LINAMAR

Power to Perform

McLAREN Engineering

ELT-191
Medium Duty Vehicle Powertrain Electrification and Demonstration

DoE VTP Annual Merit Review

PI - Mr. Wiley McCoy

McLaren Engineering

20 June 2018

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

McLAREN Engineering

Medium Duty Vehicle Powertrain Electrification and Demonstration - Overview

DOE Project EE0007513

- Wiley McCoy, Principal Investigator
  Wiley.mccoy@linamar.com

- Matt Ries, Project Administrator
  matt.ries@linamar.com

- McLaren Engineering div of Linamar
  32233 West Eight Mile Rd.
  Livonia, Michigan 48152

Medium Duty Vehicle Powertrain Electrification and Demonstration - Overview

DOE Project EE0007513

Timeline

Project start date – June '16
Project end date – Aug '19
Percent complete – 70 %

Budget

Total project funding	**$ 3.65M**
DOE share	**$ 2.64M**
Contractor share	**$ 1.01M**
Fed Funds spent	**$ 2.152M**
Funding Remaining	**$ 0.494M**

BP1 Ends Apr 30, 2018

Barriers

Addressing technical barriers from VT Program Multi-Year Program Plan

Acceptance of electric drive as Medium Duty vehicle choice.

Reduce the carbon footprint of transportation (FE Improvement)

Cost of hybridization (medium duty TCO)

Partners /Collaborators

AVL - Technical Partner
UPS – Demo Partner
Ford Commercial Chassis
Dana

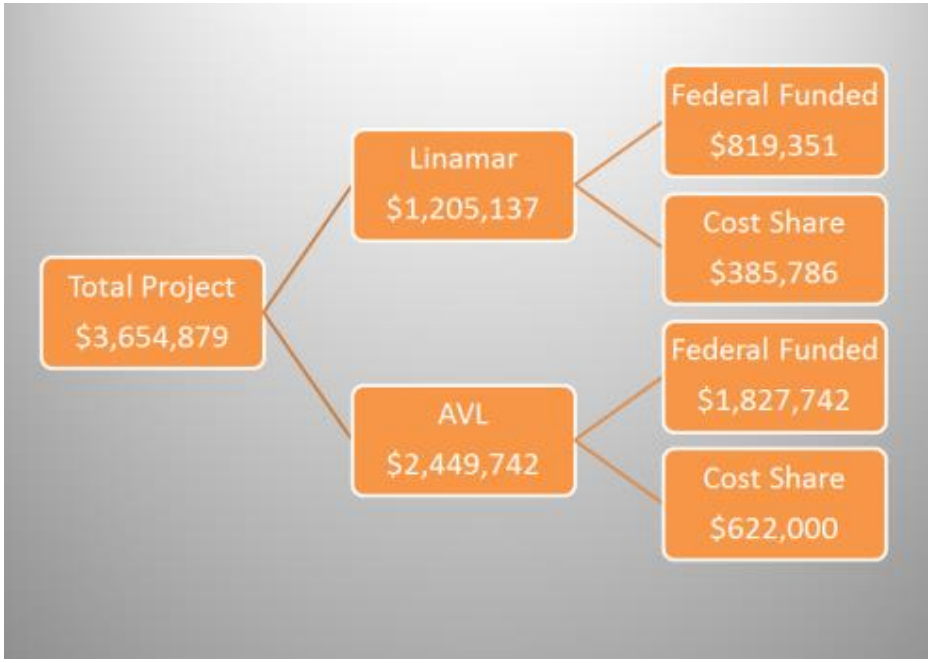
Medium Duty Vehicle Powertrain Electrification and Demonstration - Overview

DOE Project EE0007513

Timing and Budget

- **Total Project Timing is now 39 months**

- **Project is divided into three (3) phases spanning two (2) budget periods.**
  - **Phases 1 & 2 are in BP 1 (23 Months) ends April ‘18**
  - **Phase 3 is in BP 2. (16 Months) ends Aug ‘19**



