DE-FOA-0000026 - Grant Supporting Construction of United States Based Manufacturing Plants to Produce Electric Drive Components

Poster Title: Electric Drive Component Manufacturing

Project ID: ARRAVT027

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Team members:
Magna E-Car Systems of America, Inc.
Magna E-Car USA, Limited Partnership

Project Duration: 1 July 2010 to 30 June 2014

2012 DOE Vehicle Technologies Program Annual Merit Review
Arlington, Virginia

May 14, 2013

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

USDRIVE
DRIVING RESEARCH AND INNOVATION FOR VEHICLE EFFICIENCY AND ENERGY SUSTAINABILITY

This presentation does not contain any proprietary or confidential information

Overview

Timeline

- Start Date: July 1, 2010
- End Date: June 30, 2014
- More than 50% Complete

Budget

- Total Project Funding
  - DOE - $40,000,000
  - Magna E-Car - $47,402,116
- DOE Funding
  - FY2010: $ 7,821,414
  - FY2011: $ 14,038,417
  - FY2012: $ 7,665,051
  - FY2013: $ 787,577

Barriers

- Reduction in expected market demand has resulted in delays to planned capacity growth, equipment purchases, equipment installation and validation activities to balance production capacity to customer orders. The project was extended to accommodate slowed production capacity growth rate.
- Reduced market demand increasing cost and timing for unique low-volume components.

Partners

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

FY2013 Milestones

- Overall Milestone Status
  - All programs continue to follow Program Management Plan timing with minimal delays
  - PPAP of mid-cycle enhancements (Job#2) April 2013
  - Deliver quality product to production releases

Component	Milestone	Start Date	End Date	% Complete
PCM & TCM	Software Development – Job #2	12/10/12	3/18/13	95%
PCM & TCM	PPAP Activities for Mid-Cycle Enhancements – Job #2	11/16/12	3/27/13	90%
PCM & TCM	2013/14 Job #2 – Powertrain Phase (PP)	3/4/13		100%
PCM & TCM	2013/14 Job #2 – Tooling Trial (TT)	4/23/13		0%
Hybrid Controller	Production Part Approval Process (PPAP)	2/12/12	1/18/13	100%
Hybrid Controller	Production Readiness to Start of Production	1/18/13	4/29/13	10%
Battery Controller	Design Validation (DV) – Build, Test, & Analysis	11/30/12	6/13/13	50%
Battery Controller	Production Line Equipment – Kick-off, Procure & Install	4/17/13	11/20/13	0%

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**
- **2013 Objectives**
  - **Validation Mid-Cycle Enhancements for model year production, 2013-14, (Job #2)**
  - **Implement software feature additions for Job #2 activity on BEV platform**
  - **Launch Mid-Cycle Enhancements for model year production, 2013-14, (Job #2)**
  - **Install required production capacity for new hybrid control module**
  - **Continue Battery Control Module & Cell Sense Board development on HEV program**
  - **Procure production equipment for battery control module & Cell Sense Board**

Summary of Accomplishments and Progress – FY2012

Development & Manufacturing

PowerPlant System (MCU and Motor)

- Production launched – delivered 2096 PowerPlant Assy's
- Production launched – delivered 4352 Stand alone Inverters

Vehicle Control Unit (VCU)

- Production launched – delivered 1617 Controllers

Battery Charger Converter Module (BCCM)

- Gamma level design prototypes integrated into vehicles

Integrated Chassis Control Module (ICCM)

- Completion of production verification (PV) testing
- Achieved Production Run at Rate and completed PPAP

Battery Management System

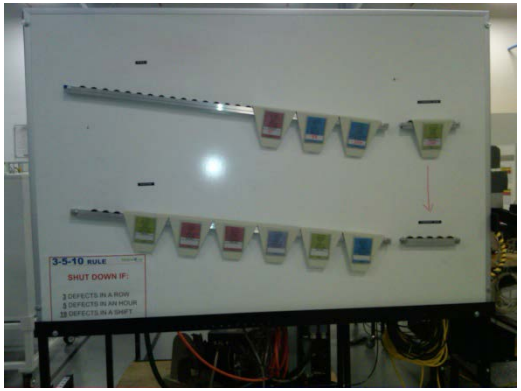
- DV testing of BSM and CSB

Vehicle Systems – Electric Powertrain Assy & Vehicle Integration

- Production launched – delivered 1897 Assy's
- On-going production support to OEM

Progress: 2012 GBEV Production Launch Motor & Inverter

- **Production Actions**
  - Inventory management
  - Visual Production Scheduling
  - Improved Pack-out process
  - Returnable Dunnage



Progress: GBEV 2012 Additions
High Volume Inverter & Quality Lab

Capacity: 45k/year, Expandable to 135K

Inverter

Housing and connector assembly

IGBT, capacitor, DC bus bar installation

Sub assemblies and gate drive board mounting

AC bus bar, control board, X-Y Filter board mounting

Hi-pot and final function tester

Housing and cover sealing

Vent plug and shipping caps installation

<u>GBEV Quality Lab</u>
Controlled Crib Coordinate Measurement Machine (CMM) Diagnostic lab with controlled environment

Accomplishment: Battery Management System (BMS) – New Production Program

MAGNA ELECTRONICS

Description

- The **Battery Management Systems** monitors and controls the high voltage battery system in EV, PHEV, and HEV's. The BMS performs all measurements and controls to determine SOC, SOH, and operates as a safety critical system to protect the battery system from over charge and over discharge.

Features/Specifications

- Communication with up to 20 external cell sensing devices
- Control of isolation devices (contactors) for Pack +, Pack -, and charging connections
- Support for J1772 charging interface
- Measurement of pack and link high voltage
- Isolation / Dielectric breakdown detection between pack and 12V vehicle systems
- Redundant microprocessor for parallel calculation and safety
- Thermal controls for fans and temperature monitoring
- Flexible multi-function I/O

Key Benefits

Green Technologies

Safety

Fuel Efficiency

Process Efficiency

Contact

Name: James Kane
Phone: 248-265-4409
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Accomplishment: Developed Battery Cell Sensing Board (CSB) – New Production Program

MAGNA ELECTRONICS

Description

The **CSB** measures individual cell voltages, module group voltages, and temperatures for a HEV or BEV battery. All cell voltages and module temperatures are reported directly to a Battery Management System (BMS). The CSB also performs internal circuit diagnostics and cell balancing.

