

DoE SuperTruck Program

**Technology and System Level Demonstration of Highly
Efficient and Clean, Diesel Powered Class 8 Trucks**



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Presenter: Kenneth Damon, P.E.

Peterbilt Motors Company

Project ID: ARRAVT081

19 June 2014

Relevance - Program Objectives

(DoE Vehicle Technologies Goals)

Objective 1: Engine system demonstration of 50% or greater BTE in a test cell at an operating condition indicative of a vehicle traveling on a level road at 65 mph.

Objective 2

a: Tractor-trailer vehicle demonstration of **50% or greater freight efficiency improvement** (freight-ton-miles per gallon) over a defined drive cycle utilizing the engine developed in Objective 1.

b: Tractor-trailer vehicle demonstration of **68% freight efficiency improvement** (freight-ton-miles per gallon) over a defined 24 hour duty cycle (above drive cycle + extended idle) representative of real world, line haul applications.

Objective 3: Technology scoping and demonstration of a 55% BTE engine system. Engine tests, component technologies, and model/analysis will be developed to a sufficient level to validate 55% BTE.

Baseline Vehicle and Engine: 2009 Peterbilt 386 Tractor
and Cummins 15L ISX Engine

Relevance - American Recovery and Reinvestment Act (ARRA) Goals

- Create and/or Retain Jobs

					Projections
Year	2010	2011	2012	2013	2014
Full Time Equivalent	75.5	85	60	46	17

States: Indiana, Texas, Michigan, Wisconsin, Tennessee, Illinois, New York, Ohio, Mass, California

- Spur Economic Activity
 - Greater Than \$72.6M Total Spend To Date
- Goals Align With VT Multi-year Program Plan 2011-2015
 - Advanced Combustion Engine R&D (ACE R&D):
 - 50% HD Engine Thermal Efficiency By 2015 (Ref: VT MYPP 2.3.1)
 - Vehicle And Systems Simulation And Testing (VSST):
 - Freight Efficiency Improvement of 50% by 2015 (Ref: VT MYPP 1.1)
- Invest In Long Term Economic Growth
 - Commercial Viability Assessment
 - Adopt Technologies into Product Plans to Meet GHG and CO2 Regs

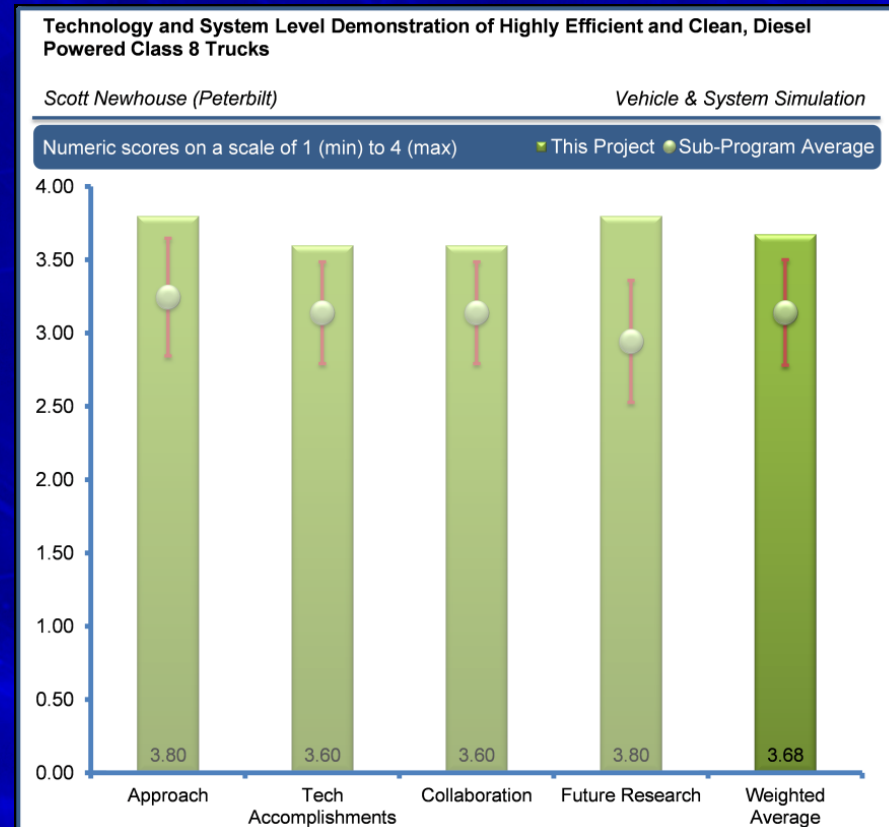
Response to 2013 AMR Reviewer Comments

- Long list of suppliers was misleading
 - List partners supported as subcontractors to the program

Addressed in Slides 5 & 12

- Be sure to include detailed plans on battery sizing and durability

Addressed in Slide 10



2013 Reviewer Scorecard

Collaborations - Peterbilt Participants

- Sub-contractors

- Eaton – Transmissions



- Delphi – Solid Oxide Fuel Cell



- New Supplier in 2013 (Not Sub-contracted)

- Corvus Energy – Lithium Ion APU



- OEM (Not Sub-contracted)