Medium Duty Vehicle Powertrain Electrification and Demonstration - Overview

LINAMAR
Power to Perform

DOE Project EE0007513

Project Overview:

- **Project Objective / Expected Outcome - to attain a 100% improvement in Fuel Economy over real world drive cycles for medium duty package delivery vehicles & achieve a system at project conclusion that can be commercialized.**

- **Project Approach - Team will design and develop a plug-in hybrid powertrain, build 4 demonstration vehicles and run a demonstration of performance, cost and reliability for a period of 12 Months.**

1966 50 2016

McLAREN Engineering

Medium Duty Vehicle Powertrain Electrification and Demonstration – Project Team Resources

DOE Project EE0007513

Overview - Project Team: (Responsibilities & Resources)

- McLaren Engineering / Linamar – PI, E Axle System engineering, build and development. Prime commercialization agent to OE and Retrofit Markets
- AVL – Plug-in hybrid system, simulation, design, development and vehicle integration; Test program data collection and analysis.
- Ford – OEM for New e-Chassis, Range Extender powertrain support
- UPS – Demonstration Partner
- Dana – Key Supplier for Axle Components

Medium Duty Vehicle Powertrain Electrification and Demonstration – Project Phase 1 Complete

LINAMAR
Power to Perform

DOE Project EE0007513

- **Phase 1 – Power Train Development – Major Tasks**
  - Confirm Vehicle Requirements
  - System Analysis, Drive Cycle Modeling, Fuel Economy Simulation ***"Build The System In The Virtual World"***
  - Preliminary Design Package; All System Concepts Complete
  - CORE Reviews and Revisions
  - Vehicle Test Plan Established
- **Key Milestones were Completed on Sept 29, 2016**
- **Phase 1 – Achieved Outcomes**
  - UPS contributed Vehicle Requirements that were integrated into the concept design
  - Analysis and Modeling showed system achieving 100% FE Improvement
  - E-Axle, Range Extender & Battery Design Concepts Completed,
  - Plan for Vehicle Demonstration established with UPS
- **Formal Gate Review was conducted Oct 2016**
- **Approved to proceed to Phase II**

1966 50 2016

McLAREN Engineering

Medium Duty Vehicle Powertrain Electrification and Demonstration – Project Phase 2 Complete Apr '18

LINAMAR
Power to Perform

DOE Project EE0007513

- **Phase 2 – Power Train Design and Build – Major Tasks**
  - Design, Analysis and release of all systems' components
  - Source and procure all systems' components
  - Build, fitting and commissioning of initial full vehicle
  - Commissioning and calibration of full vehicle
  - Confirmation of 100% FE improvement as predicted.
- **Key Milestone to be Completed on April 30, 2018**

- **Phase 2 – Expected Outcomes**
  - Systems to be built, pre-tested and assembled into Vehicle 1.
  - Initial Testing shows system achieving 100% FE Improvement
  - E-Axle, Range Extender & Battery build to be completed,
  - Plan for Vehicle Demonstration finalized with UPS
- **Formal Gate Review to be conducted May 2018**
- **Approval requested to proceed to Phase III & BP2**