Features/Specifications

- Cell balancing capable up to 50mA, limited due to housing
- 12 Cell voltage measurement
- Sampling every 3ms
- Accuracy to +/- 0.001V @ 25C
- Accuracy to +/- 0.003V @ -40C to 85C
- Sampling synchronization with all other modules
- <25uA current draw from cells

Key Benefits

Green Technologies

Safety

Fuel Efficiency

Process Efficiency

Contact

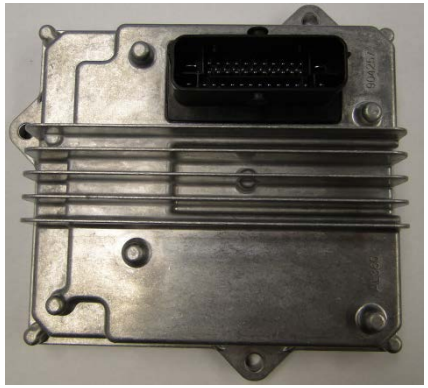
Name: James Kane
Phone: 248-265-4409
Email: james.kane@magna.com

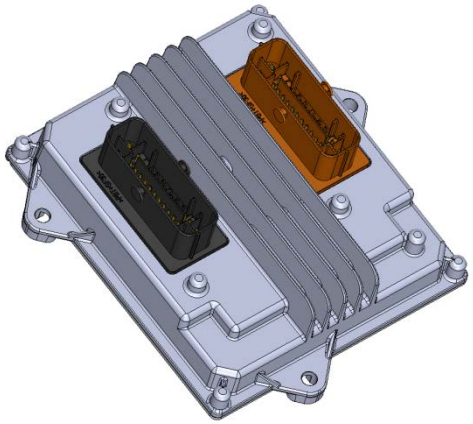
Accomplishment: Developed High Content Integrated Chassis Control Module (ICCM)

MAGNA ELECTRONICS

Description

- The **ICCM** is used on both conventional gasoline vehicles as well as HEV's. The module provides safety critical hardware with multi-function I/O that can be adapted by software for multiple vehicle applications.





Features/Specifications

- Operation between 6V and 16VDC
- 6 high current high side drives capable of on/off or PWM up to 2kHz
- 16 high current low side drives capable of on/off or PWM up to 2kHz
- 6 low side low current outputs
- 6 analog inputs for 0-5V sensor measurement
- 3 digital inputs for 12V signals
- Sampling synchronization with all other modules
- Redundant microprocessor for parallel calculation and safety

