U.S. Based HEV and PHEV Transaxle Program

HF35

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May 14th, 2013

Project ID: ARRAVT024

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Overview

Timeline

Start: October 1, 2009
Finish: August 31, 2013

Risks and Barriers

Functional
Financial
Marketing
Purchasing

Budget

Total Project Funding
DOE: $62.5M
Ford: $62.5M
Funding received in FY10 = $8.6M
Funding received in FY11 = $28.7M
Funding received in FY12 = $15.4M
Funding received in FY13 = $3.0M

Partners

No official partners identified in grant

Relevance – HEV and PHEV Applications

Hybrid Electric Vehicle (HEV)

- Combines an internal combustion engine with an electric motor and battery
- Electric power is used for vehicle launch and lower-speed operation
- Internal combustion engine takes over for higher demand operation and charges the battery

Plug-in Hybrid Electric Vehicle (PHEV)

- Combines HEV technology with a high-voltage storage battery like that used in a Battery Electric Vehicle (BEV)
- Ford's PHEV is a blended PHEV – optimally first using the battery charge and then operating in regular hybrid mode
- Offers consumers the best possible fuel economy, smallest battery and most affordable solution.

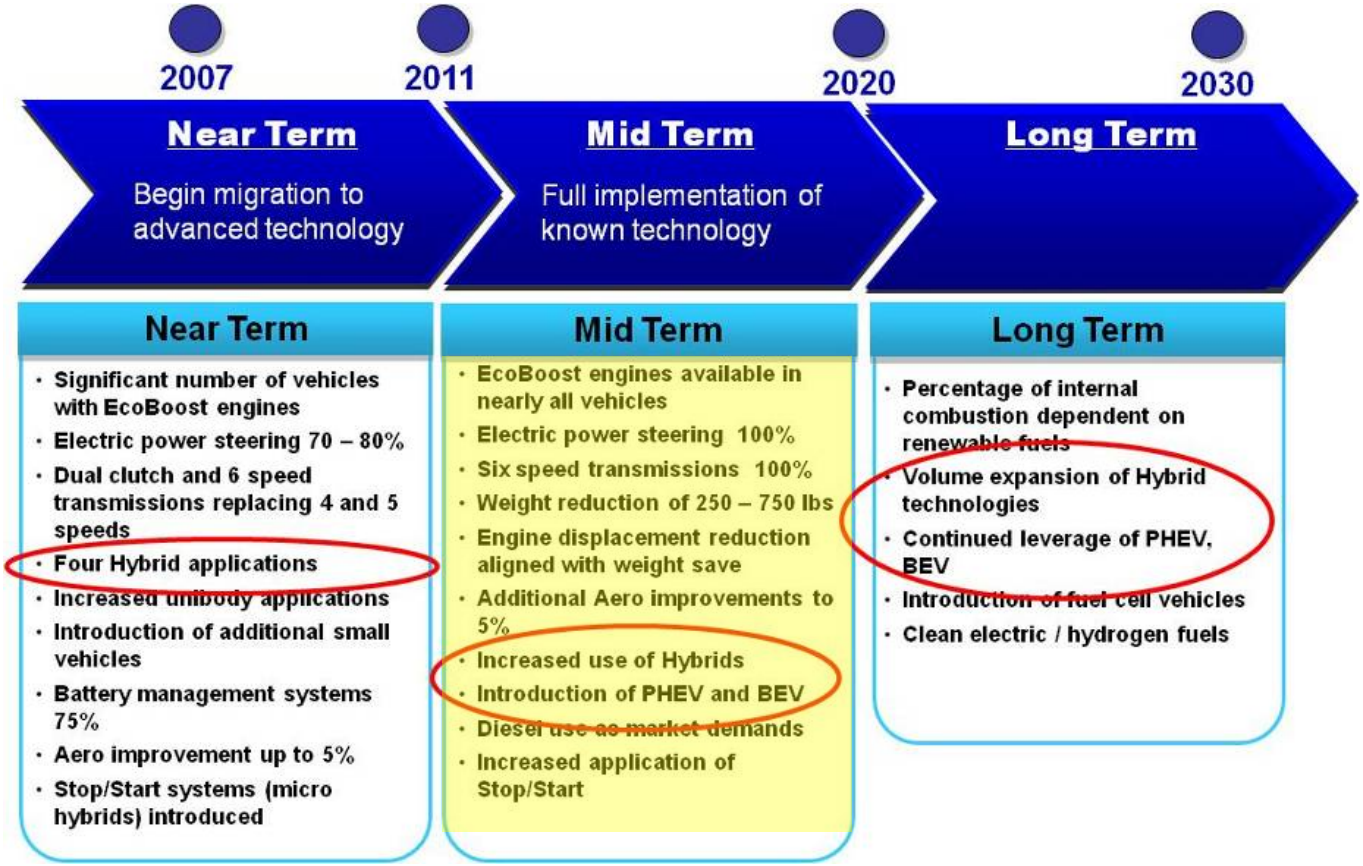
Relevance – Fuel Economy Leadership

CMax and Fusion: HEV = 47/47/47mpg; PHEV = 108/92/100mpe

MKZ HEV = 45/45/45 mpg

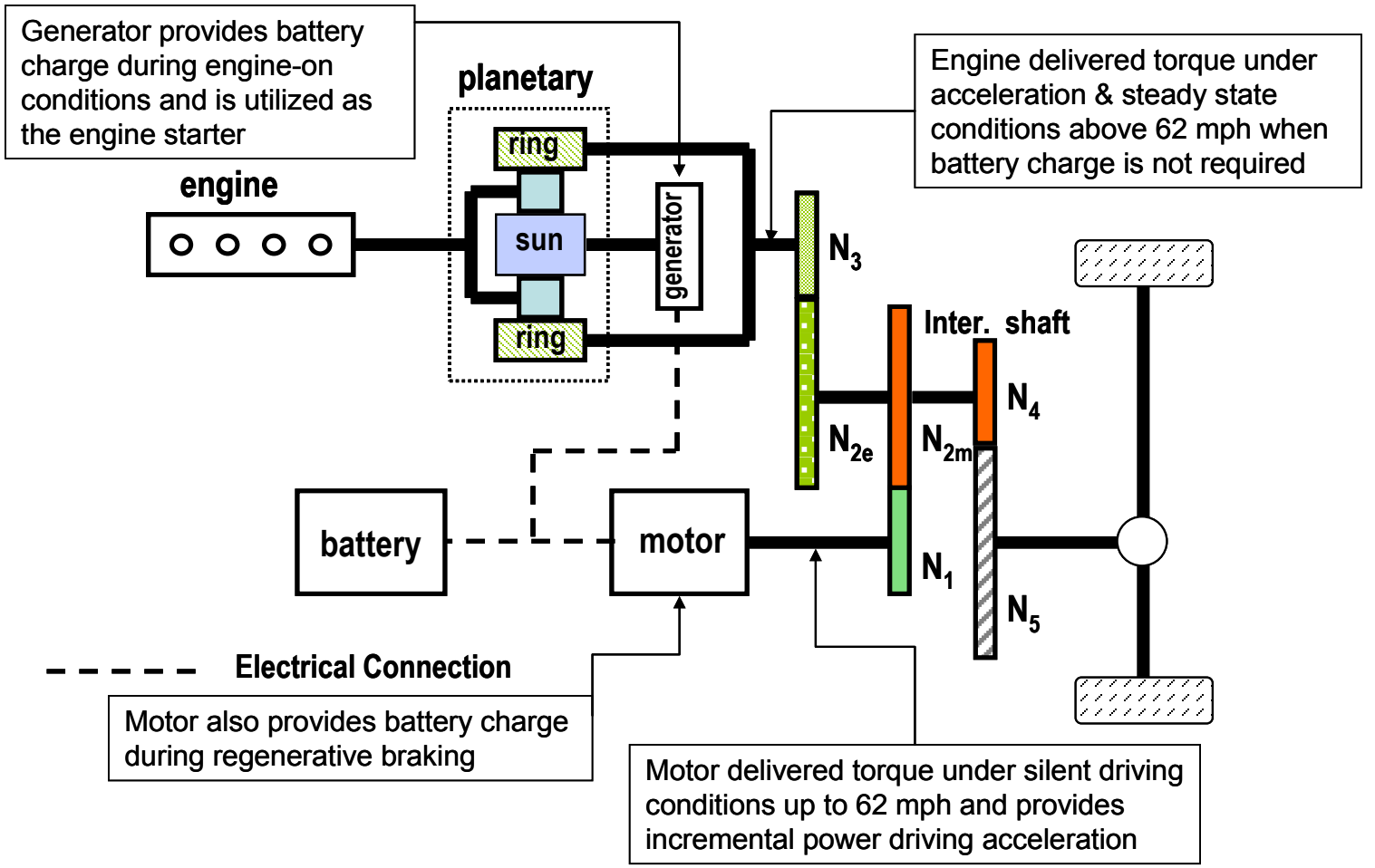
The HF35 is a key contributor to Ford's Fuel Economy Leadership going forward