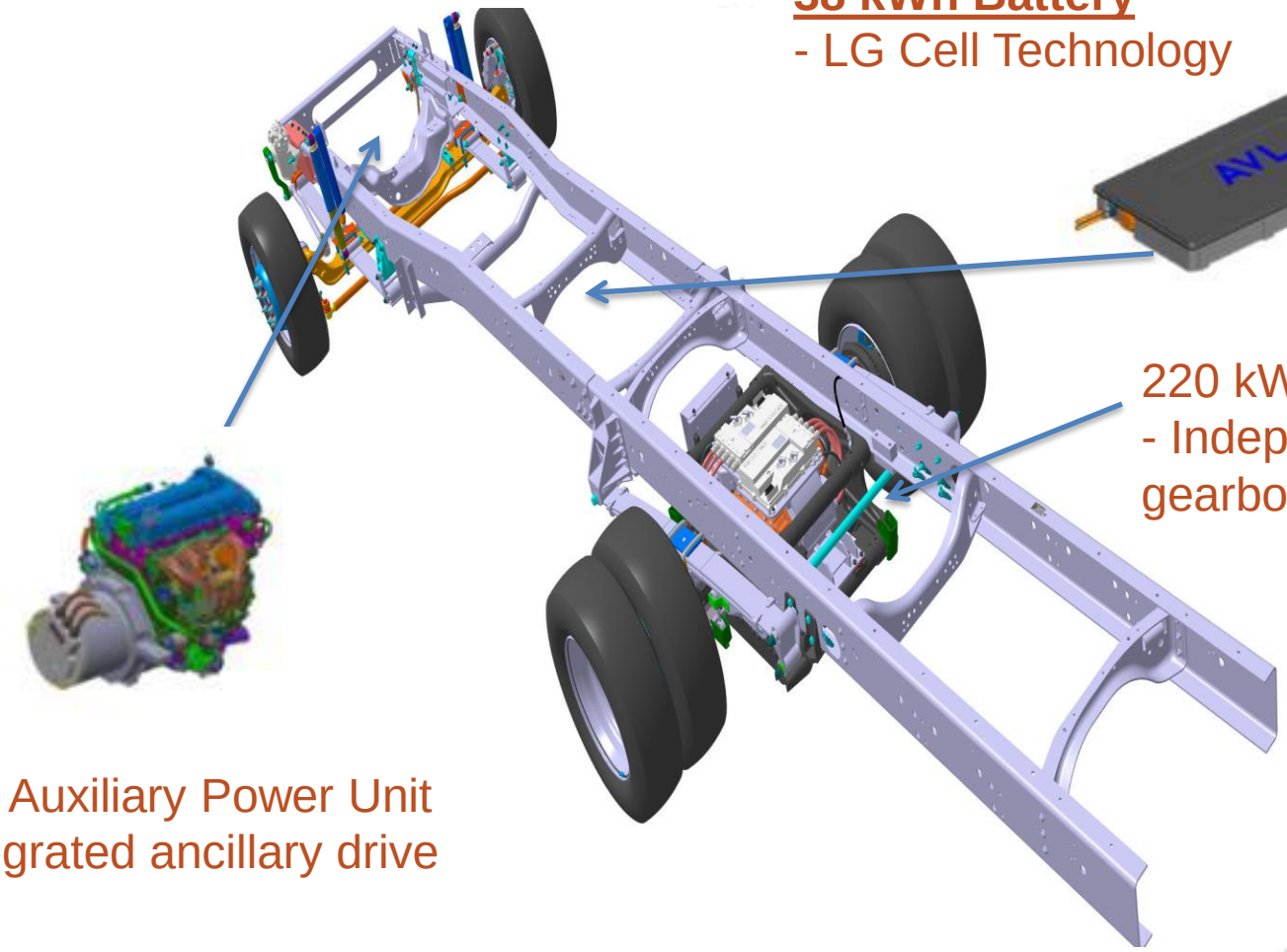
1966 50 2016

McLAREN Engineering

Medium Duty Vehicle Powertrain Electrification and Demonstration – Phase 2 Build Ford Chassis