Key Benefits

Green Technologies

Safety

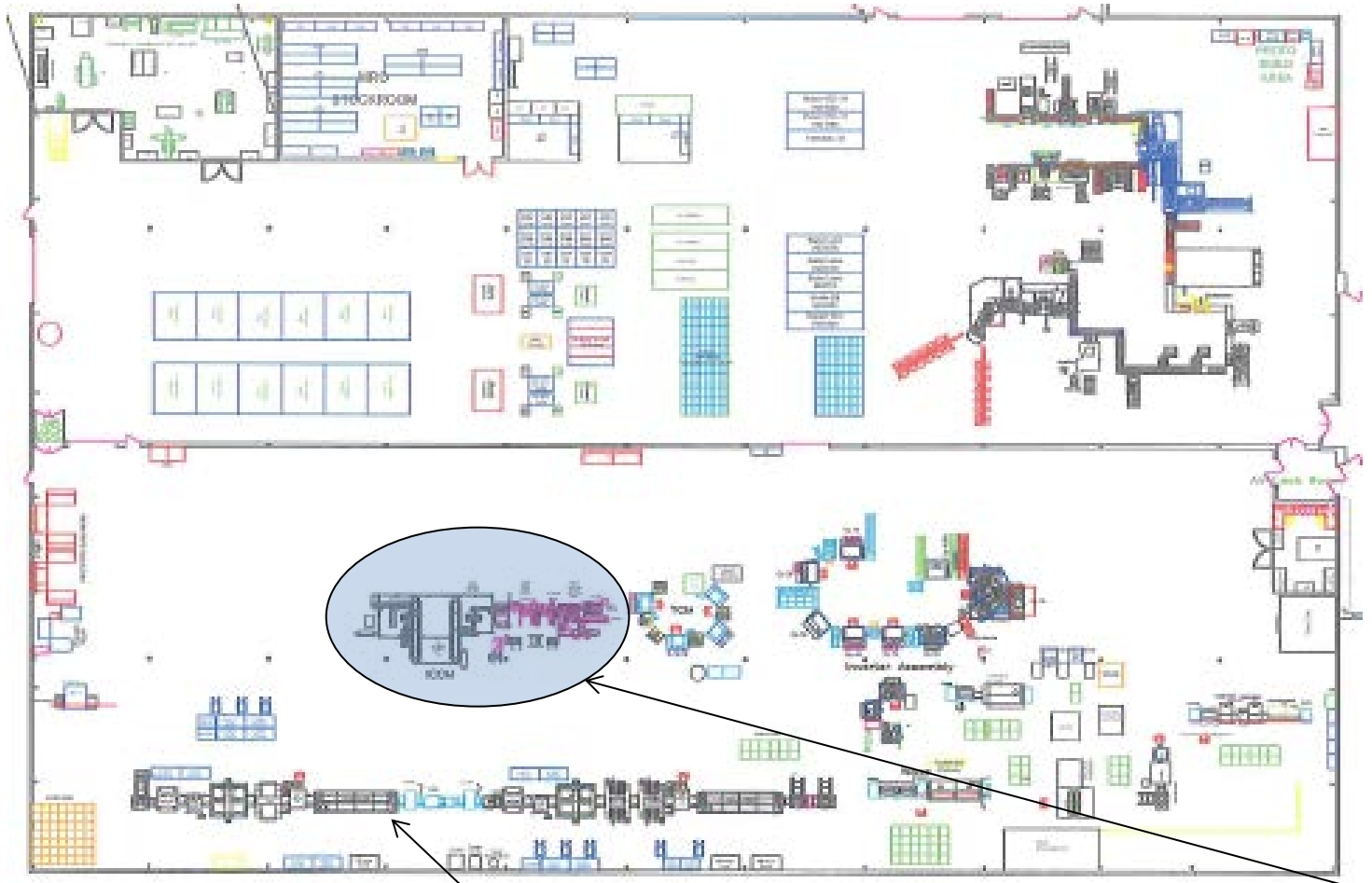
Fuel Efficiency

Process Efficiency

Contact

Name: James Kane
Phone: 248-265-4409
Email: james.kane@magna.com

Approach: Install High Volume Hybrid Controller Assembly Line



Initial Volume: 400K/year
Peak capacity: ~800k/year

Automated Final Assembly Cell for High Volume Controller
Utilize Printed Circuit Boards Capacity on existing SMD lines

Approach: Manufacturing Process with Highly Automated Final Assembly

Final Assembly Cell
Connector, PCB & Housing, Auto press connector to board & inspect

Connector & housing sealing surface treatment

Sealant & Thermal Gel Dispense
100% Machine Vision Inspection

Place housing and drive fasteners to attach PCB to housing, 100% torque/angle control

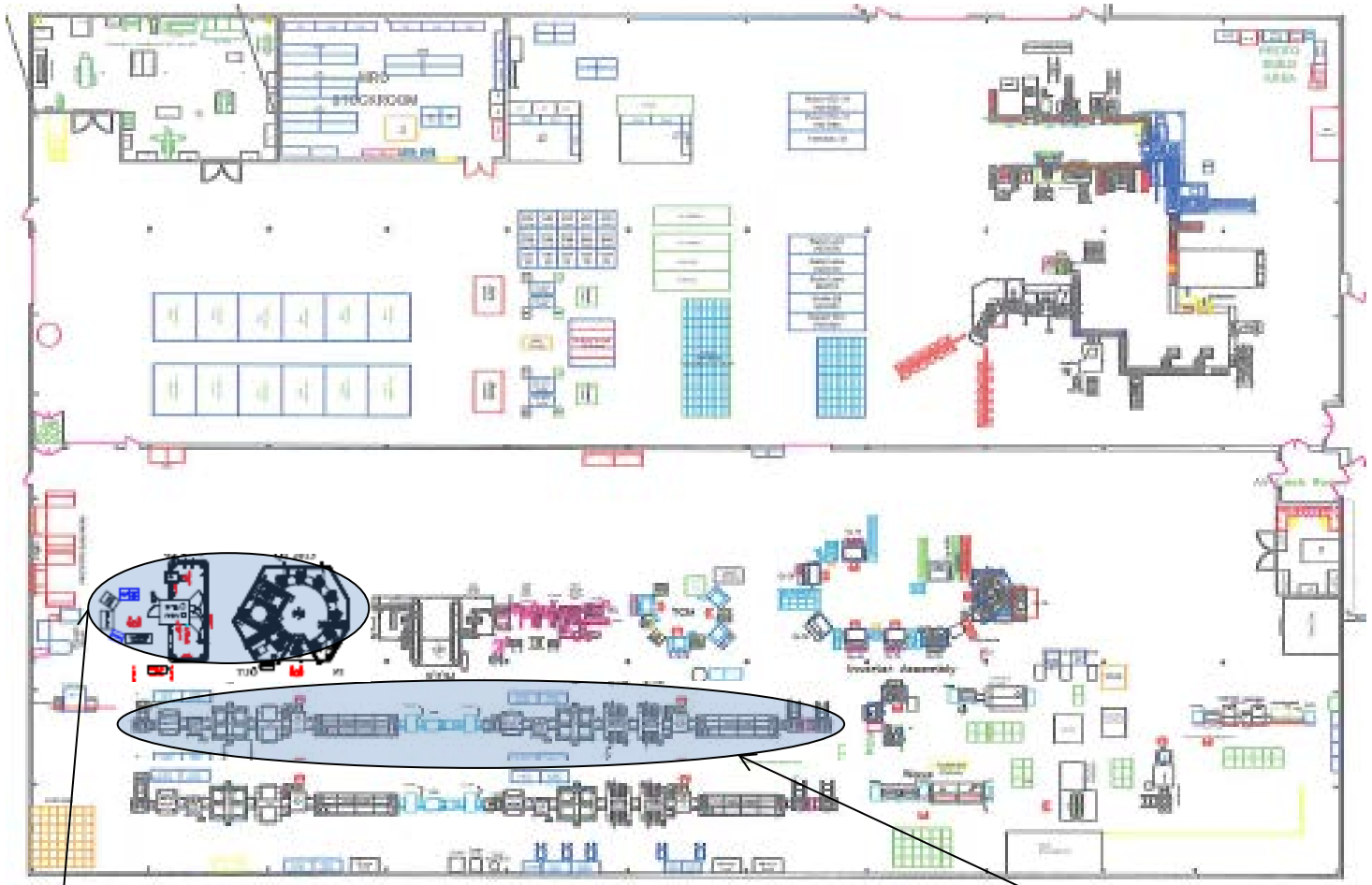
Approach: Manufacturing Process with Highly Automated Final Assembly

Robotic placement: housing, fasteners, 100% torque & angle control

Sealant Cure Station

Robotic placement: 100% Electrical verification, Leak Testing, Laser mark , Unload, Pack-out

