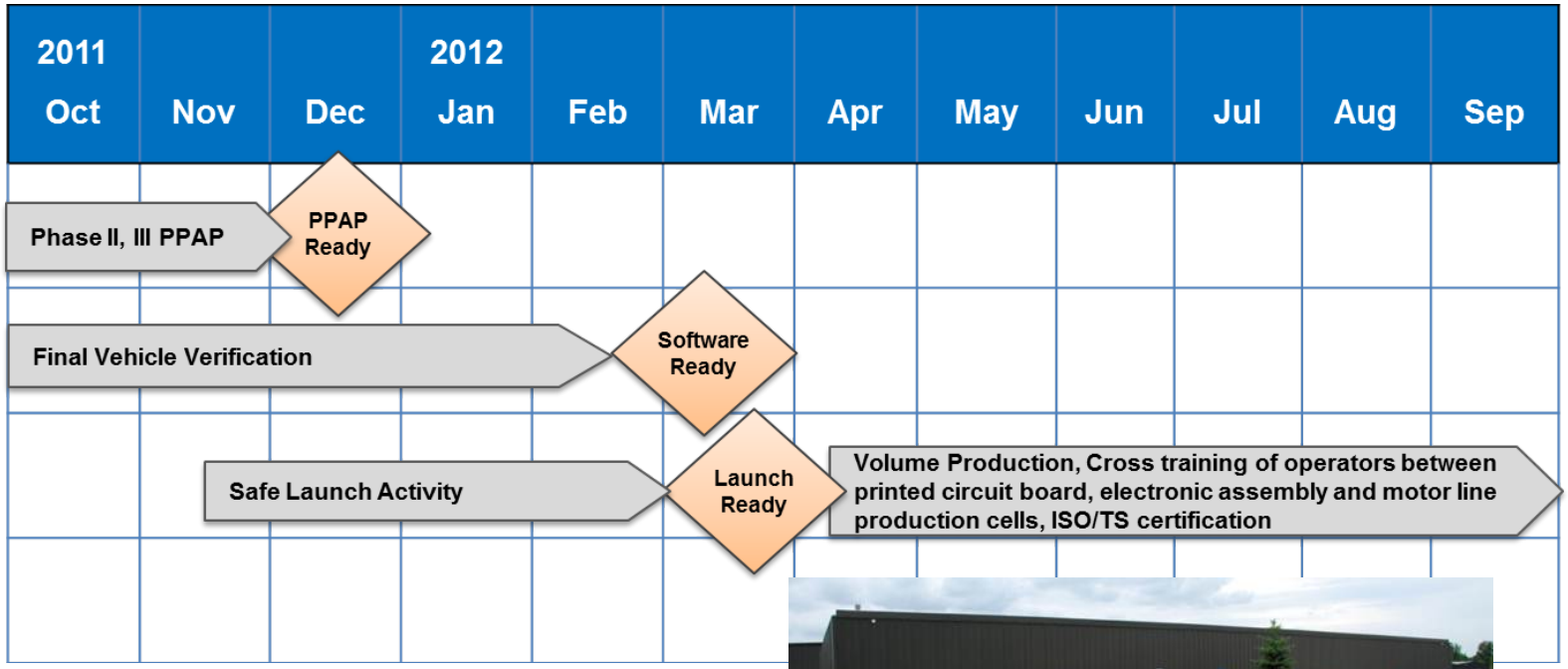
- Magna E-Car USA, LP
- Magna Powertrain USA, Inc.
- VEHMA International of America, Inc.

Relevance

Project Objectives

- Increase production capacity and validate production capability of advanced automotive electric drive component manufacturing plants in the U.S.
  - Completion of the activities required to manufacture and supply electric drive systems to existing OEM customer projects supporting long-term economic growth
  - Creation and validation of production capability of advanced automotive electric drive vehicle components for electric vehicle production programs in the U.S. spurring economic activity
  - Preparation of a newly acquired facility to house the manufacturing activities that are supported by this project creating new engineering and manufacturing jobs
- 2012 Objectives
  - Design, develop, validate and start production of key automotive electrification components for multiple OEM customer programs
    - Components include: Vehicle Control Unit (VCU), Motor Control Unit (MCU), Electric Powertrain Assembly (EPA), Integrated Chassis Control Module (ICCM)

Approach



- Go/No Go Decision Point
  - PPAP Completion
  - Final control software validation and software release
- Addressing Technical Barriers
  - Implement lean manufacturing with scalable industry standard automation
  - Allow flexibility in development and manufacturing to accommodate a range of power ratings and feature content