DOE Project EE0007513

38 kWh Battery
- LG Cell Technology



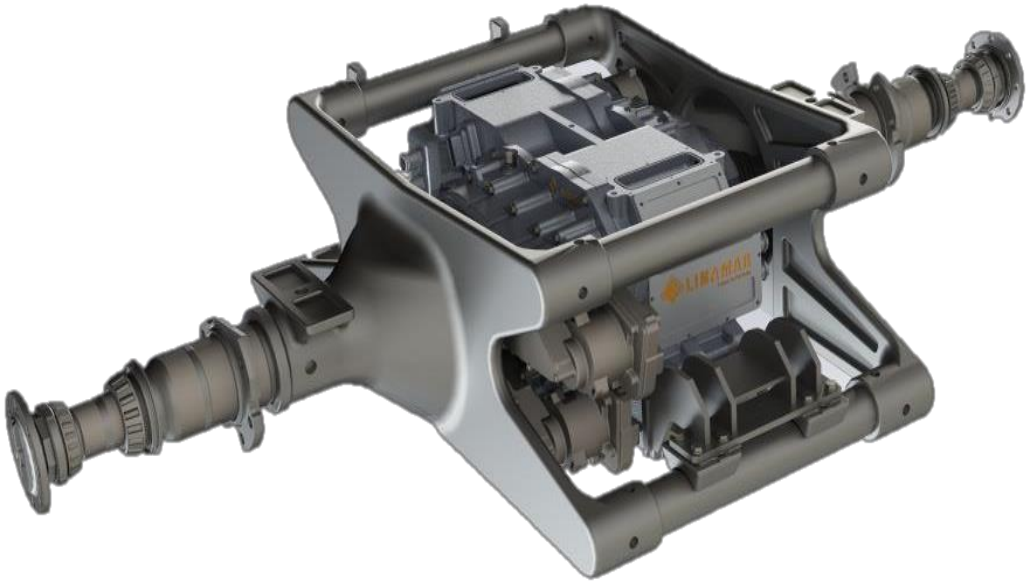
220 kW eAxle Module
- Independent 2-speed gearboxes

50 kW Auxiliary Power Unit
- Integrated ancillary drive

Class 6 Commercial Truck Dual Motor eAxle w/Gearbox

U.S. DEPARTMENT OF ENERGY

Medium Duty Plug-In Hybrid Electric Vehicle Utilizing an Electrified Axle



Features

- eAxle Assembly for Class 6 Truck
- 1 year Fleet Study in 2018
- Dual Independent motors
- 2-Speed Synchronized Gearbox
- Integrated Park Lock

