DAIMLER DAIMLER TRUCKS NORTH AMERICA

DTNA EMG INNOVATION ECASCADIA 2.0

Development and Commercialization of Heavy-Duty Battery Electric Trucks Under Diverse Climate Conditions

2021 DOE Vehicle Technologies Office Annual Merit Review

Principal Investigator: Marcus Malinosky

Organization: Daimler Trucks North America LLC (DTNA)

Project ID: elt259

Date: 6/25/2021

In partnership with

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OVERVIEW

TIMELINE

- Project Start: October 2019
- Project End: December 2022
- ~ 70% complete

BUDGET

- Total Project Budget: ~ 10 Million
  - DOE Funding: ~ 4.6 Million
  - DTNA Cost Share: ~ 5.56 Million
- Budget Period 1: ~ 4.56 Million
  - DOE Funding: ~ 2.2 Million
  - DTNA Cost Share ~2.36 Million
- Budget Period 2
  - DOE Funding
  - DTNA Cost Share

PARTNERS

- United Parcel Service (UPS)
- Meijer
- South Coast Air Quality Management District (SCAQMD)

BARRIERS

- The all-electric, medium- and heavy-duty (MD/HD) truck market is limited to short-range application
- All-electric HD trucks are produced by small volume manufacturers with limited ability to scale production, provide after-sales support or engage with dealers

TECHNICAL TARGETS

- Develop and bring to market a fully commercialized, all-electric Class 7/8 day cab tractor
- Increase range capabilities to 250 miles per day and improve efficiency to achieve 2.0 kWh/mile through a redesigned 500-550 kWh battery back system and ultra-efficient integrated e-axles.
- Provide a life-cycle cost-effective and zero-emission freight movement solution for more than 70% of use cases

RELEVANCE

DTNA Freightliner eCascadia 2.0 undergoing component shaker testing

IMPACT

- This project advances state-of-the-art heavy-duty electric truck technologies to full commercialization and provides a platform for the market to reduce:
  - fleet operation, maintenance and energy costs
  - diesel consumption
  - carbon, nitrogen oxides (NO_x), particulate matter (PM) and emissions.

PROJECT OBJECTIVES:

- Develop and demonstrate a fully commercialized Class 7/8 electric tractor with sufficient range and durability to meet the needs of 70% of U.S. freight movement

- Improve performance over baseline prototype eCascadia:
  - increased range up to 250 miles
  - increased fuel efficiency of 2.0 kWh/mile
  - increased battery capacity up to 550 kWh
  - reduced curb weight down to ~ 20,000 lbs.
  - lighter battery packaging
  - enhanced motor design, software, telematics, weatherization, and diagnostic systems custom-designed for electric trucks.

MILESTONES

PHASE	DESCRIPTION	STATUS/COMPLETION DATE*
Phase 1a Research, Design, Building and Commissioning: Vehicle Design and Specification (Budget Period 1)	100% Finalization of Component Specifications	COMPLETE (July 2019)
	Feasibility Analysis of Series Development Confirmed *(Go/No-Go)*	COMPLETE (April 2020)
	Project Implementation Specifications Confirmed	COMPLETE (April 2020)
	Supplier Pre-Selection Confirmed	COMPLETE (June 2020)
	B-Sample Vehicle Specification Targets Achieved *(Go/No-Go)*	COMPLETE (September 2020)
Phase 1b Research, Design, Building and Commissioning: Commercial Scale Production Model (Budget Period 2)	Target Vehicle Metrics Achieved	COMPLETE (November 2020)
	Final Assembly of Test Vehicles Complete (C-sample)	June 2021
	Finalization of Data List to be Collected and Analyzed (DVP)	June 2021
	Finalization of Design Elements	June 2021
	C-Sample Vehicle Specifications Will Achieve Range Targets *(range target 250miles/day)*	September 2021
Phase 2 Deployment and Demonstration (Budget Period 3)	Start of Production Tests/ 100% of Parts are Customer Ready	November 2021
	Start of Commercial Series Production	January 2022
	Vehicle Delivery and Demonstration Initiation	June 2022
	Data Evaluation, Measurement and Verification	December 2022

** Please note that this table reflects completion dates that may be impacted by the ongoing COVID-19 public health crisis.*

APPROACH

DTNA EMG is leveraging global design, engineering, sourcing and vertically integrated production capabilities to quickly achieve economies of scale and reduce product costs. Through a ‘co-creation’ approach with fleet partners, DTNA EMG will collect operator feedback and determine best practices for continuous improvement.

TECHNICAL STRATEGIES

APPROACH

Due to proprietary control of software and in-house production of key components, DTNA EMG was able to adapt problems with sourcing and supply.

DTNA Freightliner eCascadia B-sample build enjoying the sun.

DTNA Freightliner eCascadia C-sample getting some work done.