- Utility Trailer Manufacturing



- End User

- US Xpress



Overview - Schedule and Budget

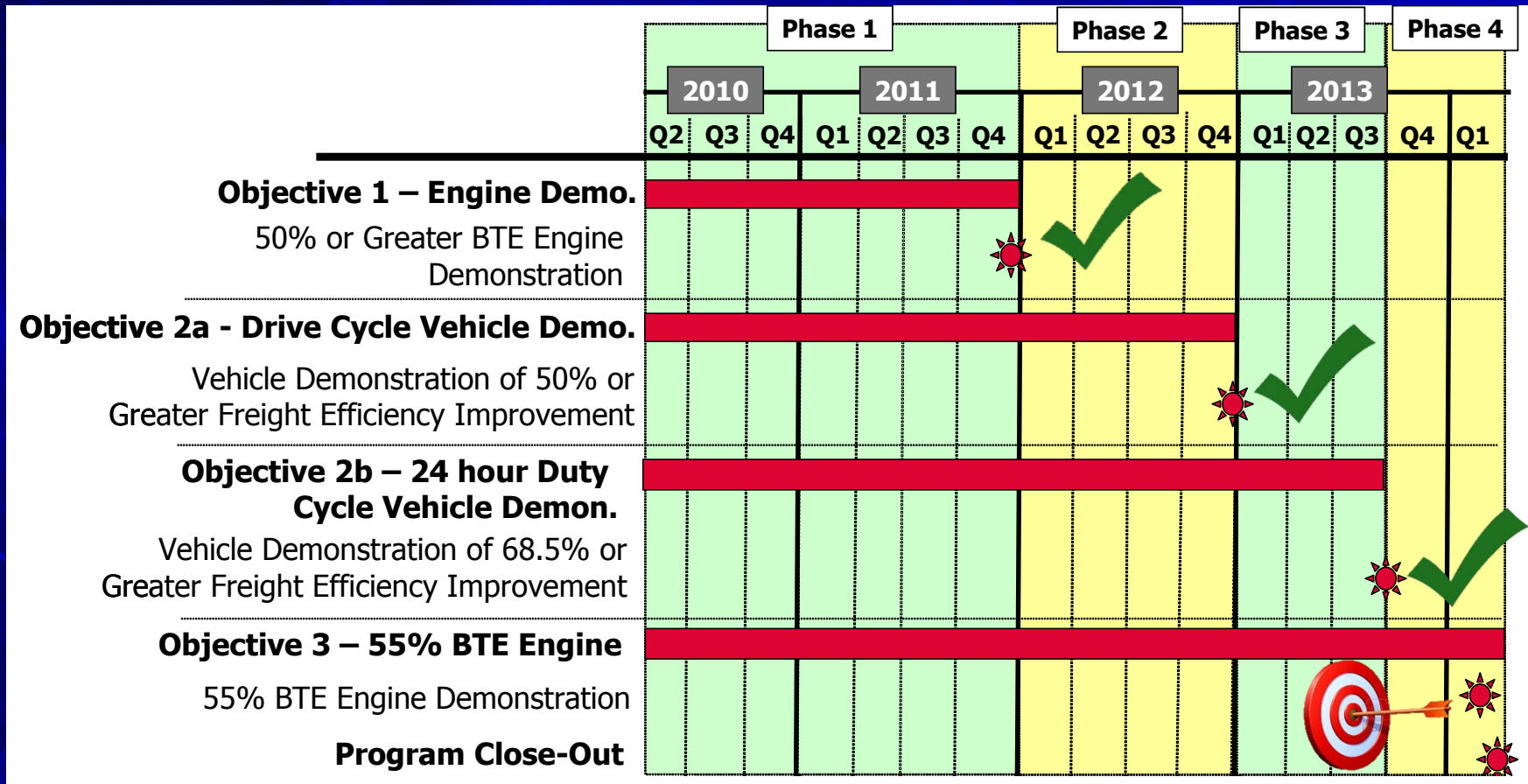
Budget

DoE Share: \$38.8M (49%)