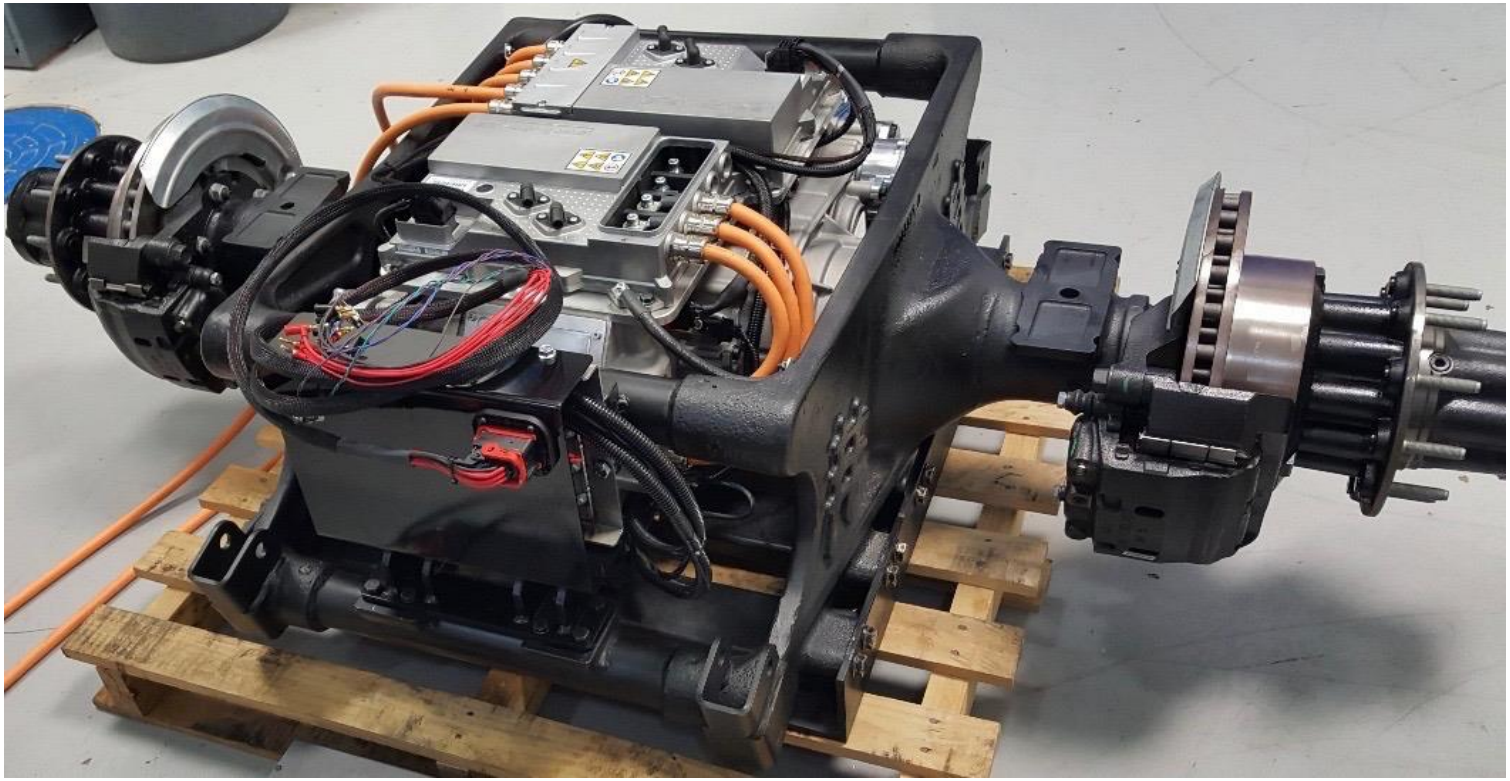
System Specifications

Total Rated Input Torque	664 Nm
Rated Input Speed	10,600 RPM
Max Output Torque	11,900 Nm
Max Output Speed	1,200 RPM
Transmission Layout	Parallel Axis
Parklock	Yes
Disconnect	Neutral Shift Position
Lubrication	Electric Forced Lube
Package Space	825x700x420 mm
# of Forward Ratios	2
1st Gear Ratio	17.9
2nd Gear Ratio	8.8
Peak Power	276 kW
Output Shafts	Splined Axle Shafts