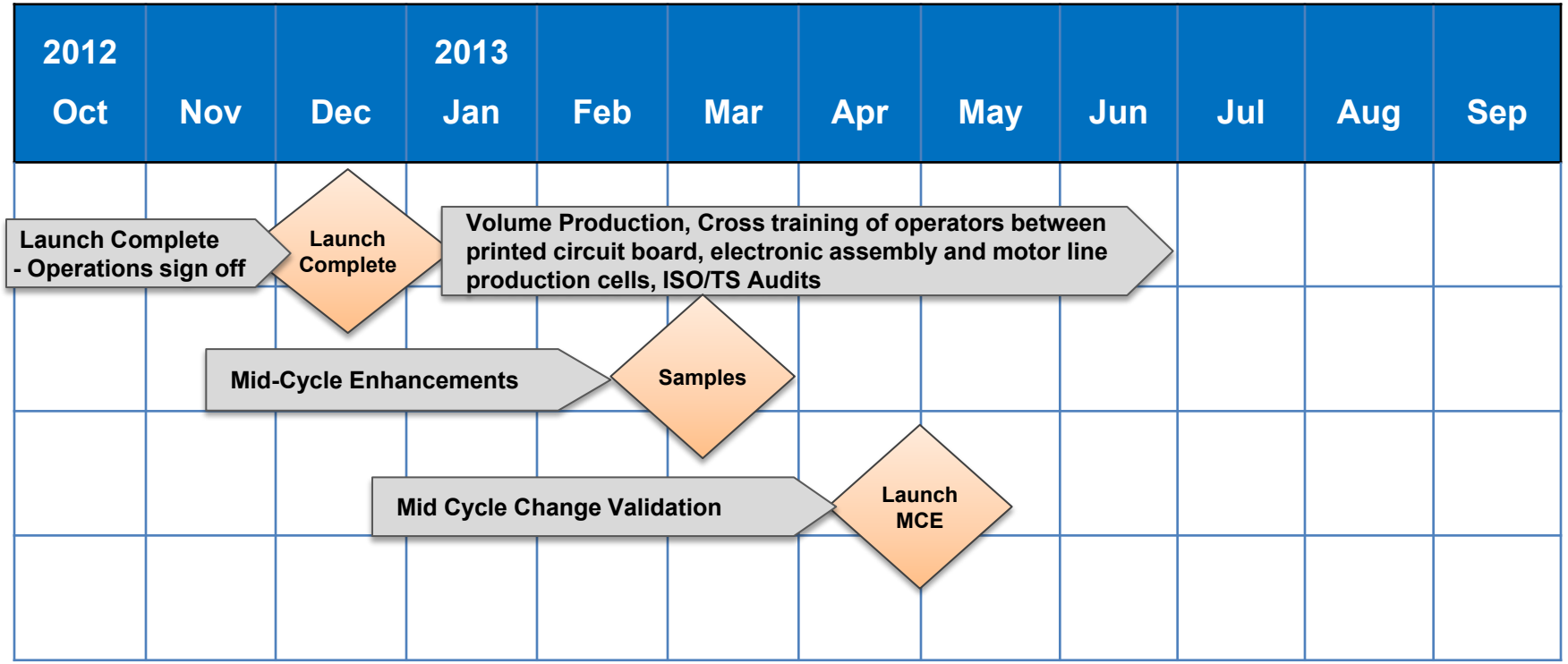
Approach: Grand Blanc Plant Layout To Support Added BSM & CSB Production



2nd SMD Line to Support BSM program (Target install Q2 ’14)

Final Assembly – BSM/CSB (2 separate lines) Target Installation Q4 2013

Future Work: FY 2013 Activity Plan TCM & PCM



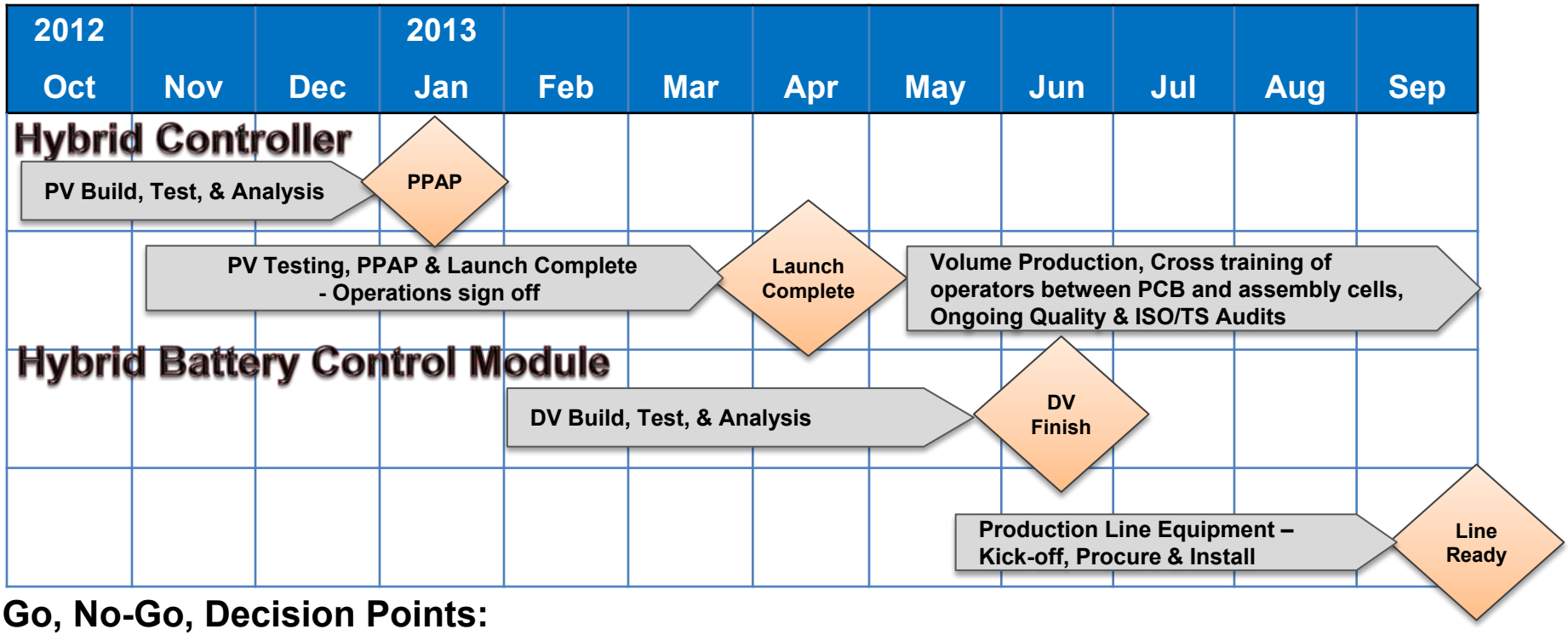
Go, No-Go, Decision Points:

