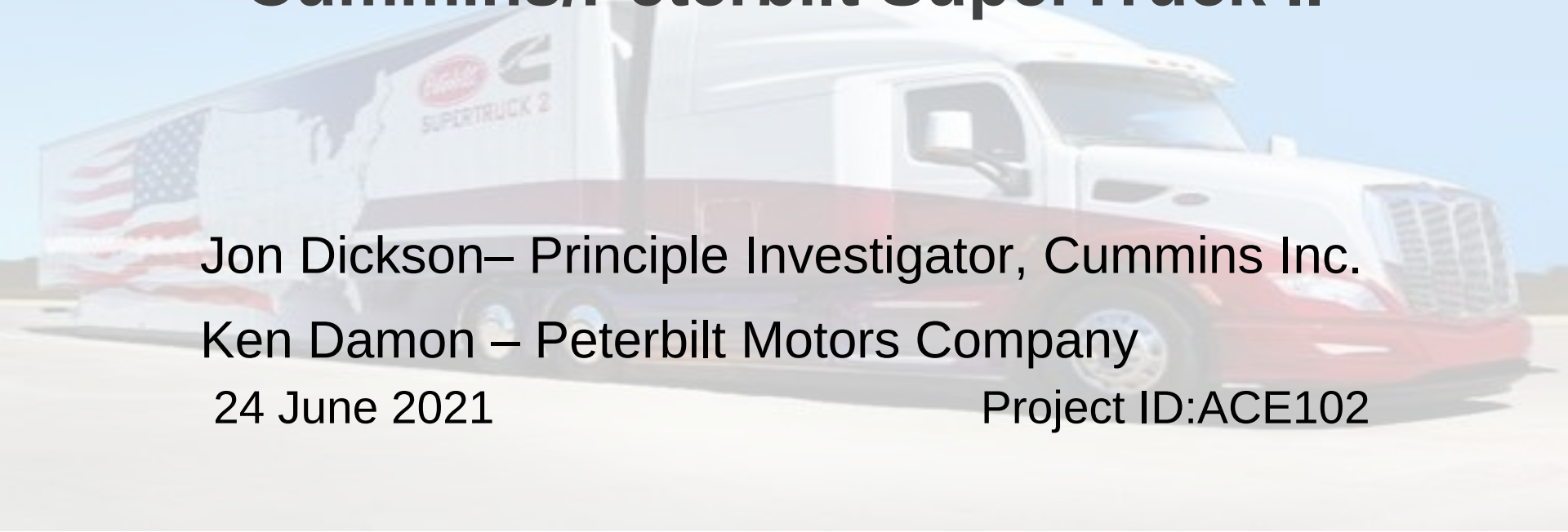
2021 Annual Merit Review
Cummins/Peterbilt SuperTruck II



Jon Dickson– Principle Investigator, Cummins Inc.

Ken Damon – Peterbilt Motors Company

24 June 2021

Project ID:ACE102

Overview

Timeline

- Begin: 10/1/2016
- End: 9/30/2022
- 85% complete

Budget

- Total Project: $40M
- $20M DoE - $20M Partners
- Total Spent: $38.4M
  - $19.2 = Partners
  - $19.2 = DoE

Barriers

- Engine Efficiency ≥ 55% BTE
- Freight Efficiency ≥ 100% FTE
- Cost effective solutions

Partners

- Cummins – Powertrain
  - Eaton - Transmission
- Peterbilt - Vehicle
- Bridgestone – Tires
  - Walmart – Customer counsel

Relevance: Objectives

- Demonstrate a *minimum* of 55% BTE at a 65 mph cruise, on an engine dynamometer test stand
  - Same engine systems also demonstrated in vehicle, operating on real world drive cycles
- Achieve a *minimum* of 125% Freight Ton Efficiency (FTE).
  - FTE = MPG*Tons of Freight
- Track, promote and report on cost effective solutions
  - Prioritize solutions that have ~3 year payback period
  - Utilize customer counsel for understanding payback variables

Relevance: Energy Consumption

- Approximately 20% of U.S. transportation petroleum goes to the production of heavy truck fuel. Proposed improvements would save more than 400 million barrels of oil per year.*
  - Reduce imports and improve energy security
  - Reduce the cost of moving goods
- Heavy Truck GHG emissions account for a CO2 equivalent 420.7 MMT per year (35th edition of the Transportation Energy Data Book).
  - Improved air quality
  - Protect the public health and environment

* https://energy.gov/eere/vehicles/vehicle-technologies-office-moving-america-forward-energy-efficient-vehicles