McLAREN Engineering

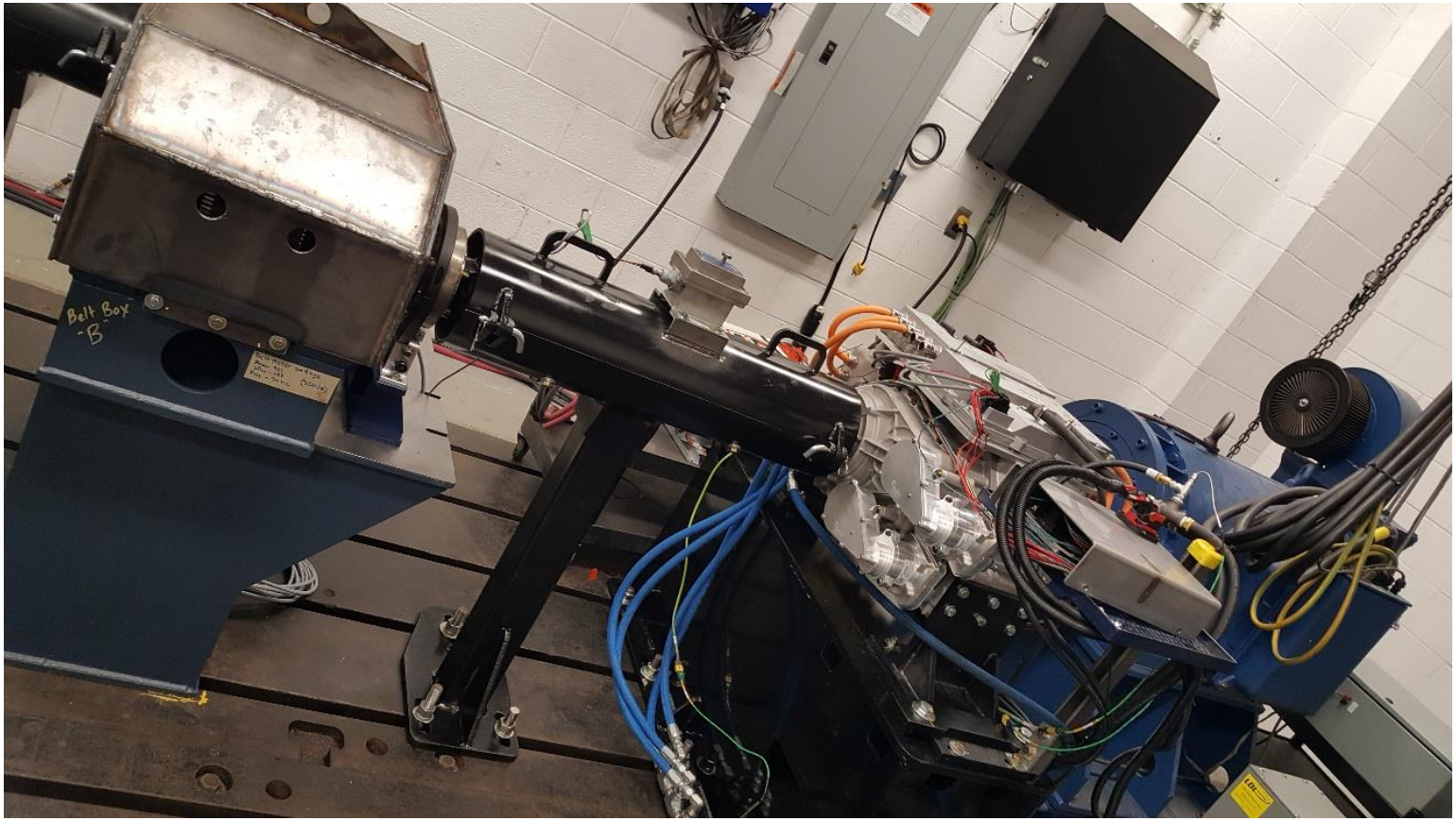
Class 6 Dual Motor eAxle for Test on AVL Dyno

Medium Duty Plug-In Hybrid Electric Vehicle Utilizing an Electrified Axle



Class 6 Dual Motor eAxle on Test on AVL Dyno

Medium Duty Plug-In Hybrid Electric Vehicle Utilizing an Electrified Axle



U.S. DEPARTMENT OF ENERGY

Medium Duty Vehicle Powertrain Electrification and Demonstration – Phase 2 Technical Challenges

LINAMAR
Power to Perform

DOE Project EE0007513

No New Technical Challenges arose in Ph 2 for the final Design Release & Build. The time to solve some of them was greater than anticipated.

- **Technical Challenges - eAxle: (critical Path)**
  - **Structural issues of the Linamar eAxle in a beam axle architecture**
  - **Vehicle Park Lock System Integrity**
- **Technical Challenges - Controls**
  - **Synchronization of shift between the left and right drive units**
  - **System drivability while achieving > 100% FE improvements**
- **Technical Challenges - High Voltage**
  - **Battery packaging in modular format to accommodate UPS needs and other typical commercial vehicle applications**
- **Technical Challenges – Range Extender**
  - **Engine-off Front End Accessory Drive (FEAD)**
  - **Alternative Fuel was deleted at Ford Request.**
- **Technical Challenges - System Integration**
  - **Interaction between foundation & re-gen braking**

1966 50 2016

McLAREN Engineering

Medium Duty Vehicle Powertrain Electrification and Demonstration – Phase 2 – To Be Complete Apr '18