Relevance – Electrification Strategy



Ford Motor Company is committed to bringing hybrid and plug-in hybrid vehicles to market quickly and affordably. With the HF35 transaxle now in production, we are squarely in the "Mid Term" portion of our strategy.

Approach – Powersplit Architecture

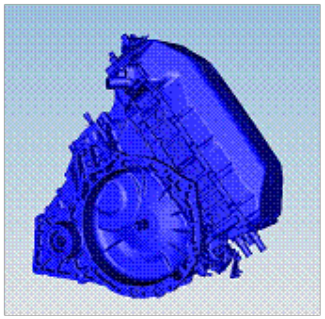


The HF35 Strategy takes advantage of a known, robust transaxle design

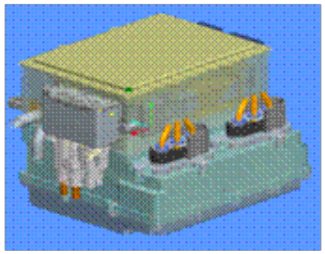
Approach – Architecture Evolution

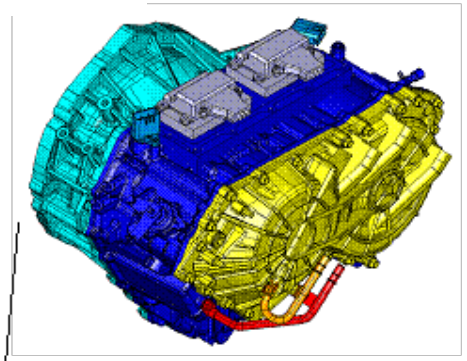
	2004 – 2011 Gen I	2008 – 2012 Gen II	2012+ HF35
Engine	2.3 L / 2.5 L Atkinson	2.5 L Atkinson	2.0 L Atkinson
Transmission	• AW PowerSplit Trans	• AW PowerSplit Trans	• HF35 Transmission
	• AW Controls	• AW Controls	• Ford Controls & Calibration
	• Integrated Power Electronics	• Integrated Power Electronics with Variable Voltage Control	• Remote Power Electronics with Variable Voltage Control
Battery	• 250 Cell NiMH	• 208 Cell NiMH	• Li Ion