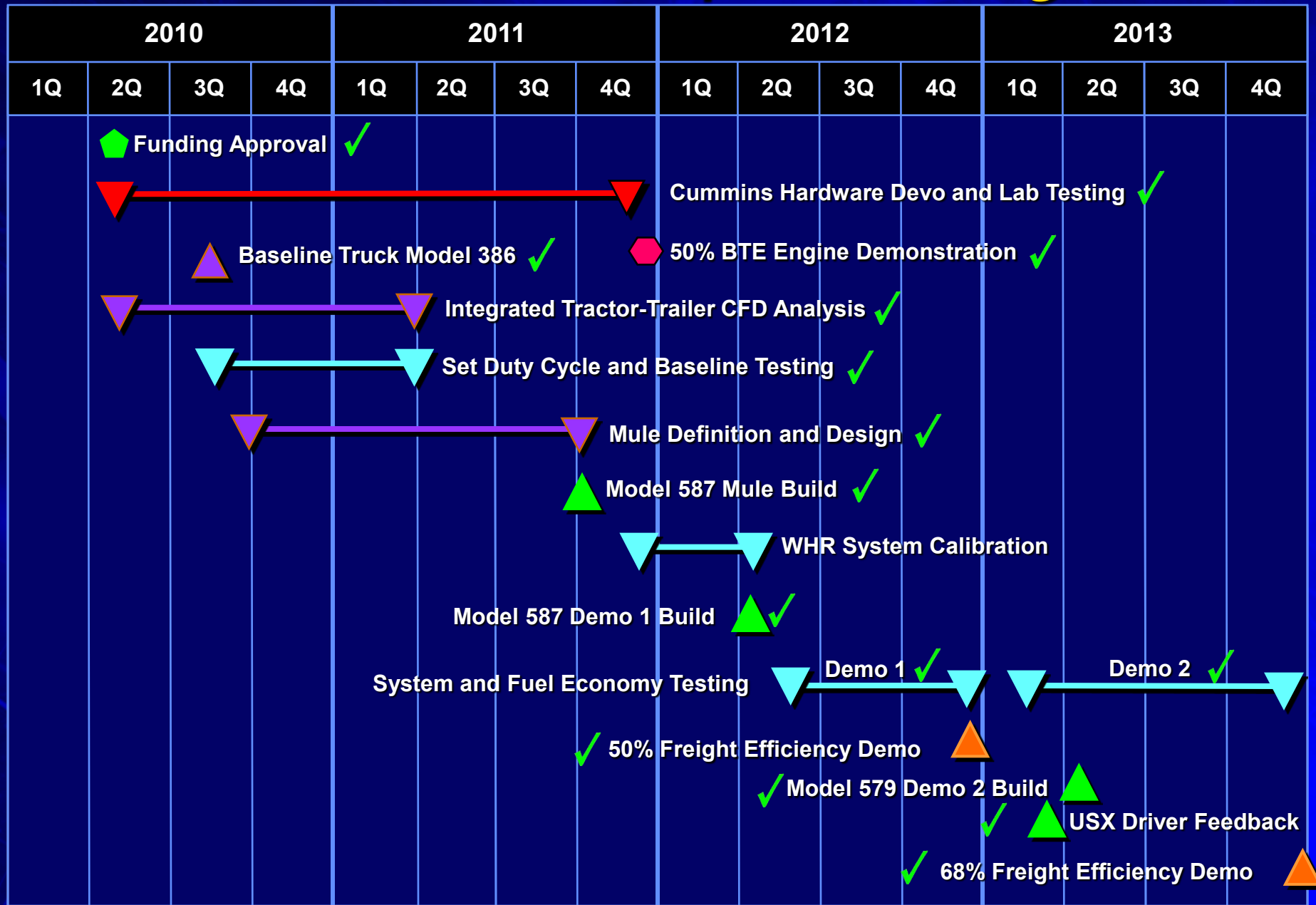
DOE Spend To-Date: \$36M

Contractor Share: \$40.3M (51%)

4-1/2 Year Program: April 2010 to Sept 2014



Overview - DoE SuperTruck Program



Overview - Program Barriers

- ✓ • Underhood Cooling with Waste Heat Recovery
- ✓ • Vehicle and Engine System Weight Reduction
- ✓ • Engine Downspeed (Reduced Engine Speed)
 - Powertrain Components
 - Vibration/Customer Acceptance
- ✓ • Vehicle and Powertrain Communication Speed
- ✓ • Trailer Aero Devices That Meet Operational Requirements
- ✓ • Alternate Power Unit – Technology Change

Technical Progress - Program Barriers

Alternate Power Unit

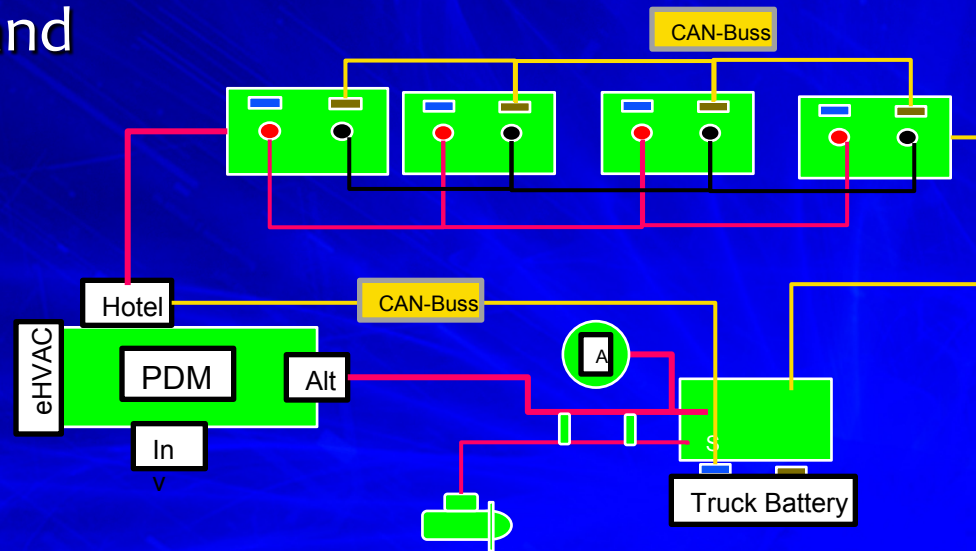
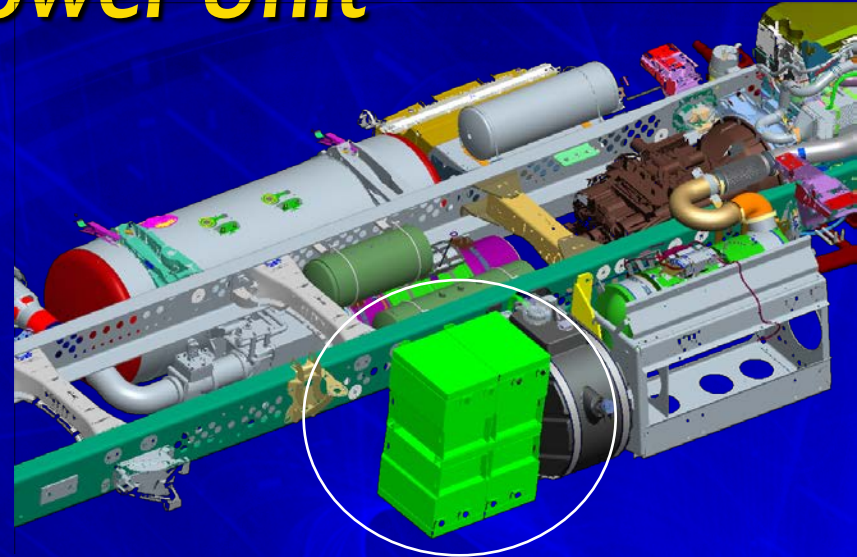
- Solid Oxide Fuel Cell (SOFC)
 - Integrated into Demo 1 (Aug 2012)
 - Functionality Verified (Dec 2012)
 - Development Challenges
 - Warm Up Time
 - Peak Power
 - Efficiency
 - Weight
 - Delphi Put Development on Hold (Jan 2013)
 - Demo 2 Options:
 - Use Demo 1 Level SOFC
 - Choose Another Technology
 - Request to Pursue Alternate Technology Approved By DOE Feb 2013