LINAMAR
Power to Perform

DOE Project EE0007513

- Phase 2 – ***Power Train Integration into Vehicle – In Progress scheduled April 2018***
  - Module Design, Release, Sourcing & 1st Vehicle Build
  - Material Procurement - E-Axle, Battery Pack, Range Extender & Auxiliary Systems
  - Module Build and Test
  - Vehicle Controls Development
  - 1st Vehicle Build and Test, Veh 2-4 assembly in process
  - Controls Testing and Calibration
  - Project Manufacturing Plan – 1st Level
- Phase 2 – ***Expected Outcome***
  - Vehicle Achieves 100% Fuel Economy Improvement on 'Real World' drive cycle. (HIL)

1966 50 2016

McLAREN Engineering

VEHICLE 1 FE Test
AVL Performance Summary
(to be reported verbally)

Medium Duty Vehicle Powertrain Electrification and Demonstration DOE Project EE0007513

Medium Duty Vehicle Powertrain Electrification and Demonstration – Phase 3 - Future Work Tasks

LINAMAR
Power to Perform

DOE Project EE0007513 Any proposed future work is subject to change based on funding levels

- **Phase 3 – *Vehicle Build Test and Demonstration – Starts May '18***
  - **2nd – 4th Vehicle Builds Completed**
  - **UPS Demonstration Site Preparation**
  - **Demonstration conducted – 1 year duration**
  - **Data Collection and Analysis – All Sub-Systems**
  - **Linamar Manufacturing Plan to be completed**
- **Phase 3 – *Expected Outcomes***
  - **4 Vehicle Test Fleet meets UPS OP Requirements**
  - **Vehicle Fleet Achieves 100% FE Improvement in 'Real World'**
  - **Commercialization Plan Finalized**

1966 50 2016

McLAREN Engineering

Medium Duty Vehicle Powertrain Electrification and Demonstration – Phase 3 Future Work

DOE Project EE0007513 Any proposed future work is subject to change based on funding levels

- **Demonstration Location – UPS Depot, Chula Vista, CA. (near San Diego)**
- **UPS plans to use 4 trial units on normal delivery runs**
- **Data collection system will verify performance**

Medium Duty Vehicle Powertrain Electrification and Demonstration – Commercialization

DOE Project EE0007513 Any proposed future work is subject to change based on funding levels

- **Commercialization Strategy**
  - **Commercialization targeted at fleet partner usage**
  - **Volumes will be based on TCO benefits to users after product costing is completed.**
  - **Collaborations with:**

    Ford chassis builder through the fleet partner
  - **Linamar will leverage its $6+ billion components & systems manufacturing business to commercialize medium / heavy duty electric drive systems.**
  - **Linamar can build OEM systems in its low volume assembly facility in Livonia, MI.**

Medium Duty Vehicle Powertrain Electrification and Demonstration Summary Slide

LINAMAR
Power to Perform

DOE Project EE0007513

- **Summary**
  - **Phase 2 was successfully completed but timing was extended by 7 months.**
  - **100% Fuel Economy Improvement to be demonstrated on Vehicle 1 as originally planned.**
  - **Phase 2 was extended due to design complexities and supply base delays. Demo partner is more concerned with "getting it right" than timing issues.**
  - **Any added costs are being borne by the project partners. No Fed funds increase requested.**
  - **Phase 3 will be a four vehicle fleet demonstration in the 'Real World'. TCO and commercialization plan will be developed.**

1966 50 2016

McLAREN Engineering

- **Prior Year Reviewer Comments**

- Most all comments were positive citing the team composition and the process as well as the use of UPS drive cycle data as a base for system definition. 'Design for the real world' was cited as a positive approach.

- One reviewer asked why the commercialization plan was not further advanced.

Ans. - In the Linamar system of product development, product costing is only prepared and finalized after a full design is released and has shown assembly feasibility. Originally we were to have that work completed for this review. However, since design and build timing was extended, this activity is started but is not yet complete. We have identified cost improvement areas to include in a final product.

- **QUESTIONS???**