Pass Validation Testing for Mid-Cycle Enhancements to Robustness & Productivity
New Software Functions Validated at component and vehicle level

Challenges or Barriers:

Final software feature implementation timing
Validation Mid-Cycle Enhancements in time for next model year production
Maintaining cost position at reduced volume forecasts for 2012-2013

Future Work: FY 2013 Activity Plan – Hybrid Controller & Battery Control Modules



Go, No-Go, Decision Points:

Hybrid Controller:

Launch Readiness for April start of production

Battery Controller:

Design Validation Completed

Challenges or Barriers:

Hybrid Controller:

Run at Rate to required production volumes

Battery Controller:

Design Validation Monitoring equipment and laboratory readiness

Technical Back-Up Slides

Electric Drive Component Functionality

Internal Combustion Engine

Electric Vehicle Propulsion System

- **Electric propulsion system & controller functions**
  - Converts electric energy to mechanical energy and vice versa
  - Controllers for Battery Monitoring, Torque & Vehicle Management
  - Enables Zero emission battery and fuel cell electric vehicles (EV)
  - Improves efficiency & reduce emissions in hybrids (HEV & PHEV)
  - Flexible powertrains with power electronics and advanced motors
  - Enable readiness for future fuel cell electric drive technologies

Accomplishment: Integrated Inverter

MAGNA ELECTRONICS

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

Name: Zhao Zilai
Phone: (248) 265-4461
Email: zilai.zhao@magna.com

Accomplishment: Chassis Motor

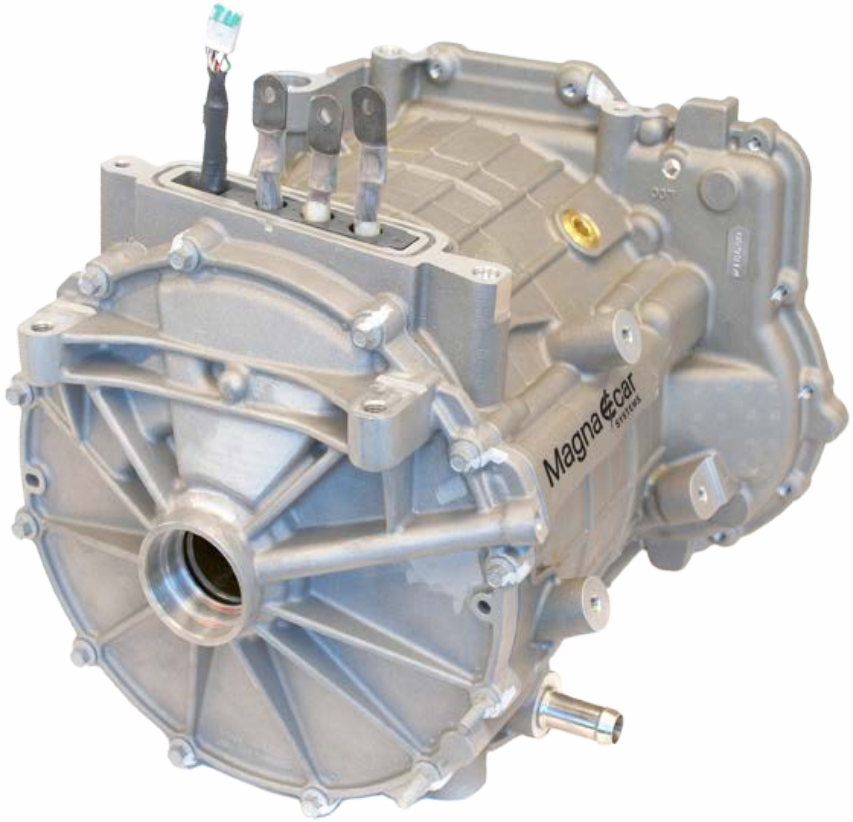
MAGNA ELECTRONICS

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

Name: Zhao Zilai
Phone: (248) 265-4461
Email: zilai.zhao@magna.com

Accomplishment: PowerPlant System

MAGNA ELECTRONICS

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

Contact

Name: Zhao Zilai
Phone: (248) 265-4461
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Accomplishment: PowerPlant System with Coaxial Gearbox

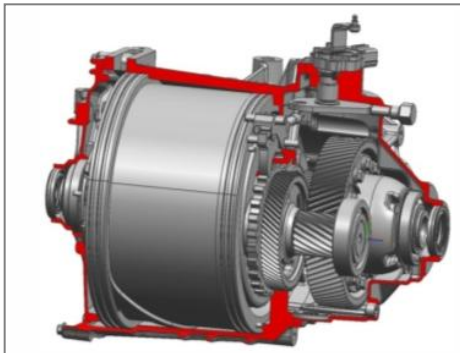
MAGNA ELECTRONICS

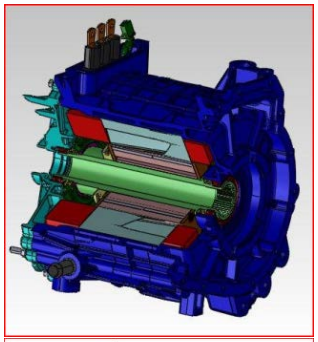
Description

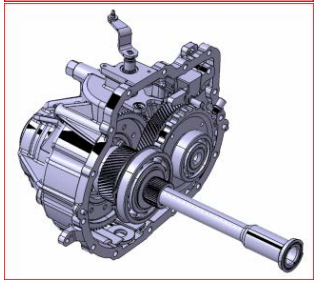
Magna's integrated **electric Drive** with fully integrated motor module and park lock system provides efficient construction with modular design to adapt to various layouts/ratio requirements.