Technical Progress - Program Barriers

Alternate Power Unit

- Lithium Ion APU
 - (4) Li Ion Pack + Start Battery
 - 240a Alternator
 - 13.2 kW-h Capacity
 - 12.2 kW-h Load Profile
 - 400lb Battery, Structure, and Cables
 - 6hr Highway Re-charge
 - Capable Development Level System



Technical Progress

Model 579 Demo 2

Advanced Formula
Aftertreatment

Cab and Trailer Aero
Components

GPS Cruise
Control

Cummins 15L High
Efficiency ISX Engine

Advanced Super
Single Tires

High Speed
Routers

Waste Heat
Recovery System

High Efficiency
Cooling Package

Pneumatically
Retractable Trailer
Skirts

180° Trailer Tandem
Service Door



Collaboration

Cooling Package and
Heat Exchangers



Power
Distribution



Li Ion Start
Batt & APU



Alum Hybrid
Driveshaft



Route Display



Alum 5th Wheel



Ceramic Brake Drums



Light Steer Axle and
Trailer Tandem



Downspeed-enabling
Transmission



Advanced Light
Wheels



Magnesium
Crossmembers



Variable Gage
Steel Frame Rails



6x2 Rear Tandem
w/ eTrac



Integrated Air
Suspension Bags



Objective 2b: 24 hr Duty Cycle Testing

Technical Progress

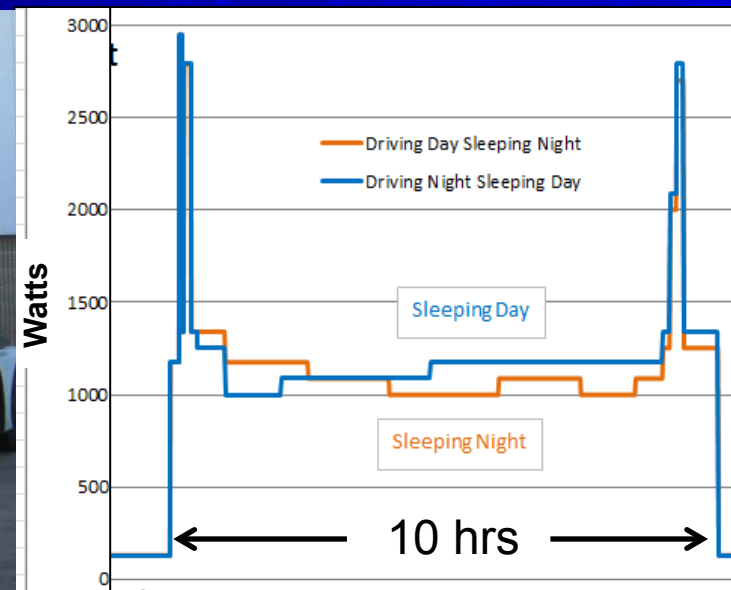


Start of Testing: Dec 2013

Objective 2b: 24 hr Duty Cycle Testing

Technical Progress

- Identical 12.2 kW-hr Load over 10 Hours
- Baseline Supported with Engine Idling
- Demo 2 Supported with Lithium Ion Batteries



Hotel Cycle/Battery Conditioning

Objective 2b: 24 hr Duty Cycle Results Technical Accomplishment (Dec 2013)



	GVW (lb)	Freight (lb)	MPG (Range)	(Avg) FTMPG Improvement	(Avg) MPG Improvement
579 Demo 2	65k	32,576	9.4-9.5	86%	75%
		+1305			