Milestones by Quarter

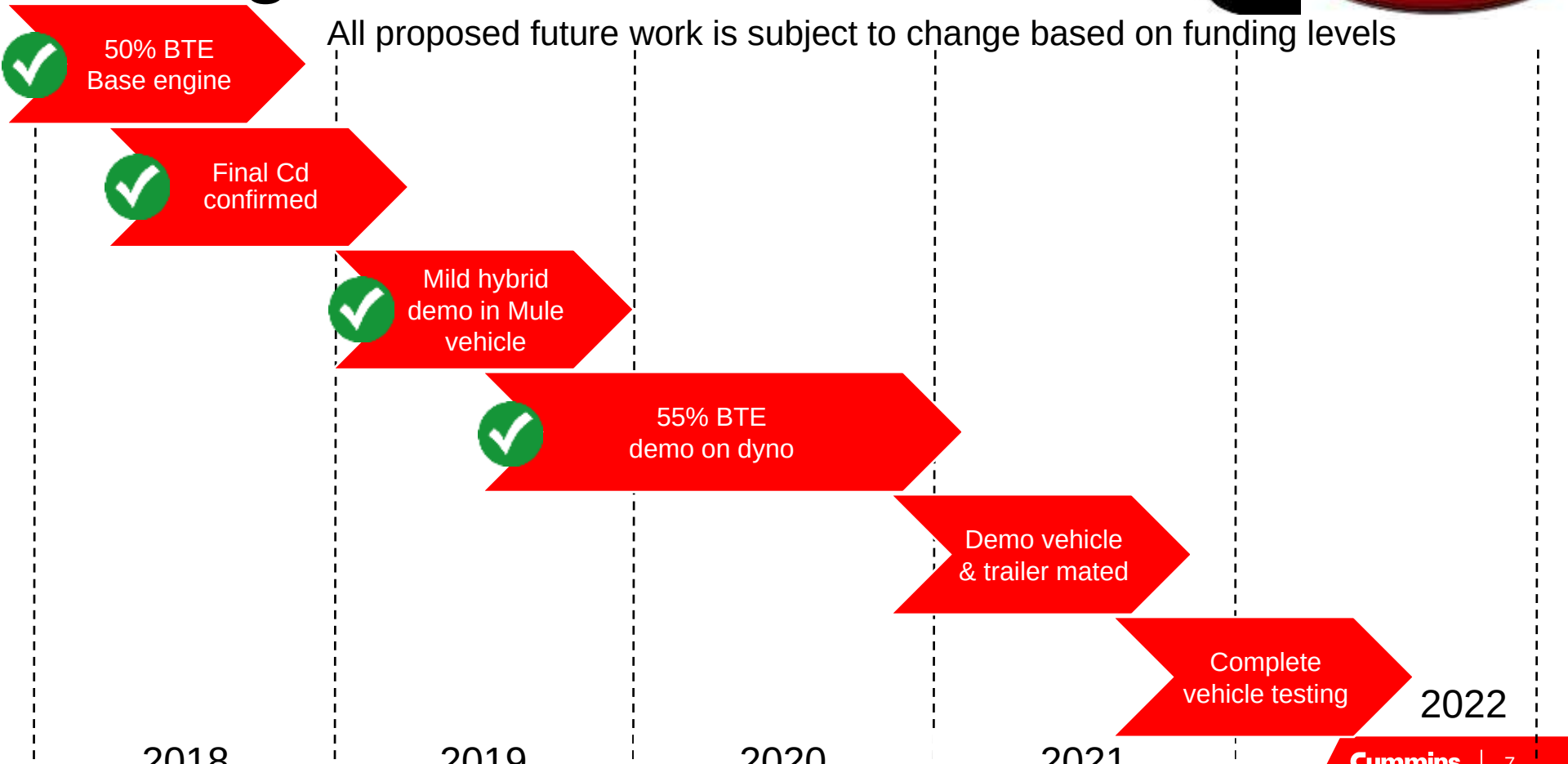
FY 2020	Description
Confirmed Vehicle System Path-to-Target	Path to Freight Efficiency objective confirmed with powertrain/hybrid efficiency, aerodynamics/tire, and weight target modelled
Technical Viability Report	Complete commercial viability assessment
55% BTE Demonstration	Dynamometer demonstration of engine system at 55% BTE
Confirm ACEM capability	Features selected and integrated into Demo vehicle

Milestones by Quarter

FY 2021	Description
Complete Freight Efficiency Demonstration Engine Build 	Ready the engine for final calibration
Begin Freight Efficiency Demo Chassis Build 	Begin assembly and population of the frame system
Complete Freight Efficiency Demo Engine Calibration 	Prepare the engine, WHR system, and 48V mile hybrid system for the demonstration vehicle
Complete engine installation into FTE Demo chassis	Installation of the engine into the freight efficiency demonstration vehicle