Gen I & Gen II



HF35

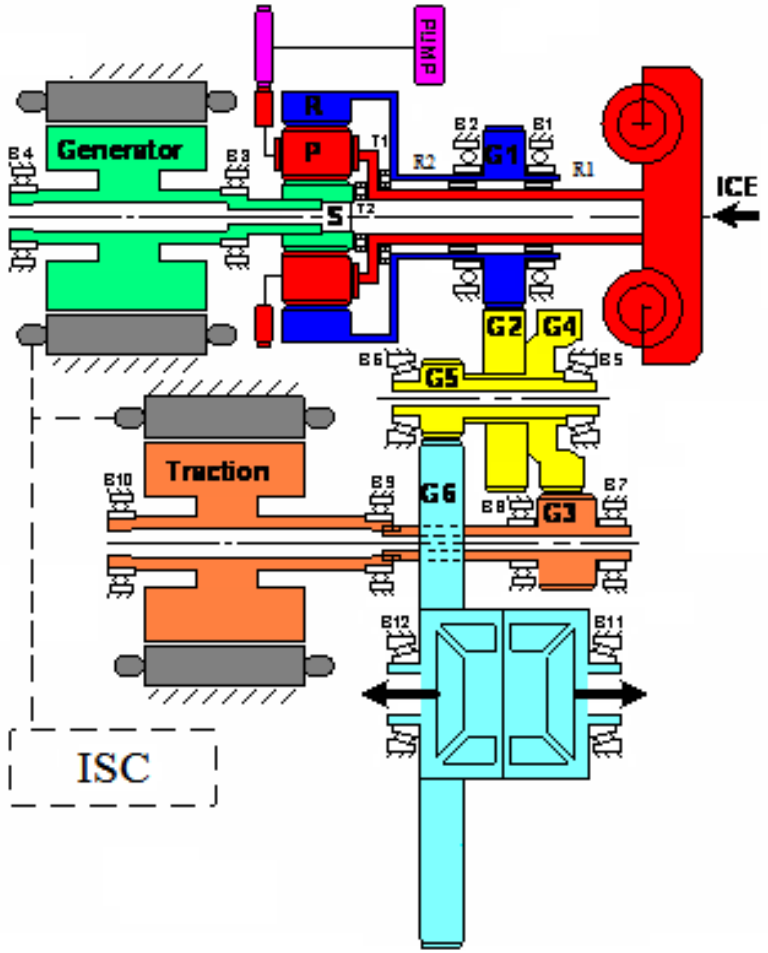




Separate power electronics from trans hardware & motors

The HF35 is Ford's third generation Powersplit transaxle, and the 1st internally manufactured – taking advantage of evolutionary design of a robust product

Approach – HF35 Architecture



HF35 Major Components

- Motor/Generator Set
- Planetary Gearset
- Transfer Gears
- Final Drive Differential
- Shafts
- Bearings
- Pump/Filter
- Flywheel/Damper Assy

Components not shown

- Park System
- Electrical wiring/sensors
- Case and Bell Housing

134 New Parts
43 Carryover parts

The cost of the HF35 is mitigated with the utilization of components common with other Ford transaxle products.