Temp Min/Avg/Max: 30/46/70°F
Wind Avg/Max Gust: 14/28 mph

Goal: 68%

Testing Beyond Scope

Demo 2 vs. Baseline - Drive Cycle Route

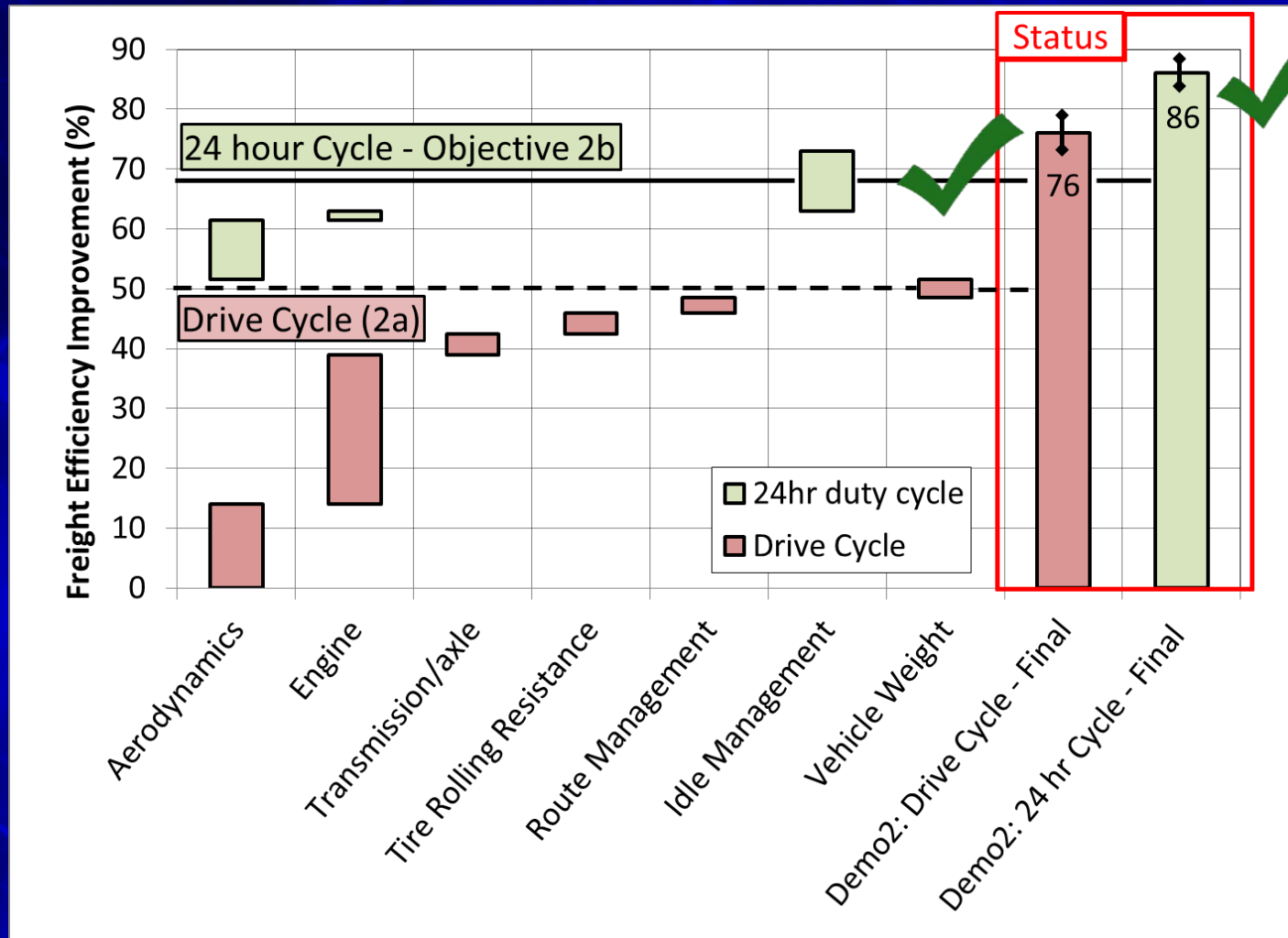
Technical Accomplishment



	GVW (lb)	Freight (lb)	(Avg) FTMPG Improvement	(Avg) MPG Improvement
579 Demo 2	65k	32,576	76% (Demo 1: 61%)	66% (Demo 1: 54%)
		+1305		