Program Level Milestones

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

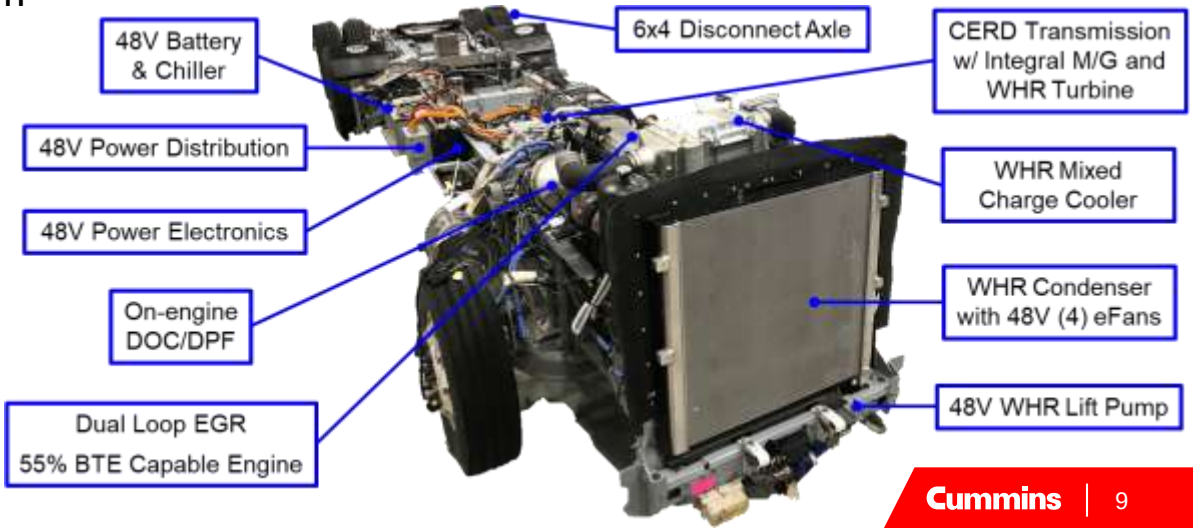


Technical Approach

- Reduce Work/Mile on test route
  - Vehicle aerodynamics & tire improvements
  - Reduce losses in engine and accessories
    - Enable engine-off-coasting (EOC) to reduce motoring losses
    - Electrify accessories for EOC
  - Enable 48V hybridization to minimize brake losses
- Enable high Engine + WHR efficiency
  - Maximize efficiency on test route
  - Advanced Cycle Efficiency Manager (ACEM) to favor high load engine operation
- Maximize freight capacity via weight reduced powertrain/truck/trailer

Accomplishment- Powertrain Developed

- Hardware and Software Integration of the following sub-systems:
  - 48V mild hybrid with Electrification Thermal Management, M/G, Power Electronics, and DC/DC
  - Transmission integral WHR turbine expander and gearbox
  - Cooling module integration of WHR Condenser with 48V fans and topping radiator
  - Advanced Cycle Efficiency Manager
  - 6x4 Disconnect axle system
- Key Development activities:
  - Transmission shifting
  - System fault handling, development, and accessory management
  - 48V accessory management



Accomplishment- 55% BTE

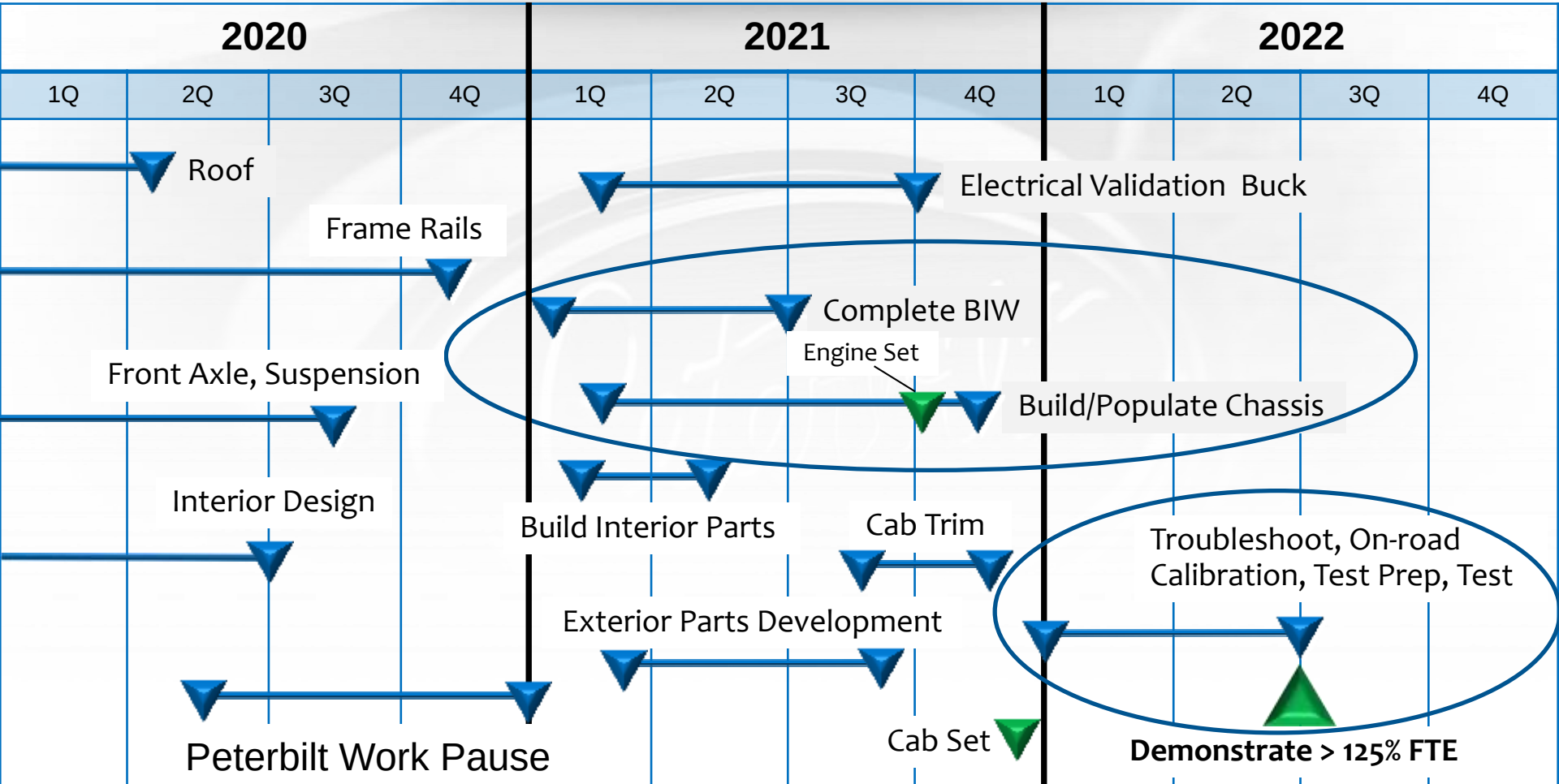
- Goal: 55% BTE at fuel centroid
- Approach:
  - Assess theoretical opportunity
  - Build on engine-only 50% BTE success + WHR
- Challenges:
  - Simultaneous improvements to OCE, CCE, MCE, and WHR needed
  - Coupling of energy flows, LHT piston technology frailty, supplier delivery challenges
- Results:
  - System BTE: 55%
  - WHR: 4.4%
  - Transient and steady state test cell calibration complete