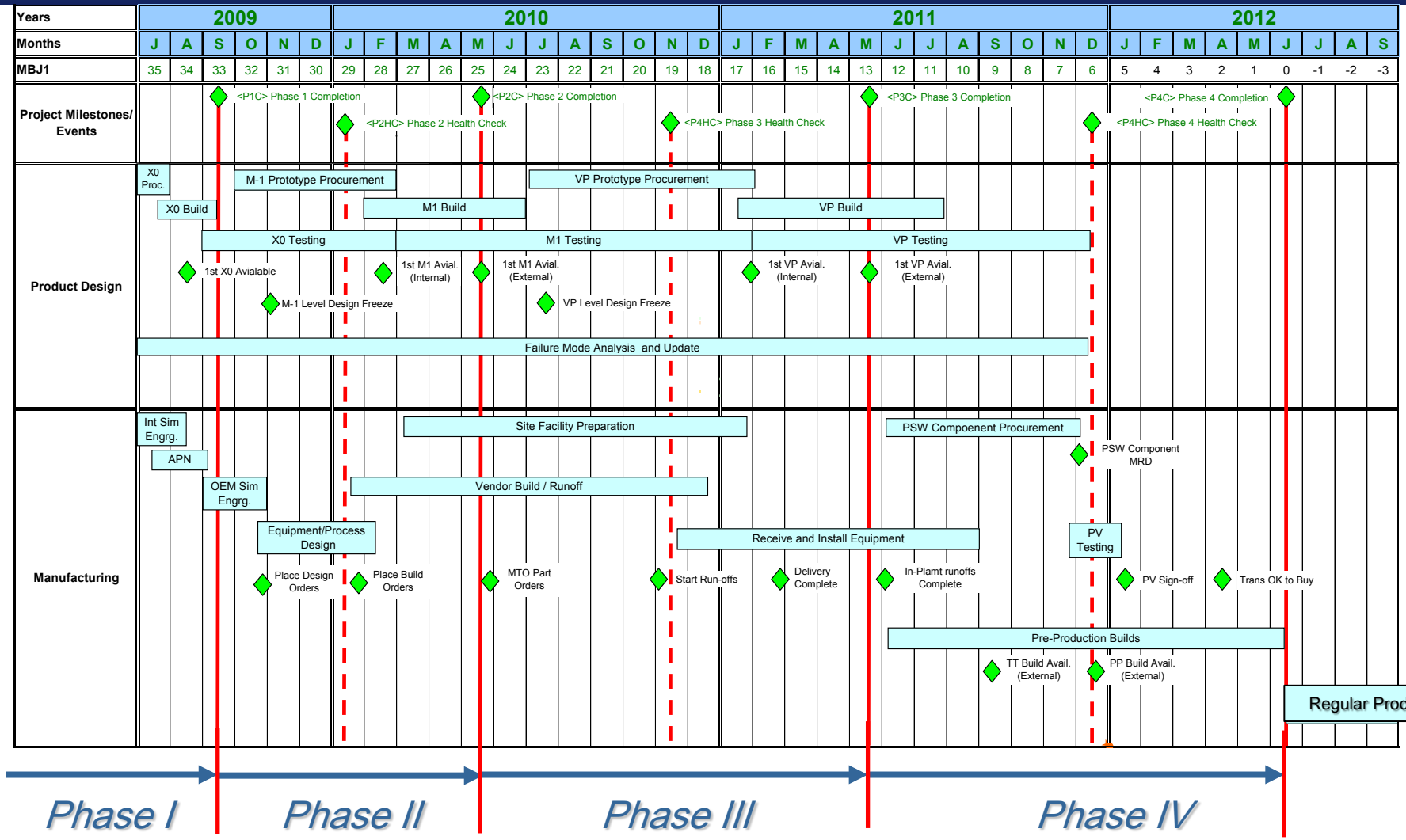
Approach – Flexible Assembly

Test Loop

Assembly Loop

Ford's 1st flexible transaxle assembly process for gas and hybrid models enables nimble response to customer demand fluctuations

Approach – Phased Project Plan



The project is now fully executed and in production. We are automating some content in the original project in calendar year 2013 to increase capacity of the assembly system.

Milestones Completed in Phase I (Period ending September 2009):

- ✓ **<Unit PTC> Program Target Compatibility GPDS Milestone – September 2009 (Go / No Go Decision Point)**
- ✓ Long Lead Funding Approved – September 2009
- ✓ Component Sourcing Agreements Signed – September 2009
- ✓ First Phase I (X0) Transaxle Available – September 2009

✓ = Completed

The objective of Phase I was to finalize the initial design and deliver the first functional prototype transaxle for testing.

Milestones Occurring in Phase II (Period ending May 2010):

- ✓ Phase II (M1) Level Design Freeze – October 2009
- ✓ Production Equipment Design Orders Initiated – October 2009
- ✓ **<Unit PA> Program Approval GPDS Milestone – February 2010 (Go / No Go Decision Point)**
- ✓ Component Commercial Pricing Agreements Signed – February 2010
- ✓ First Phase II (M1) Transaxle Available (Internal) – February 2010
- ✓ Production Equipment Build Orders Initiated – February 2010
- ✓ First Phase II (M1) Transaxle Available (External shipped to build site) – May 2010

✓ = Completed

The objective of Phase II was to refine the Phase I design and address any failure modes found during Phase I testing.

Milestones Occurring in Phase III (Period ending May 2011):

- ✓ Machine Tryout Parts Ordered – June 2010
- ✓ Phase III (VP) Level Design Freeze – July 2010
- ✓ Production Equipment Run-off's Initiated – November 2010
- ✓ **<FDJ> Final Data Judgment GPDS Milestone – December 2010 (Go / No Go Decision Point)**
- ✓ First Phase III (VP) Transaxle Available (Internal) – January 2011
- ✓ First Phase III (VP) Transaxle Available (External) – May 2011

✓ = Completed

The objective of Phase III was to finalize design refinements and build confirmation prototypes in preparation for regular production.

