# Super Truck Program: Vehicle Project Review

# Recovery Act – Class 8 Truck Freight Efficiency Improvement Project

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**aimler Trucks North America LLC**
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Project ID: ARRAVT080

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# Overview

## Timeline

- Project start: April 2010
- Project end: March 2015
- Percent complete: 20%

## Budget

- Total project: $79,119,736
  - DOE: $39,559,868
  - Daimler: $39,559,868
- Budget is split between engine and vehicle projects (DDC & DTNA)

## 2010 DTNA direct hrs + material

- Total: $2,707,000
- DOE: $1,354,000
- DTNA: $1,354,000

## Barriers

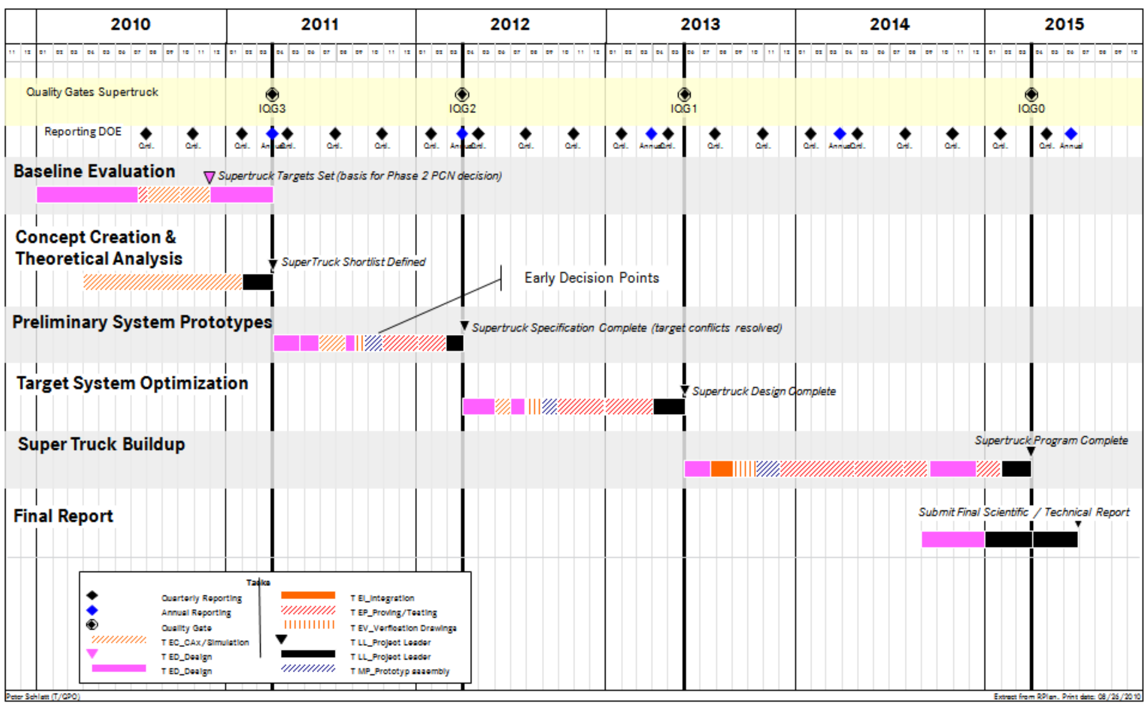
- Risk: aggressive freight efficiency target
- Complexity of vehicle integration