- Next steps:
  - Demo Vehicle installation, vehicle calibration, and on-road freight efficiency testing

- Key Engine Technologies:
  - High Efficiency Combustion System
  - High Efficiency Turbocharger
  - Low Heat Transfer Head & Exhaust Manifold
  - Liner Form Hone
  - Variable PCN and Pump Control
  - High Voleff Camshaft
  - Low DP Aftertreatment
- Key WHR Technologies:
  - Base System Design – (HPL and LPL)
  - Energy Sources (Coolant, Charge, Exhaust, EGR)
  - Best Point Turbine
  - 2nd TP Boiler for LPL
  - Insulation- minimize heat loss

Ken Damon
Principal Engineer

Program Schedule



Technical Approach: Path to Target

Engine

Aerodynamics

Transmission/Axle

Downspeeding

Lightweighting

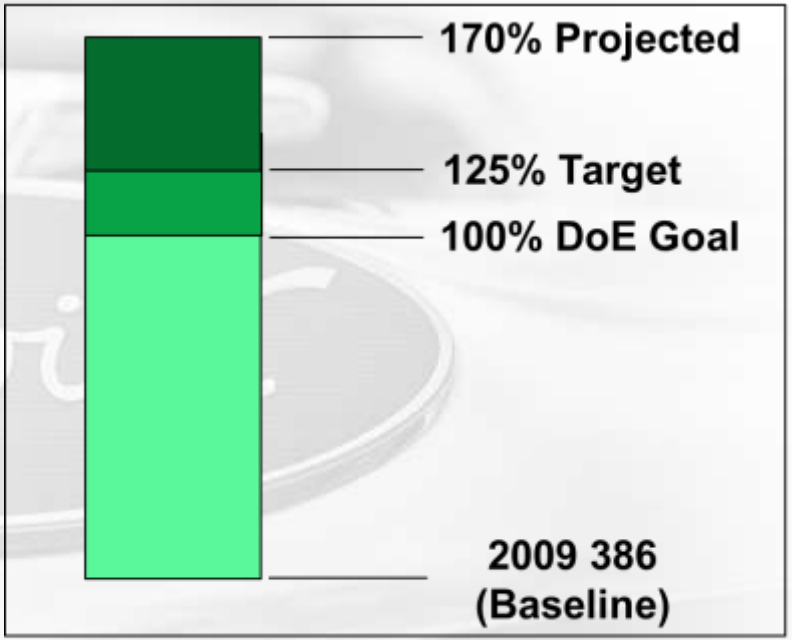
Route Management

Rolling Resistance

Mild Hybrid/Solar

Technical Approach: Path to Target

- 55% Engine Efficiency
  - Dyno Demonstration Complete ✓
- Goals vs. 2009 Baseline
  - Goal: 56% Aerodynamic Drag Reduction
  - 63% Achieved ✓ +
  - Goal: 3800lb Weight Reduction
  - 4700lb Achieved ✓ +
  - Goal: 30% Reduced Rolling Resistance
  - 33% Achieved ✓ +