Compressed testing schedule to keep project on-schedule despite supply chain delays due Covid-19

Use of ‘dummy’ battery packs and other temporary components were made in-house when key shipments were delayed or damaged during compressed testing

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Phase 1a Milestones and Accomplishments - *July 2019-September 2020*

- B-sample build completed
- B-Sample vehicle completed
- C-Sample vehicle design and integration completed

Phase 1b Milestones and Accomplishments - *November 2020-June 2021*

- Target vehicle metrics achieved
- Final Assembly of Test Vehicles Complete – (*on schedule for June completion*)
- Finalization of Data List to be Collected and Analyzed (DVP)
- Finalization of Design Elements
- C-Sample Vehicle Specifications Will Achieve Range Targets *(range target 250miles/day)*

Phase 2: Milestones and Accomplishments - *Starts June 2021*

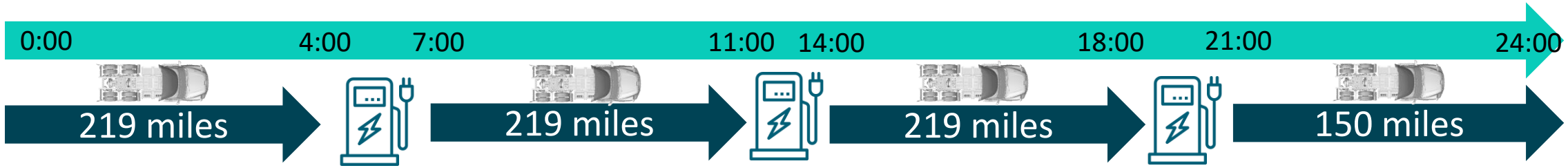
Key Takeaway: The project team has achieved critical project milestones for Phase 1a and Phase 1b.

Phase 2: Deployment and Demonstration is underway.

DTNA Freightliner eCascadia glider chassis inverter installation

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

250 miles per day can be achieved (Test Case – Max Mileage)



219 miles x avg. 2.165 kWh/mile
=
475 kWh used

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219 miles / 50mph
=
~4hrs

DC – Charger: 3h charge - @ 160 kW
=
up to 475 kWh recharge

Assumptions:

- Truck drives at 50mph
- Average efficiency = 2.165 kWh/mile based on real world B-sample testing
- Truck is eCascadia 6x4 at 80k lbs and 13°C with 475kWh battery
- Charger is 160kW charger that takes 3hrs to fully charge 475kWh battery

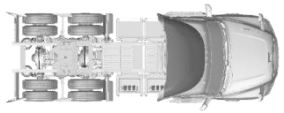
Conclusion:

- Truck averaging 50mph will drive 807miles in one day with assumptions
  - averaging 30mph will drive 558miles
  - averaging 20mph will drive 419miles

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

250 mile daily trips w/ a short opportunity charge are very realistic – Customer Use Case

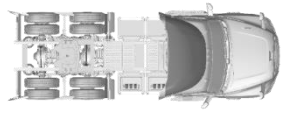
Example A – Grocery Application:



Morning shift
4 AM – 1PM

- Starting fully loaded (80k lbs) and dropping to an empty Reefer with several stops
- Mileage: 130-150 miles (300 kWh used on avg.)

DC – Charger: 3h charge - 400A w/ up to 160 kW

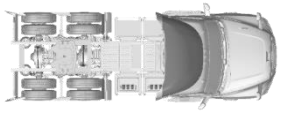


Afternoon shift
4 PM – 1AM

- Starting fully loaded (80k lbs) and dropping to an empty Reefer with several stops
- Mileage: 130-150 miles (300 kWh used on avg.)

DC – Charger: 3h charge - 400A w/ up to 160 kW

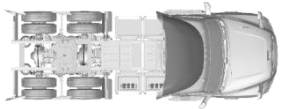
Example B – Drayage/Intermodal:



1st Partial shift

- Port Drayage/Intermodal operation with hauling freight/containers out of port to e.g. warehouse/railyard (often 1-way empty container from depot to port/railyard)
- Mileage: 150 - 200 miles

*DC – Charger: **Opportunity charge** for 45min - 400A w/ up to 160 kW for (up to 60 miles)*



2nd part of shift

- Finishing drops/pick-ups and go back to depot for overnight charge
- Mileage: 60 – 100 miles

DC – Charger: overnight charge

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Testing at Proving Grounds (B-sample Design)

- Testing Daimler High Dessert Proving Grounds (Madras, OR)
- Road load data acquisition for shaker tests and simulation
- Data collected can be used for shaker and accelerated testing to ensure vehicle and components meet B10 lifetime

Defrost test (B-sample Design)

- Thermal system passed defrost test for cold weather
- Defrosted windshield quicker than baseline diesel vehicle
- Meets FMVSS 103 requirements
- System (PTCs) bring air to temperature a lot quicker than a diesel (waiting for engine to heat up before blowing hot air)

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Front Box Shaker (C-sample Design)

- Completed B10 lifetime – 10 years of service mileage
- Minor structural failures (brackets breaking at welds, incorrect torque, increase bolt size)
- Components sent back to suppliers for evaluation
- Changes being implemented for C-sample durability

Battery Shaker (C-sample Design)

- In process – expected to complete 10 years of service mileage in 6 weeks
- Buck of battery and frame rail installation for component shaker
- Accelerated testing of higher risk components using RLDA inputs
- This amount of weight (batteries) has not been supported by our frame rails before

Daily Software Testing (B & C-samples)

- Daily testing on-going with B-sample and C-sample trucks
- ‘Bugs’ being identified and resolved for future software builds
- Global team works in unison to remove bugs and improve software for next release

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Can DTNA EMG provide technical details about the technology used to address the diverse climate conditions the vehicle will operate under (hot/cold) and address EV range loss relative to heating, ventilation, and air conditioning requirements?