Temp Min/Avg/Max: 22/36/52°F
Wind Avg/Max Gust: 13/33 mph

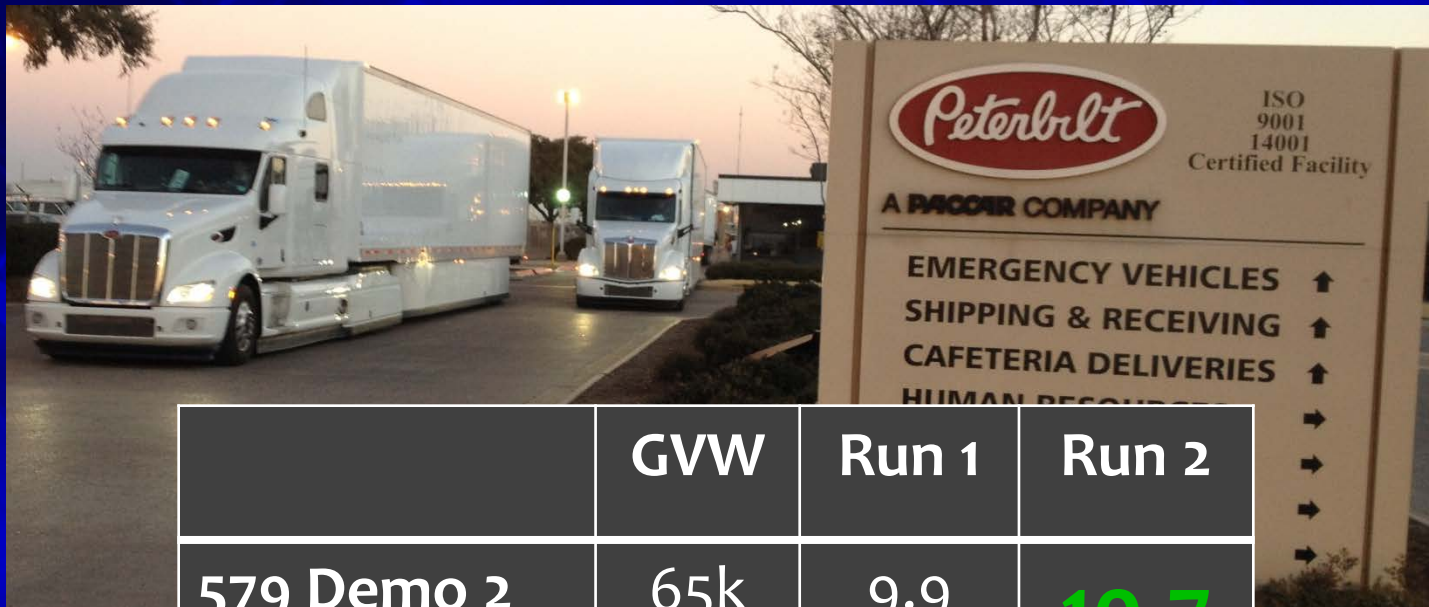
Technical Accomplishment Freight Efficiency Status



Testing Beyond Scope

Demo 2 vs. Demo 1 - Drive Cycle Route

Technical Accomplishment



	GVW	Run 1	Run 2
579 Demo 2	65k	9.9	10.7
587 Demo 1	65K	8.9	10.1

Temp Min/Avg/Max: 38/47/53°F
Wind Avg/Max Gust: 6 mph/steady

Testing Beyond Scope Technical Accomplishment

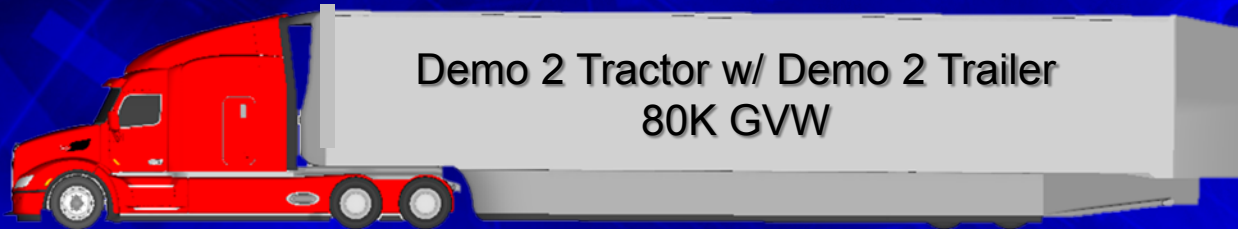
Peak MPG



Demo 2 Tractor w/ Trailer Skirts
65K GVW

9.4

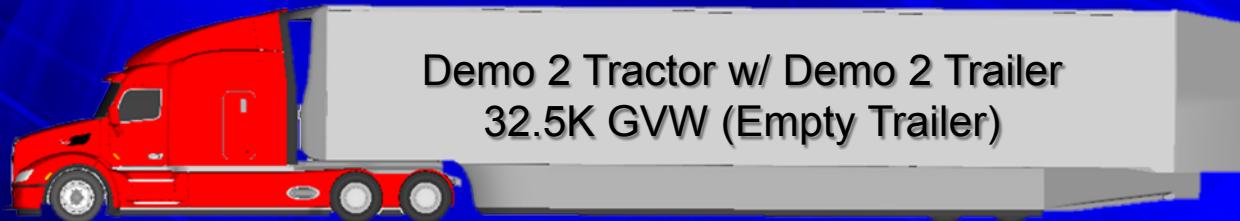
Temp Min/Avg/Max: 55/68/77°F Wind Avg/Gust: 9/18 mph