Freight-Ton Improvement

Technical Approach: Applied Technologies

Active Extenders

Aerodynamic Body

Forward-Looking Yaw Sensor

6x4/6x2 Disconnect Tandems

Cameras/Displays

MMC Brake Drums

48v ePower Steer

Chassis Height Control

Lightweight Chassis

Low Crr Tires

High Efficiency Engine/Transmission

24.5” Aluminum Wheels

48v eHVAC

Advanced Cycle Efficiency Manager

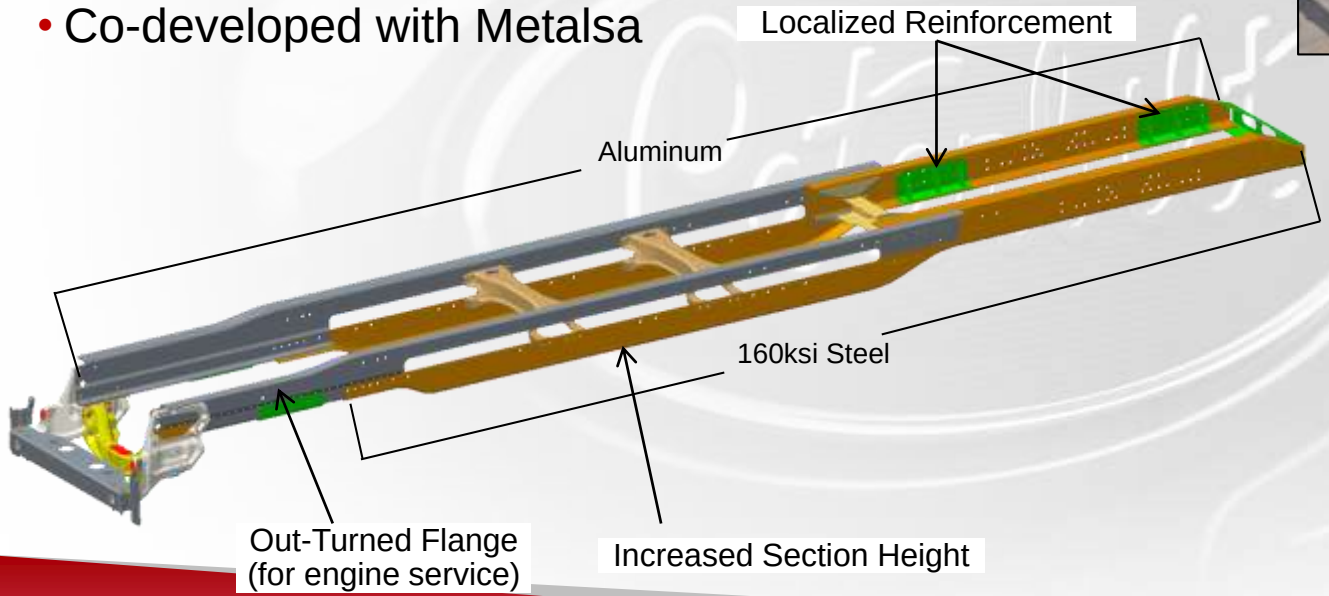
Mild Hybrid Driveline

Peterbilt

Technical Progress: Advanced Chassis

Lightweight Chassis

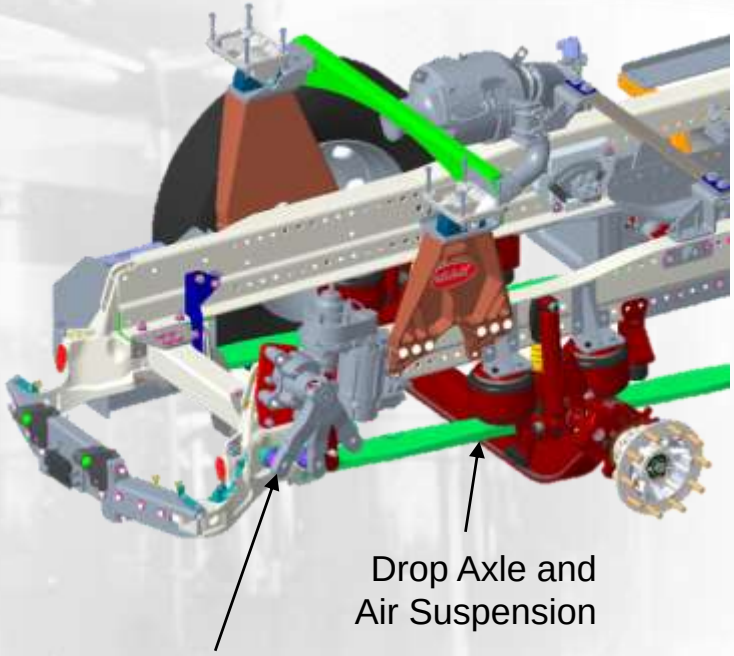
- Hybrid Steel/Aluminum
- Equivalent Modal Response
- 500lb Weight Reduction
- Co-developed with Metalsa