Features/Specifications

- Integrated motor/gearbox, with co-axial layout and on-board Motor Controller
- 2 Stage Helical Gearing for compact gearbox
  - Ratio's 5.27, 6.34 & 7.82
- IPM Motor (260mm Dia)
  - Power/Torque
    - 103kW/245Nm Peak – 30 sec duration
    - 45kW/150Nm Continuous
  - Speed
    - 10,000 rpm max. unloaded
    - 8,800 rpm loaded
- Liquid-Cooled 8l/min. 70ºC inlet
- Direct Cable Park lock actuation with position feedback







Key Benefits

- Green Technologies
- Process Efficiency
- Vehicle Performance
- Fuel Efficiency

Contact

Name: Zhao Zilai
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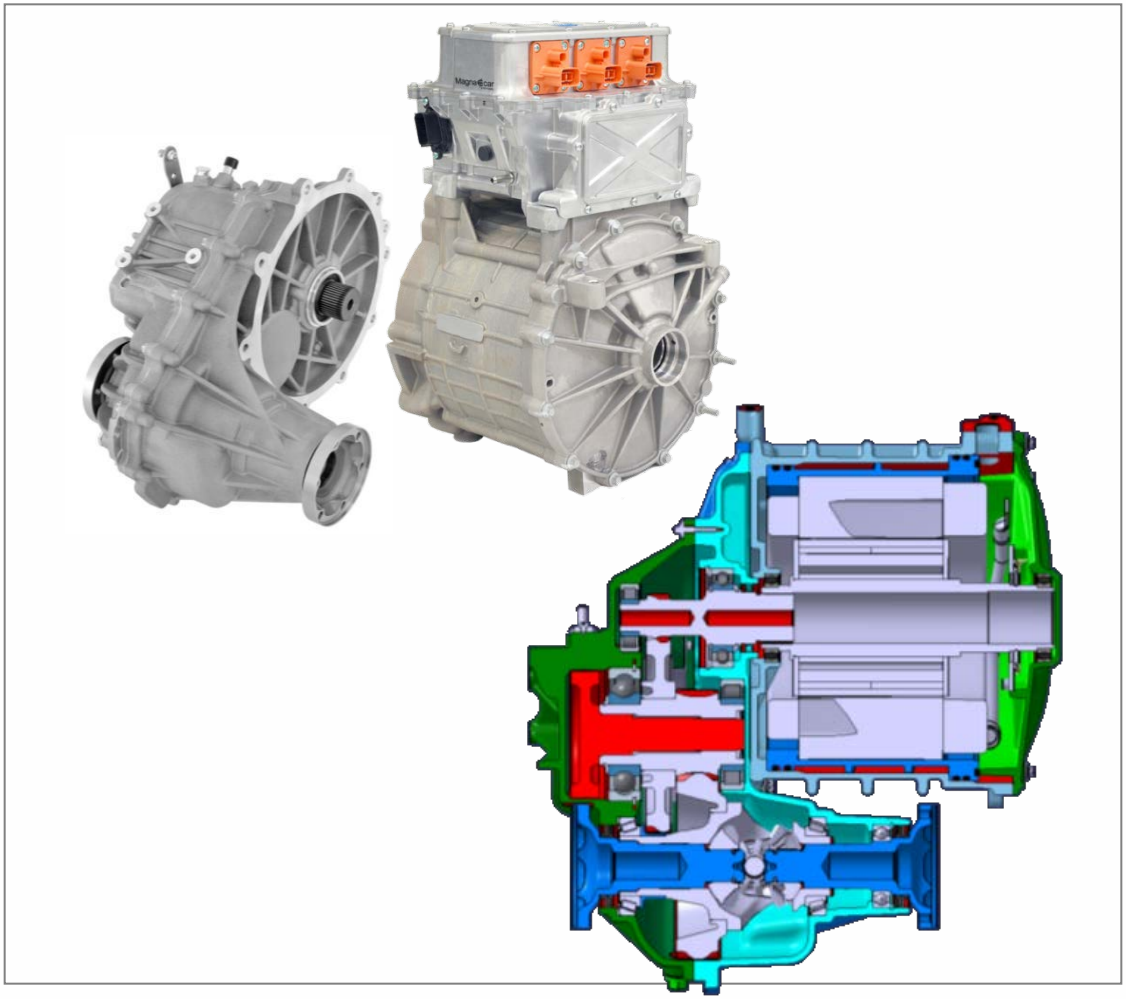
Accomplishment: PowerPlant System with Offset Gearbox

MAGNA ELECTRONICS

Description

Magna integrated **electric Drive** with fully integrated motor module and park lock system.



Features/Specifications

- Integrated motor/gearbox with off-set layout for low hood line
- 2 Stage Helical Gearing for compact gearbox
  - Ratio 10.23 : 1
  - Mass - 37kg
- IPM Motor
  - Power/Torque
    - 105kW/282Nm Peak – 30sec
    - 45kW/ 150Nm Continuous
  - Speed
    - 10,000 rpm Max. Operating speed
    - 8,800 rpm speed under load
- Liquid-Cooled 8l/min. 70ºC inlet
- Direct Cable Park lock actuation with position feedback

Key Benefits

Green Technologies
Process Efficiency
Vehicle Performance
Fuel Efficiency

Contact

Name: Zhao Zilai
Phone: (248) 265-4461
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Accomplishment: Stand Alone Inverter

MAGNA ELECTRONICS

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

Fuel Efficiency

Process Efficiency

Contact

Name: Zhao Zilai
Phone: (248) 265-4461
Email: zilai.zhao@magna.com

Accomplishment: Vehicle Control Unit (VCU)