Demo 2 Tractor w/ Demo 2 Trailer
80K GVW

10.4

Temp Min/Avg/Max: 49/56/64°F Wind Avg/Gust: 6.5 mph/steady



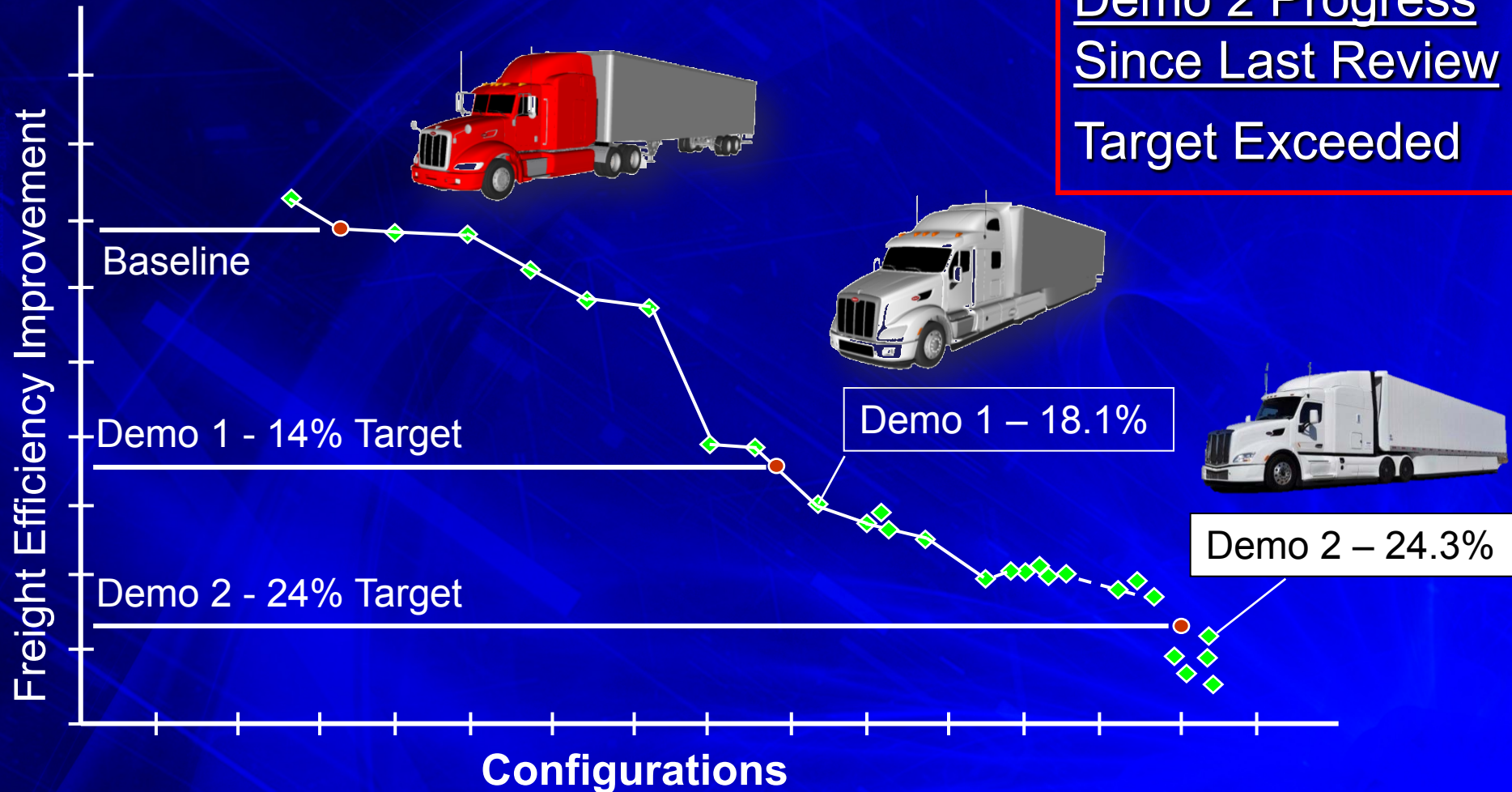
Demo 2 Tractor w/ Demo 2 Trailer
32.5K GVW (Empty Trailer)