Technical Progress: Chassis Systems

Forward Chassis Section

- Front Deep Drop Axle/Air Suspension
  - Parts Received Feb ‘21 HENDRICKSON
- Enables Chassis Height Control
  - 4” High-Speed to Low-Speed Delta
- Chassis Height System Controls
  - Height Control Demonstrated IMI NORGREN
  - Final Software Nov ‘21
- 48v ePower Steer ZF
  - Reduced Engine Parasitics
  - Control During Engine-Off Coast
  - Steer Hardware Received April ‘21
  - Software Available Nov ‘21

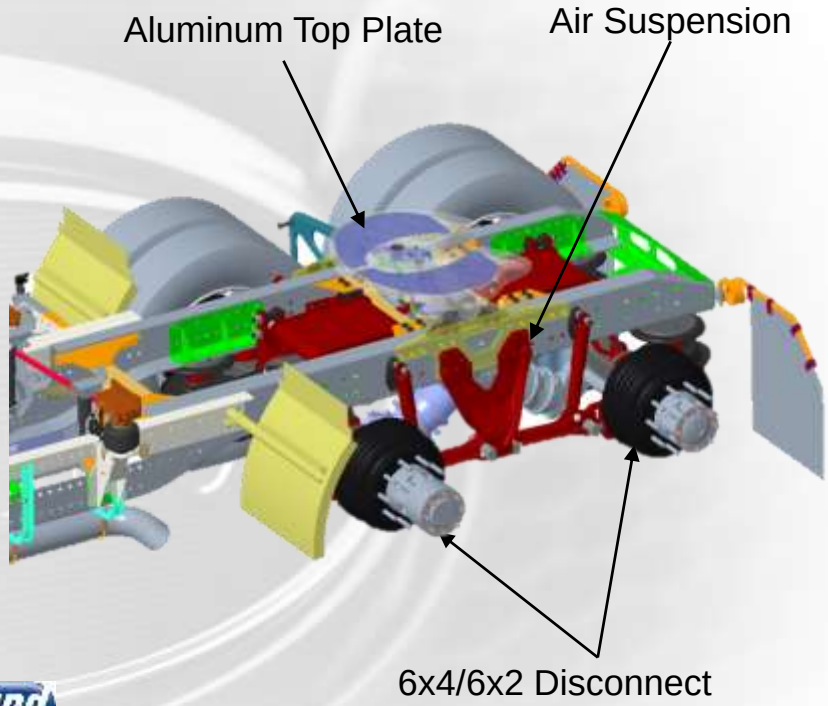


Peterbilt

Technical Progress: Chassis Systems

Aft Chassis Section

- Air Suspension HENDRICKSON
  - Parallel Link
  - Enables Chassis Height Control
  - Demo System Harvested from Mule Truck
- 6x4/6x2 Disconnect Axles MERITOR
  - 6x4 for Low-Speed Traction
  - 6x2 for Cruise (Disengage Fwd Drive Axle)
  - Functionality Demonstrated on Mule
  - Demo System Harvested from Mule Truck
- Aluminum Top Plate Fifth Wheel SAF Holland
  - Production Option

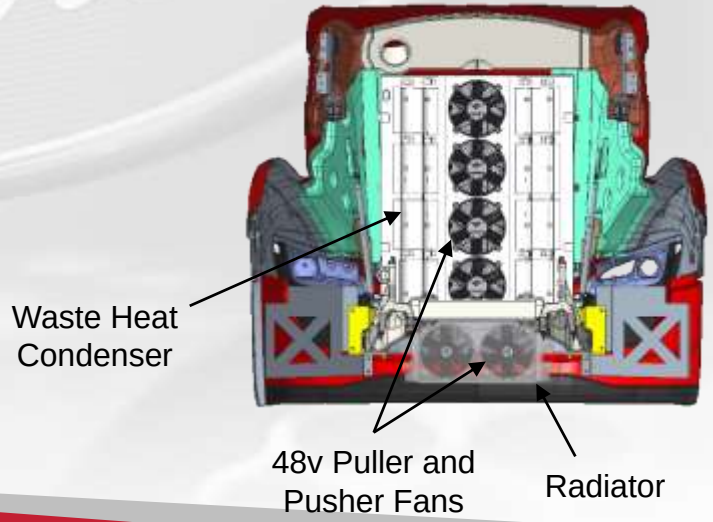


Technical Progress: Active Aerodynamics

- Dynamic Sleeper Extender
  - Pneumatically Controlled Surface
  - Input from Roof-Mounted Yaw Sensor
  - High Yaw Drag Mitigation (Trailer Gap)
- Accomplishments
  - Control Surface Complete
  - Control System Demonstrated
    - Refinements On-going
  - Yaw Sensor
    - Prime Path: Ultrasonic (off the shelf)
    - Previously: High Resolution LiDAR
      - Maturity Not Yet Ready