Milestones

- Overall Milestone Status
  - All programs continue to follow Program Management Plan timing with minimal delays
  - Start of production March 2012 for multiple component and OEM programs
  - Development continues on additional and next generation products

Milestone	Component	Start Date	End Date	% Complete
Final Data Judgment (FDJ) –Complete all validation testing, and freeze engineering designs to allow kick-off and procurement of production	VCU, MCU and Motor	02/2011	02/2011	100
Installation of Line at Production Facility –Install and test purchased production assembly equipment in the Magna E-Car production facility	VCU	10/2010	06/2011	100
	MCU and Motor	10/2010	01/2011	100
Verification Prototype –Production-intent builds to satisfy specific test requirements and ensure vehicle compatibility and design completeness	VCU	03/2011	03/2011	100
	MCU and Motor	02/2011	03/2011	100
VP Validation Testing –VP component- and vehicle-level testing is completed using VP-level parts to validate conformance to all objectives of production tooled components	VCU	04/2011	10/2011	100
	MCU and Motor	03/2011	08/2011	100
Production Part Approval Process (PPAP) –Phase I, II, III PPAP	VCU	10/2011	01/2012	100
	MCU and Motor	08/2011	01/2011	100
Final Engineering Completion (FEC) and Launch Readiness (LR) –All issues have been resolved and final approval to proceed to tooling trial is given	VCU, MCU and Motor	10/2011	10/2011	100
Mass Production (MP1) –Start of production at Magna E-Car production facility	BMU, VTM, VCU, MCU, Motor, BCCM	3/2011		

Technical Accomplishments and Progress

Engineering and Development

Powerplant System

- Production planning design released
  - Production planning builds – 115 powerplants
  - Successful demonstration of Run at Rate
- Final validation and testing of all software features and calibrations
- OEM customer process sign off milestone

Motor Control Unit (MCU)

- Product trial run and production validation completed
- Installation of production equipment for additional OEM customer program

Vehicle Control Unit (VCU)

- Final production intent software
- Customer tooling trials and production planning builds
  - 186 units
- Updates made to in-circuit and final function test production equipment
  - Improvements to electromagnetic capability (EMC) performance

Technical Accomplishments and Progress

Engineering and Development

Battery Charger Converter Module (BCCM)

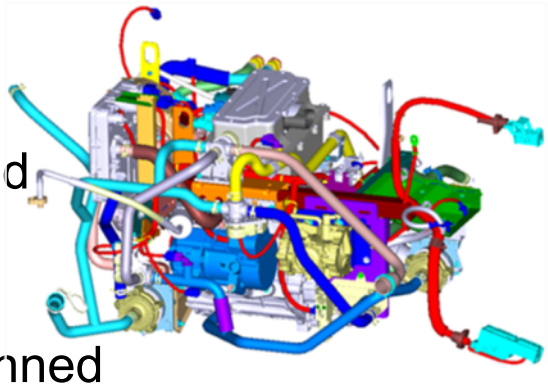
- Gamma level design prototype builds
  - Successful integration into customer vehicles

Integrated Chassis Control Module (ICCM)

- Completion of design verification testing
  - Design updates to improve EMC test performance
- First generation software released
- Vehicle integration builds commenced for application development and validation testing

Vehicle Systems

- Final engineering completion (FEC) milestone completed
- First phase of production planning build finalized
  - Second phase to start at OEM customer assembly plant
- On-going production support development activities planned



Laboratory and Testing

Battery Laboratory

- Cycling units, environmental and abuse chambers installed and commissioned
- Runs 85-100% utilization



Power Electronics Laboratory

- Upgrades made to low- and high-voltage laboratories
- EMC laboratory commissioned


Dynamometer and Testing

Test Cell	Test Properties		Status of Test Properties
1	Dyno_300	224 kW	2011 – Q4 Cell upgrade to 100kW Dyno Operational as of January 2012
2	Dyno_300	224 kW	Operational as of May 2010 for functional testing. This Test Cell in use for 100kW Motor Controls Development and Verification.
3	Dyno_350A	350 kW	Operational as of July 2010. This Test Cell in use for greater than 100 kW Motor Controls Development and Verification.
4	Dyno_350B	350 kW	Operational as of January 2011. This Test Cell in use for greater than 100 kW Motor Controls Development and Verification.
5	Dyno_5	N/A	Operational as of July 2011. High Speed Characterization Dyno