12.7

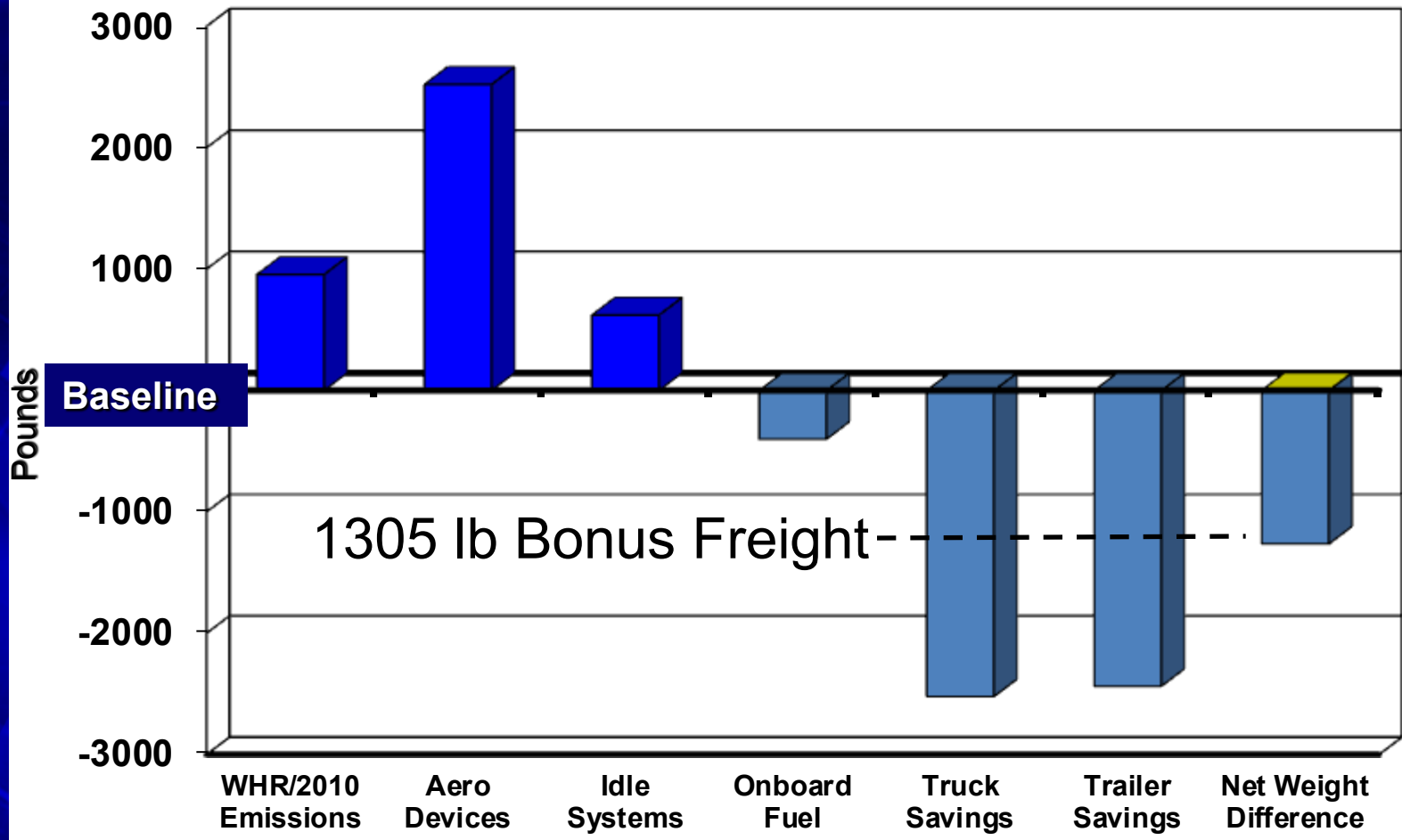
Temp Min/Avg/Max: 54/63/68°F Wind Avg/Gust: 23/40 mph

Aerodynamic Improvements – Technical Progress

Demo 2 Progress
Since Last Review
Target Exceeded



Demo 2 Truck/Trailer Weight Technical Progress



Driver Acceptance Collaboration

- US Xpress Drive Event, Demo 1
 - Mar 21, 2013
 - Irving, TX to Laredo, TX
(950 mile round trip)
 - Commercial Freight
 - US Xpress Drivers
- Feature/Functional Evaluation
 - Loading/Unloading Aero Trailer
 - Drivability
- Very Positive Event
- Critical and Valuable Feedback



Driver Acceptance

Collaboration/Technical Progress



Added Trailer Features for Demo 2



Service Access



Retractable Skirt

Promoting the DOE Program Technical Progress



White House Press Event

February 18, 2014

Technical Accomplishment



Safeway Distribution Center
Upper Marlboro, MD

Department of Energy

February 19, 2014

Technical Accomplishment



Energy Secretary
Dr. Ernest Moniz



Asst. Energy Secretary
Dr. David Danielson

Technical Accomplishment/Collaboration



Mid-America Truck Show
March 27-29, 2014

Milestones and Technical Accomplishments

- March 2013 to March 2014 – **Technical Accomplishments**
 - ✓ Demonstrated 86% freight efficiency improvement (Objective 2b – 24hr)
 - ✓ 75% fuel economy increase
 - ✓ Demonstrated 76% freight efficiency improvement (Objective 2a – Drive)
 - ✓ 66% fuel economy increase
 - ✓ Demonstrated Li-Ion Battery & SOFC capability
 - ✓ Completed wind tunnel and vehicle testing of Waste Heat Recovery
 - ✓ Validated an advanced transmission efficiency model
 - ✓ Path-to-Target analysis for a 55% thermal efficient engine
 - ✓ Demonstrated 49.4% BTE in engine only (Objective 3)
- March 2014 to September 2014 – **Future Work**
 - 55% BTE path to target roll-up analysis (Objective 3)
 - Final Report and Commercial Development

Summary

- Program remains on schedule
 - Meeting the ARRA and DoE VT MYPP goals
- Demonstrated a 50+% BTE engine system (Objective 1)
- Demonstrated a 70+% vehicle freight efficiency gains (Objective 2a & 2b)
 - Analytical roadmaps updated with experimental component data
 - Built and tested sub-systems
 - Cummins Waste Heat Recovery vehicle testing (Objective 2a)
 - Advanced transmission dynamometer and vehicle test (Objective 2a)
 - Solid Oxide Fuel Cell APU in lab and vehicle tests (Objective 2b)
 - Li-Ion battery APU (Objective 2b)
 - Tractor-Trailer aerodynamic aids (Objective 2a)
- Developed framework and analysis for 55% thermal efficiency
 - Completed analytical roadmaps for both diesel and dual fuel approaches
 - Completing targeted engine tests to validate roadmaps
- Developed working relationship with excellent vehicle and engine system delivery partners

FTE Deliverables On Track

Technical Accomplishment



COMPLETE!