MAGNA ELECTRONICS

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

Safety

Fuel Efficiency

Process Efficiency

Contact

Name: James Kane
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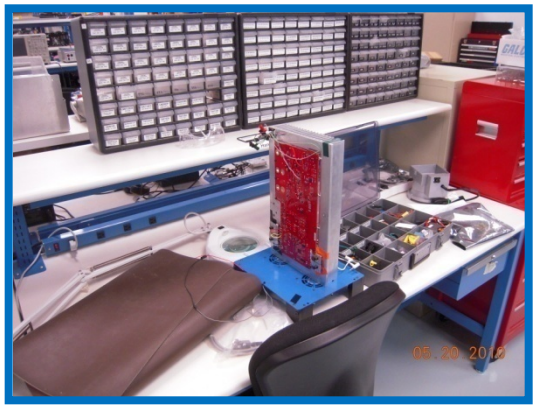
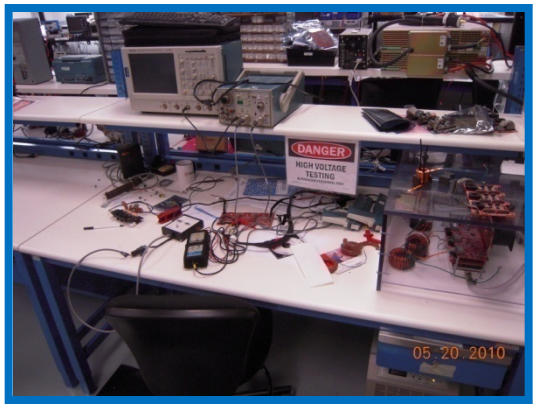
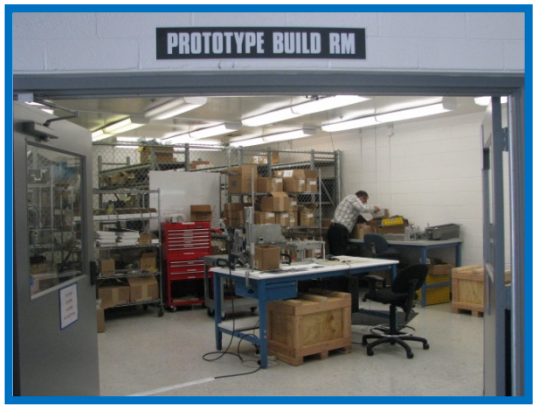
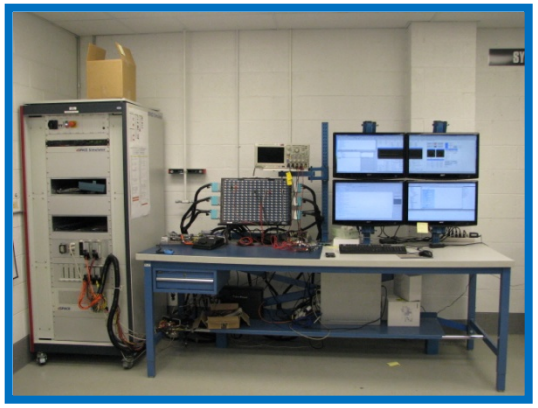
Progress: Power Electronics Lab Upgrades



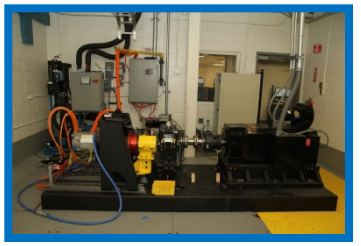


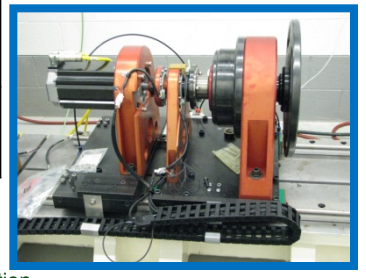




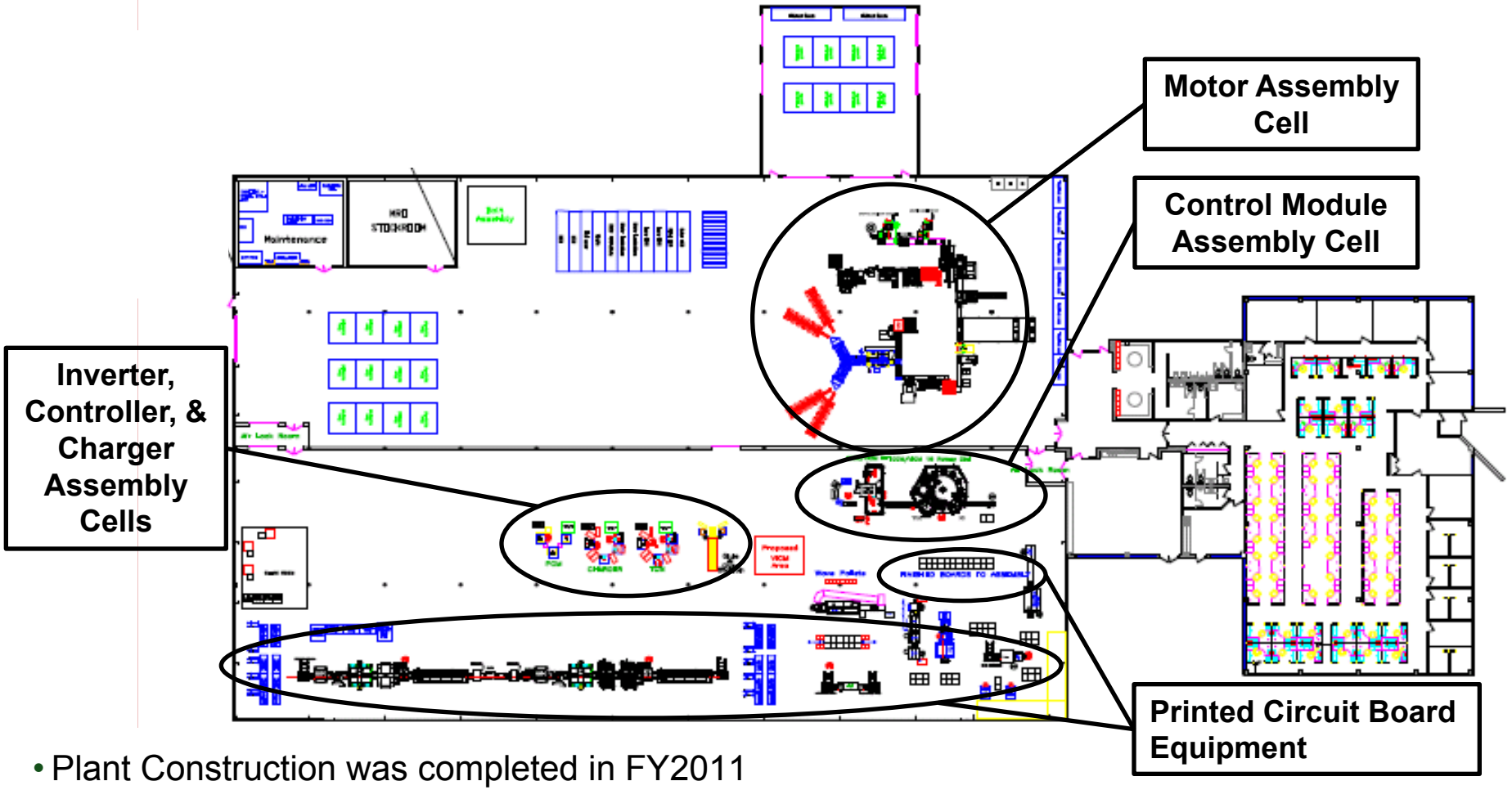
Progress: Dynamometer Upgrades
Motors and Controls Testing