Technical Accomplishments/Collaboration: Demonstrator

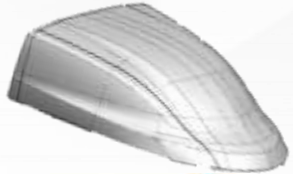
- Complete
  - Aluminum Wheels Alcoa
  - Steer, Drive, Trailer Tires Bridgestone
  - Wiper System Valeo
  - Windshield and Side Glass Pilkington
  - Roof RMC
  - Hybrid Frame Rails Metalsa
  - Axles, Suspension Hendrickson
- In Process:
  - Cab Body in White Magna
  - Cooling Module w/ 48v Fans Mahle
  - Interior Point Innovation
  - 48v ePower Steer ZF
  - 48v eHVAC Bergstrom



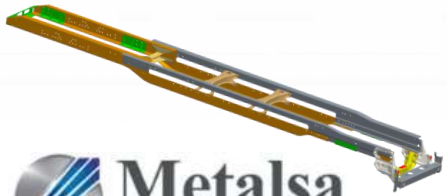
2021 Vehicle Schedule Summary

1Q-2Q21

MAGNA



RMC
A NanoXplore Company

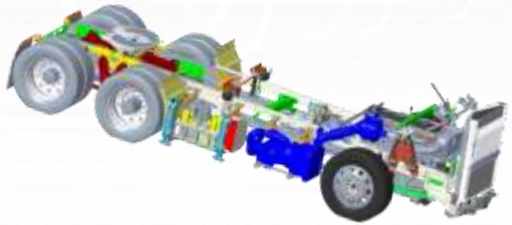


Metalsa

2Q-3Q21

Cab Trim

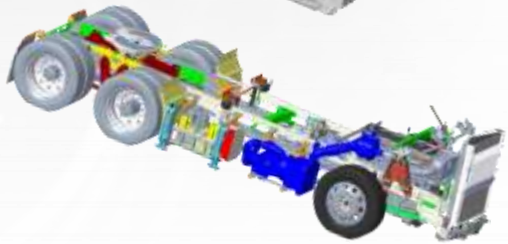
POINT INNOVATION
Product Development



Chassis Trim

Peterbilt Cummins

4Q21



Cab Set/Troubleshoot

Peterbilt Cummins

Technical Progress: Lightweight/Aerodynamic Trailer

- 2000lb Weight Reduction
- Glass Reinforced Polypropylene
  - Bonded Side Walls
  - Pontoon Skirts
- Honeycomb Laminate Doors
- Aluminum Landing Gear & Air Tank
- Extruded Aluminum Floor
- Carbon Fiber Leading Edge
- Modified Commercial Tail
- Delivery: October 2021

Collaboration: Walmart Application

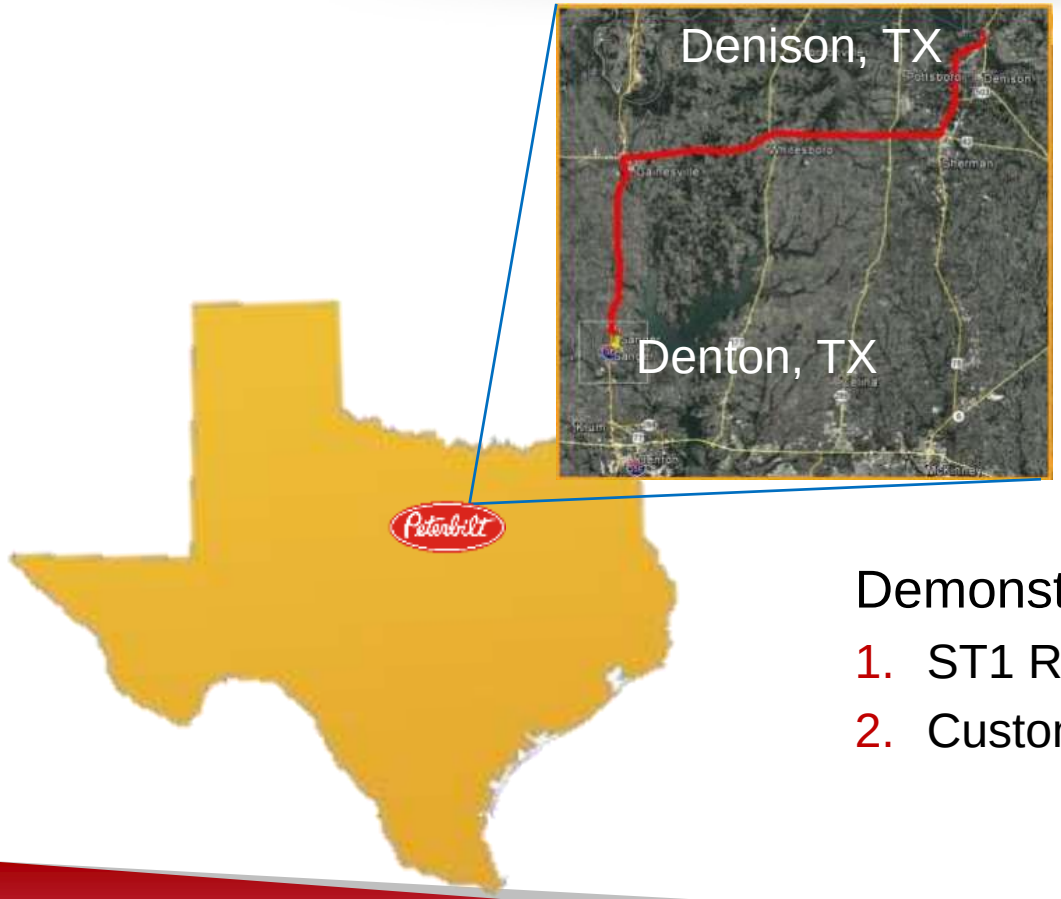
Data Collection

- Road Grade
- Max Elevation
- Major vs. Local Roads
- Duty Cycle
  - Long & Short Term
  - % Time at Speed, Load