The cab HVAC and batteries are on an independent cooling/heating circuits. Drivers can use a preconditioning option to “wake up” the vehicle ahead of time and give the batteries adequate time to reach the optimal temperature.

The range effect will vary based on whether the vehicle is plugged into charge. DTNA is collecting test data to determine the exact conditions that affect the range.

What regulatory approvals are required prior to production release date?

- ❑ FMVSS -Brakes, defrost, etc.
- ❑ EPA -OBD, Noise, AC Leakage
- ❑ FMCSR-Ingress/egress, etc.
- ❑ MBN LV123 -HV Components
- ❑ ISO 26262 -Functional Safety
- ❑ UN ECE R100/2 -HV Components
- ❑ UN/DOT 38.3 -HV Battery
- ❑ CARB ZEV & HVIP

The C-sample build and go/no-go approval are both shown to occur in the same month.

Is enough time allotted for testing the hardware and software?

The criteria for go/no-go is set. However, the validation of those criteria will come before D-sample.

Software will be continuously tested to SOP with quarterly cycles.

Durability and Endurance testing is scheduled to be completed by June 2022.

Partner Organizations

- **Organization**: Meijer
- **Location** : Grand Rapids, MI
- **Contribution**: In-kind support, Fleet Partner for Vehicle Deployment & Demonstration in Meijer fleet operations in Michigan

- **Organization**: United Parcel Service (UPS)
- **Location** : Atlanta, GA
- **Contribution**: In-kind support, Fleet Partner for Vehicle Deployment & Demonstration in UPS fleet operations in Southern California

- **Organization**: South Coast Air Quality Management District (SCAQMD)
- **Location**: Diamond Bar, CA
- **Contribution** : In-kind support, Regulatory Guidance

REMAINING CHALLENGES AND BARRIERS

COVID-19

- Social distancing is still in effect in DTNA EMG facilities in accordance with public health guidelines regarding COVID-19 which recommend 6 ft of distance between individuals. This has slightly delayed production of the B- and C- sample builds, however the project team has still made significant progress and remain on track to complete vehicle assembly within the original timeline.

- The COVID-19 public health crisis impacted the project team's ability to travel and meet with fleet partners in order to access their infrastructure needs. Infrastructure evaluation for United Parcel Service (UPS) and Meijer are planned for the upcoming year under the assumption that travel restrictions will be eased.

Compressed Vehicle Testing Schedule

- Compressed vehicle testing schedule was adopted to accommodate supply chain delays without revising project schedule and timeline. Compressed schedule led to increased wear and tear on sample build vehicles which required additional maintenance to complete tests. Vehicle testing was ultimately successful, and the final phase of production is in progress.

FUTURE RESEARCH

Budget Period 1

- Continue B- Sample vehicle testing
- Complete C-Sample vehicle design, integration and simulation
- Begin C-Sample vehicle procurement
- Complete D-Sample vehicle development supplier selection
- Begin D- Sample tooling supplier selection to begin

Budget Period 2

- Continue C-Sample vehicle component procurement
- Build and Commission C-Sample test vehicles
- Procure D-Sample vehicle components
- Begin vehicle testing for integration, functionality, durability and reliability

Budget Period 3

- Complete vehicle testing
- Demonstrate technical and commercial market readiness
- Deliver first trucks to fleet customers
- Data evaluation, measurement and verification (EM&V)

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

SUMMARY

Key Takeaway: Despite the challenges and barriers outlined in this presentation, DTNA EMG remains on track to develop the fully commercialized, all-electric Class 7/8 day cab tractor with improved range, efficiency, durability and performance. The project team has passed critical milestones and technical progress to date is summarized in the table below.

PHASE	STATUS
Phase 1a: Vehicle Design and Specification	**Completed**
Phase 2b: Research, Design, Building and Commissioning: Commercial Scale Production Model	**Completed**
Target Vehicle Metrics Achieved	Completed November 2020
Final Assembly of Test Vehicles Complete	Complete June 2021
Finalization of Data List to be Collected and Analyzed	Complete June 2021
Finalization of Design Elements	Complete June 2021
C-Sample Vehicle Specifications Will Achieve Range Targets *(range target 250miles/day)*	Complete September 2021
Phase 2: Development and Deployment	Underway