Test Cell	Test Properties		Status of Test Properties
1	Dyno_300	224 kW	Cell upgrade to 100kW Dyno Operational for functional testing. Used for Motor Controls Development & Verification
2	Dyno_300	224 kW	Cell upgrade to 100kW Dyno Operational for functional testing. Used for Motor Controls Development & Verification.
3	Dyno_350A	350 kW	Cell upgrade to 350kW Dyno Used for high power Motor Controls Development and Verification.
4	Dyno_350B	350 kW	Cell upgrade to 350kW Dyno Used for high power Motor Controls Development and Verification.
5	Dyno_5	N/A	High Speed Characterization Dyno



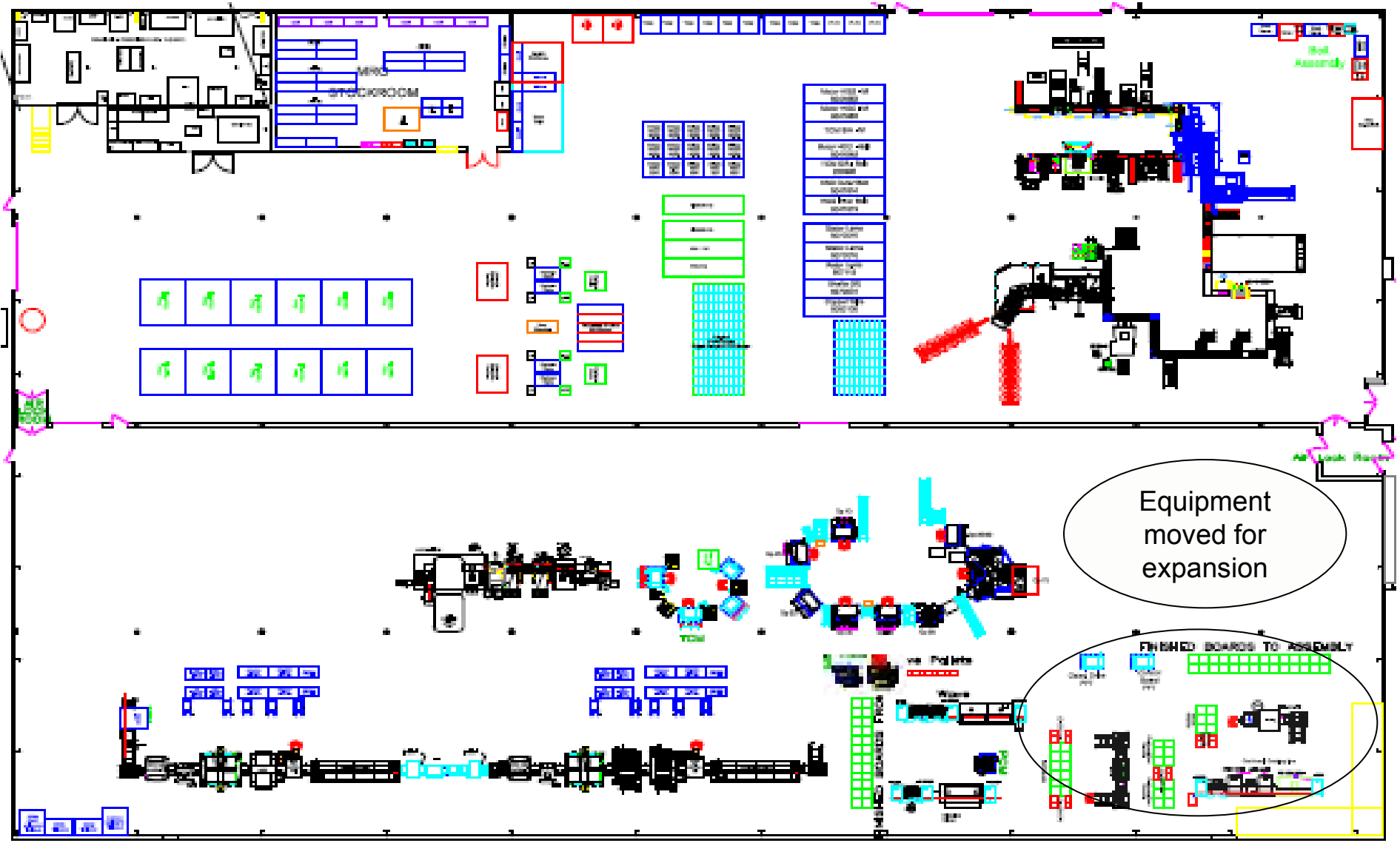


Progress: Grand Blanc, Michigan
Manufacturing Layout (GBEV)



- Plant Construction was completed in FY2011
- Process Validation (PV) Build completed FY2012
- Tooling Trials (TT) Completed FY2012
- Production Launched - Currently in Mass Production

2012 Production Flow Improvements



straight line process flow instituted for efficient product flow