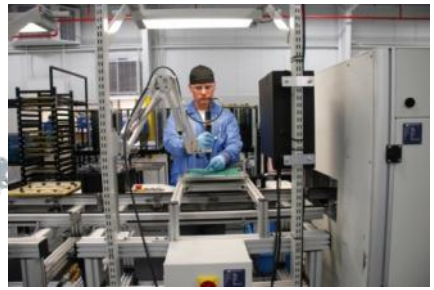


Component Manufacturing - Inverter, Controller and Charger Assemblies

- MCU Layout: 4 stations
  - All screw assembly operations include torque, angle, linear stroke and deflection monitoring; auto dispense screws
  - Error proofing for part presence, proper installation and orientation
  - Barcode scanning and serialization for traceability

- VCU Layout: 3 stations
  - All screw assembly operations include angle and torque monitoring. Servo press operation to assemble VCU to housing
  - Error proofing for part presence, sequence and critical process parameters
  - Fixture sensors for correct tooling; barcode scanning for lot traceability

- BCCM Layout: 4 stations
  - All screw assembly operations include angle and torque monitoring; auto dispense screws
  - Error proofing for part presence, sequence and critical inputs such as torque
  - Fixture sensors for correct tooling; barcode scanning for lot traceability



Capacity: 30k/year, Expandable to 100K

Component Manufacturing - Motor Assembly

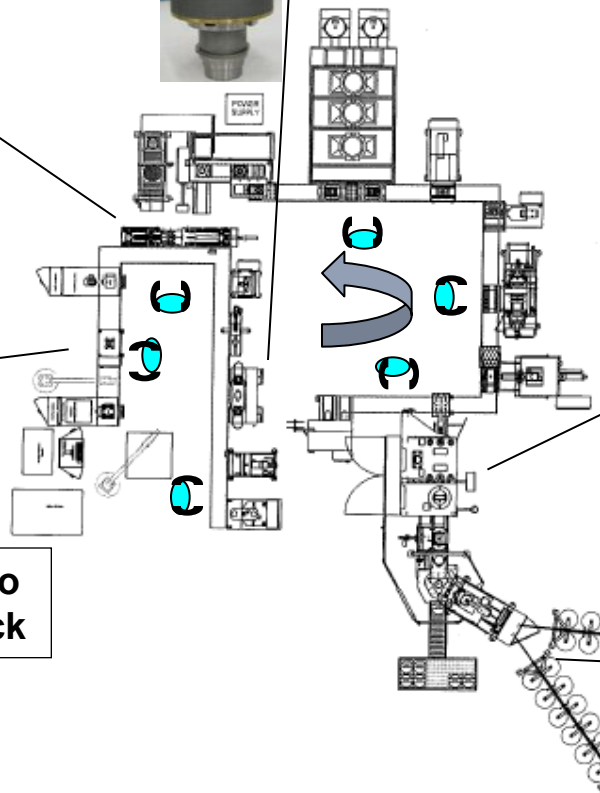
- Automated operations to control quality (manual part movement between stations and component loading)
- All operations include error proofing for part presence, position and orientation
- Component lot traceability and in process data collection for final motor serialization

Motor Assembly

Inverter Assembly to Motor, Test and Pack

Permanent Magnet Rotor Assembly

Capacity: 30k/year, Expandable to 100K in same footprint



Stator Winding and Assembly

Collaborations / Partnerships

Magna E-Car Systems of America, Inc.

- Primary Recipient

Magna E-Car USA, LP

- Engineering, development and testing of VCU, MCU and Motor
- Assembly and manufacturing of VCU, MCU and Motor

Magna Powertrain USA, Inc.

- Development and manufacturing of gearbox
- Assembly and integration of the electric powertrain assembly

MAGNA POWERTRAIN

VEHMA International of America, Inc.

- Development and manufacturing of the cradle for the powertrain assembly

MAGNA COSMA INTERNATIONAL

Future Work

Motor Control Unit (MCU) and Motor

- Completion of all production validation testing and PPAP requirements leading to part submission warrant (PSW) certification
- Start of production (Job 1 launch)

Vehicle Control Unit (VCU)

- Complete PPAP with suppliers and OEM customer
- Completion of production validation and EMC testing

Vehicle Systems

- Finalize production planning build
- Ramp up to full line rate at assembly plant

Corporate Functional Safety and Certification

- Qualify QMS and prepare for ISO/TS-16949 audits
  - Certification issue December 2012
- Acquire ISO 14001 certification August 2012
- Acquire ESD S20.20 certification August 2012
- Align documentation with latest release of ISO 26262