NREL Data Collection and Analysis (2017)

Location	Trucks	OEM	Engine	Total Mileage
Loveland, CO	8	Peterbilt 579	Cummins ISX15	40,895
Sanger, TX	24	Peterbilt 579	Cummins ISX15	131,605
Grove City, CO	17	Brand X	Brand Y	101,238
	7	Brand X	Cummins ISX15	
Total	**56**			**273,738**

Collaboration: Walmart Application



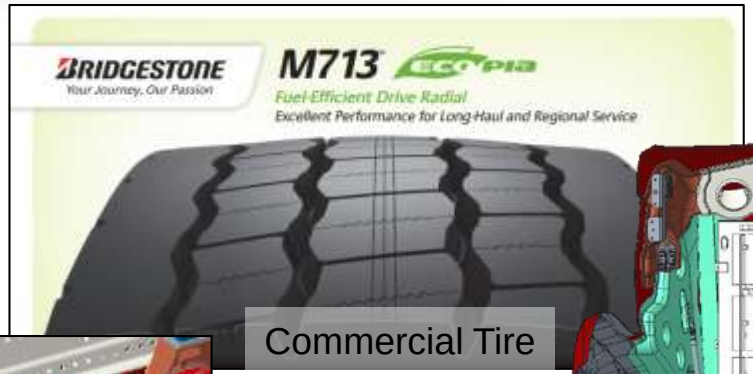
Custom Walmart Route
- 62.5 miles
- 90% Major Roads
- 6.3% Local Roads
- 272m Max Elevation

Demonstrator Testing to Include:

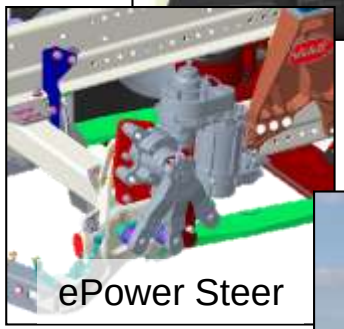
1. ST1 Route (General OTR Route)
2. Custom Walmart Route

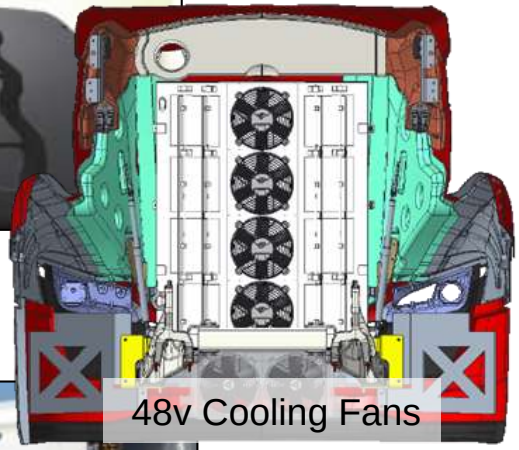
Commercial Harvesting

- 2021
  - Bridgestone M713 Tire
- 2024-2027
  - 48v Power
    - eHVAC
    - ePower Steer
    - eAPU
    - eCooling Fans
    - eCompressor
- Advanced Outer Body
  - Zero Emission Vehicles
  - Autonomous Vehicles
- Trailer Sail Plates



Commercial Tire


ePower Steer


48v Cooling Fans

Advanced Outer Body

Proposed Future Research

- Deliver Cost Effective Solutions
  - Refine cost/payback model optimization
  - Assess manufacturing alternatives for low heat transfer components
- Demonstrate >125% FTE improvement
  - Powertrain Mule truck evolution
    - Final calibration of 48V system and Advanced Cycle Efficiency Manager
  - Refine and build Demonstrator truck and trailer
    - Final procurement of cab system
    - Build demonstrator truck and trailer
    - Complete on-road testing and confirm Freight Efficiency objective
- Use Walmart Simulated Route to demonstrate technology applicability versus baseline

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

Program Summary

- Powertrain
  - Powertrain development in mule vehicle is on plan
  - Engine development met 55% BTE
- Vehicle
  - Aerodynamic System, Weight Reduction, Tire CRR Ahead of Target
  - Bridgestone Tire Samples Complete
  - Final Demonstrator Build on Track for Completion in 2021
- Cummins and Peterbilt will deliver 55% BTE and a minimum 125% FTE

THANK YOU!

QUESTIONS