Approach – Phased Project Plan

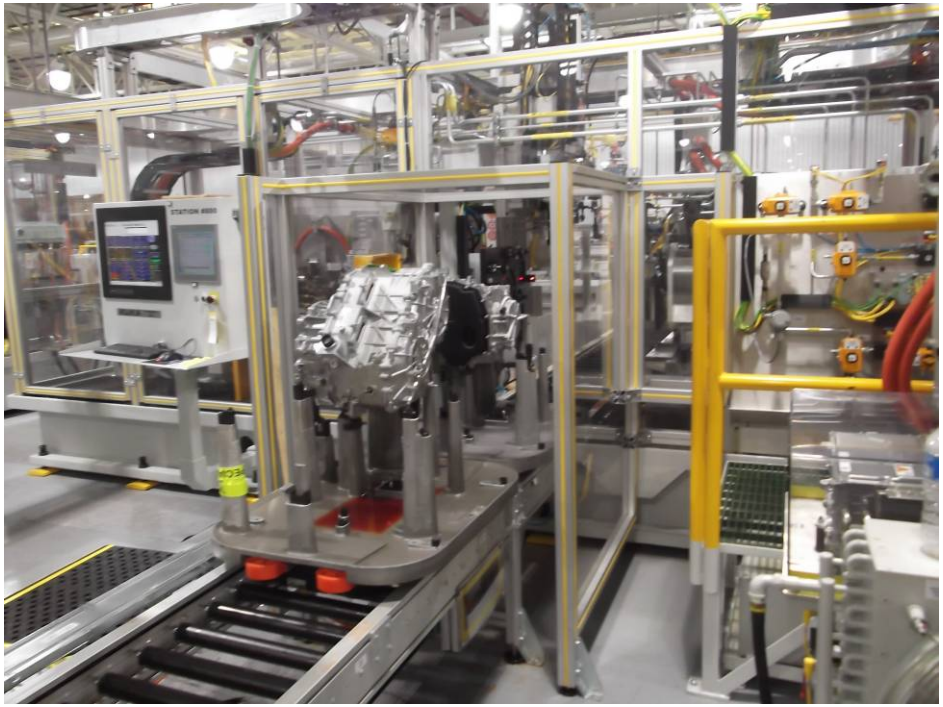
Milestones Occurring in Phase IV (Period ending June 2012):

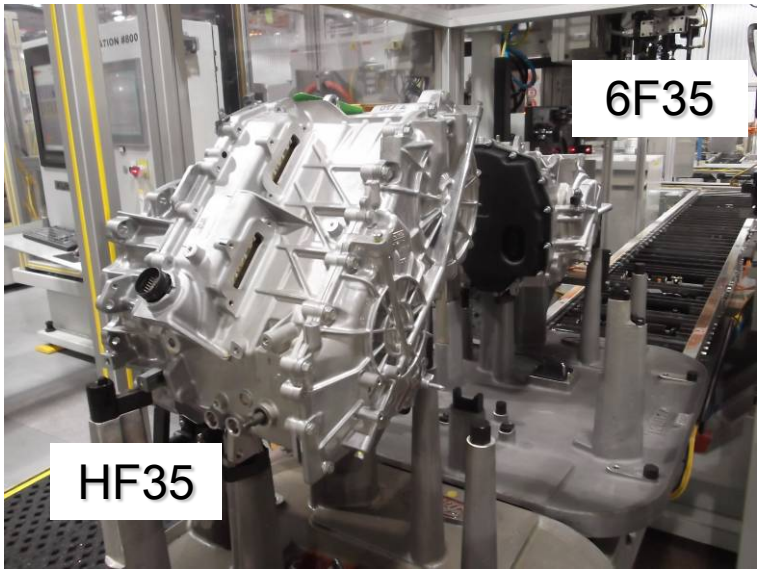
- ✓ Production Equipment Delivery Completed – July 2011
- ✓ Production Equipment In-Plant Runoffs Completed – September 2011
- ✓ 1st Production HF35 Build at Transaxle Assembly Plant – October 2011
- ✓ **<FEC> Final Engineering Confirmation GPDS Milestone – December 2011 (Go / No Go Decision Point)**
- ✓ HF35 Production Validation (PV) Testing Sign-off – January 2012
- ✓ 1st Production HF35 Build at Vehicle Assembly Plant – January 2012
- ✓ Transaxle OK-to-Buy – April 2012
- ✓ **<MP1> Mass Production 1 GPDS Milestone – June 2012**

✓ = Completed

The objective of Phase IV was to deliver production level transaxles to the vehicle assembly plant and complete product launch.