Summary

- Program continues to follow projected timeline, milestones and budget with minimal exception
  - Customer design and volume changes are primary barriers
- Components designed, prototypes built and undergoing various levels of development testing and validation
  - Production validation and design verification testing continuing on components at various stages of development and manufacture
- Corporate and manufacturing process certifications being established to conform with OEM customer requirements and industry standards
  - ISO/TS-16949, ISO-14001, ISO-26262, ESD-S20.20
- Facilities upgraded and prepared for manufacturing
  - Manufacturing, assembly and testing equipment has been installed and validated; tooling trials and production planning builds accomplished
  - Start of production to begin March 2012; creation of additional engineering and manufacturing jobs
  - Continue commercialization development plans with OEM customers spurring sustainable economic growth

Technical Back-Up Slides

Integrated Inverter

Description

- **The Inverter provides up to 120 kW peak power to an electrical motor. With Magna E-Car Systems proprietary motor control algorithm, the Inverter accurately controls electric motor torque and power flow.**

Features/Specifications

- **Directly mounted on electric motor**
- **Compact and robust design for automotive reliability**
- **High power density**
- **State-of-the-art power electronics**
- **Optimized software and controls for efficient and accurate motor torque generation**
- **Integrated 3-circuit high voltage DC distribution**
- **Liquid-cooled**
- **High-speed CAN interface**
- **Specifications**
  - Input voltage range: 260V to 400V
  - Peak power: 120 kW
  - Peak Efficiency : >94%
  - Peak current: 400 Arms
  - Maximum efficiency: 98%

Key Benefits

Green Technologies

Safety

Fuel Efficiency

Process Efficiency

Contact

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Chassis Motor

Description

- **The Chassis Motor is an Interior Permanent Magnet Synchronous Machine (IPMSM) designed for electric and hybrid vehicle application traction drives. This highly efficient and quiet motor is well-suited for both primary and auxiliary vehicle propulsion systems.**

Features/Specifications

- **Scalable from 75kW to 150kW design**
- **Modular to accommodate various transmissions**
- **Water-cooled for high continuous power ratings**
- **Capable of providing a high level of regenerative braking**
- **Low-cost housing design**
- **Integrated MCU mounting**
- **Smooth, quiet operation**
- **100kW Motor Specifications**
  - Peak Power: 100 kW
  - Peak Torque: 282 Nm
  - Continuous Power: 45 kW
  - Continuous Torque: 150 Nm
  - Maximum Speed: 10,000 rpm
  - Peak Efficiency: 97%

Key Benefits

Green Technologies

Fuel Efficiency

Process Efficiency

Contact

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Powerplant System

Description

- **Integrated Traction Motor and Inverter with proprietary Motor Control Software having a Controller Area Network interface to the vehicle for a turn-key motor drive system. The design mates with a coaxial or offset transmission, which is separately supplied.**

Features/Specifications

Traction Motor

- Peak Power: 105 kW
- Peak Torque: 282 Nm
- Continuous Power: 45 kW
- Continuous Torque: 150 Nm
- Maximum Speed: 10,000 rpm
- Peak Efficiency: 97%
- Water-cooled for high continuous power ratings
- Reduced wiring & EMI with integrated Inverter
- Provides full regenerative braking capability
- Production Validated with automated assembly

Inverter

- Input voltage range: 250V to 420V
- Peak power: 120 kW
- Peak Efficiency : >94%
- Peak current: 400 Arms
- Maximum efficiency: 98%
- Compact and robust design for reliability
- High power density
- Optimized software and controls for efficient and accurate motor torque generation
- Integrated 3-circuit high voltage DC distribution
- Liquid-cooled
- High-speed CAN interface

Key Benefits

Green Technologies

Fuel Efficiency

Process Efficiency

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Stand Alone Inverter

Description

- **The Inverter provides up to 120 kW peak power to an electrical motor. With Magna E-Car Systems proprietary motor control algorithm, the inverter accurately controls electric motor torque and power flow.**

Features/Specifications

- **Directly mounted on electric motor**
- **Compact and robust design for automotive reliability**
- **High power density**
- **State-of-the-art power electronics**
- **Optimized software and controls for efficient and accurate motor torque generation**
- **Integrated 3-circuit high voltage DC distribution**
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Vehicle Control Unit (VCU)

Description

- **The Vehicle Control Unit functions as the master controller in hybrid and electric vehicles. It is responsible for reading driver input and determining the required wheel torque, while also monitoring safety systems and providing thermal and energy management.**

Features/Specifications

- **Redundant processor safety strategy**
- **Low-level hardware/software interface layer**
- **Optional Magna-supplied vehicle control software**
- **Calibration over CCP or ETK**
- **6-16VDC operating voltage**
- **3 CAN interfaces, 1 LIN interface**
- **Over 66 channels of I/O**
- **OBD on all I/O**
- **198-way connector**

Key Benefits

Green Technologies

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Fuel Efficiency

Process Efficiency

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