HF35 Testing on Production Test Equipment



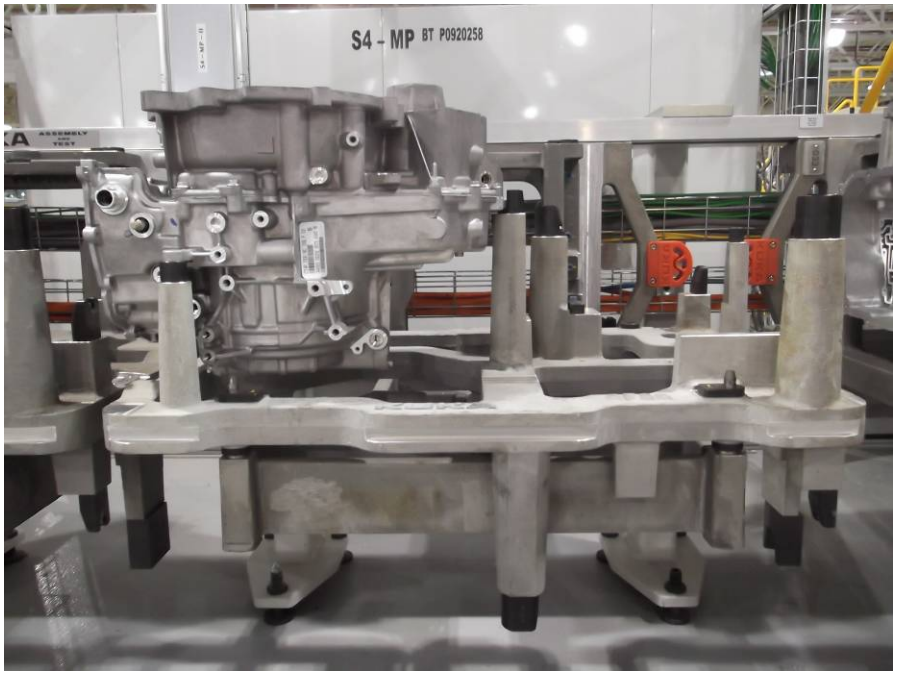


Same view => Zoom in

This picture shows our new HF35 hybrid transmission (near) trailing our existing 6F35 gas transmission into our flexible final test stand in production. True “batch of one” process capability!

Flexible Assembly System – Conveyor Selection and Pallet Design

Main Line Vertical Conveyor



6F35 Product on Flex Pallet

The conveyor system selected provides access to (3) sides of the product during assembly as well as future flexibility for changeover and / or expansion

The pallet design is flexible for both gas and hybrid versions of Ford's FWD transaxles

Rotor Magnetization

Rotors queued up for processing

Rotors entering bearing press after magnetization

The Traction and Generator Rotors are carryover design, magnetized internally at Ford for the 1st time during the assembly process.

Future Work – 2013

The project has been fully executed per the original plan.

To support customer demand, some incremental actions are planned and will be executed through 3Q 2013.

These actions include:

- Provide additional equipment to increase capacity and process robustness of the Offline 10 “Transmission Case Prep Sub-assembly Line”
- Full automation of Main Line Stator Install stations
- Automation of Main Line unload and Test Line packout stations
- Full automation of Test Line Rotor Install stations

Collaborations / Partnerships

No partners were officially identified for the DOE grant awarded to Ford

The ultimate success of the project is a reflection of new and existing relationships that were furthered as a result of this project. These include but are not limited to:

Production Component Suppliers

- Toshiba, Weber Automotive, Auma-Bocar, Systrand, Yazaki NA, …

Machine Tool Suppliers

- Kuka AT, Magnetic Instrumentation, Cinetic, WMA Inc., …

Community

- United Auto Workers
- State of Michigan
- City of Sterling Heights, Michigan

Summary

- The HF35 project facilitates the launch and commercialization of hybrid electric vehicles via U.S. design and production of a world-class HEV/PHEV transaxle system
- Our approach leveraged robust design evolution, common components, and a flexible assembly system at a world class Ford manufacturing facility.
- We have accomplished or exceeded all objectives for the entire scope of the project
    - Lessons learned through prototype testing and simultaneous engineering were applied to the design leading into Phase IV and ultimately the production launch of the product
- The HF35 transmission is now in FULL PRODUCTION!!
- We are well positioned to complete the remaining scope of the project through 3Q 2013
- We are confident the remaining activities to be executed will enhance the already successful launch of the HF35 product