## Partners

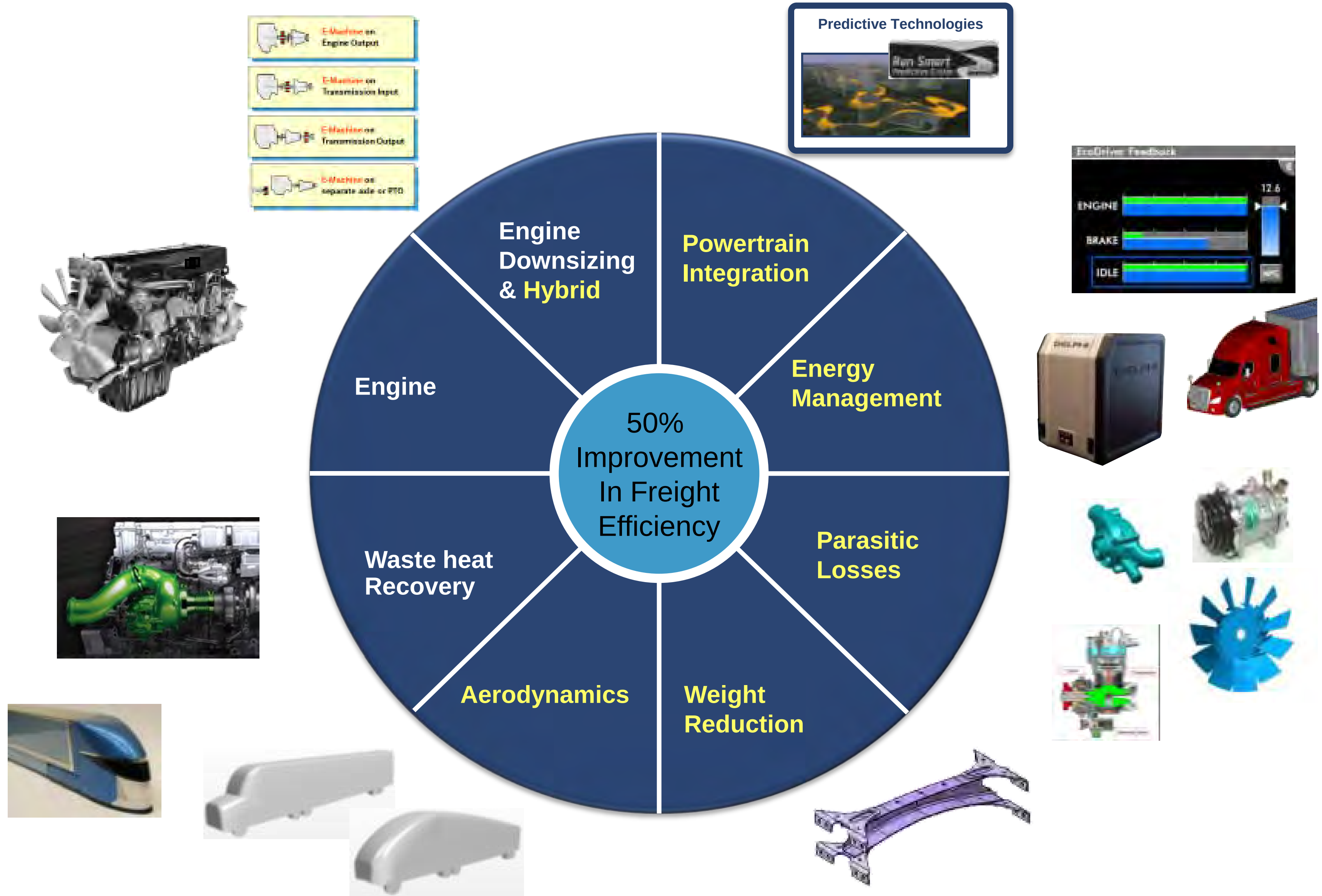
- Oregon State University
- Detroit Diesel, Daimler Research
- Schneider National, Walmart
- Great Dane
- ARC
- Solar World Industries America Inc.
- Department of Energy

# Program Objective

- Super Truck (ST) program goal:  50% improvement in freight efficiency
  - Measured in ton/miles/gallon over typical heavy truck drive cycle
  - Baseline is production 2009 Cascadia with DD15 Engine



# Eight Cross-Functional  Workstreams



# Baseline Evaluation

**126 Separate Measurements Taken**

## Highway Cycle (58 mph)

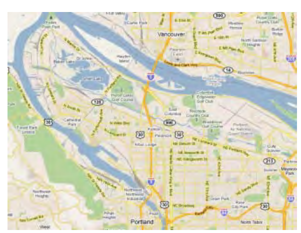
| | |
|---|---|
| Distance: | 401 miles |
| Tests completed: | 5 x round trip |
| | 2 x tractors |
| **Data** | |
| Collected: | 1.7 GB |
| Channels: | 126 |


## Highway Cycle (65 mph)

| | |
|---|---|
| Distance: | 438 miles |
| Test completed: | 5 x round trip |
| | 2 x tractors |
| **Data** | |
| Collected: | 1.7 GB |
| Channels: | 126 |


## Urban Cycle (30 – 45 mph)

| | |
|---|---|
| Distance: | 25 miles |
| Test completed: | 15 x round trip |
| | 2 x tractors |
| Data Collected: | 0.7 GB |
| **Data** | |
| Collected: | 0.7 GB |
| Channels: | 126 |



## Idle Cycle

| | |
|---|---|
| Cycle: | 10 hour idling |
| Duration: | 5 hours *(summer mode)* |
| | 5 hours *(winter mode)* |
| Test completed: | 4 x tractors |
| **Data** | |
| Collected: | 0.4 GB |
| Channels: | 126 |




# Vehicle Simulation Scenarios

| | Baseline Truck | Target Truck 1 | Target Truck 2 | Target Truck 3 |
|---|---|---|---|---|
| |  |  |  |  |
| **Coefficient of Drag & Frontal Area (Cd*A)** | Cascadia 125” BBC 72” RR | Cascadia with Component upgrade | Cascadia-based Full exterior upgrade | “Bullet” Truck |
| **Coefficient of Rolling Resistance (Crr)** | Baseline | Low RR Dual Tires | Low RR Super-Single | Advanced Tire Technologies |
| **Transmission & Axle Ratios** | Overdrive std. rear axle ratio | Direct Drive Faster rear axle ratio | + optimized control strategy | Advanced Powertrain Technologies |
| **Axle Efficiency (η)** | Baseline Axles | Conventional Axle Upgrades | 0.975 | Advanced Axle Technologies |
| **Auxiliary Loads { off , on }** | on | on | off | off |
| **Freight Mass** | 15.6 t | 15.4 t | 15.8 t | 16.3t |
| **Regeneration** | No Regeneration | Partial EB | Partial EB + SB | Full EB + SB |
| **Idling** | Main Engine | Current APU | SOFC /Hybrid | Advanced APU Technologies |
| **Intelligent Controls** | Baseline | Controllable Systems + Predictive Cruise | + Additional Predictive Technologies | Advanced Controls |

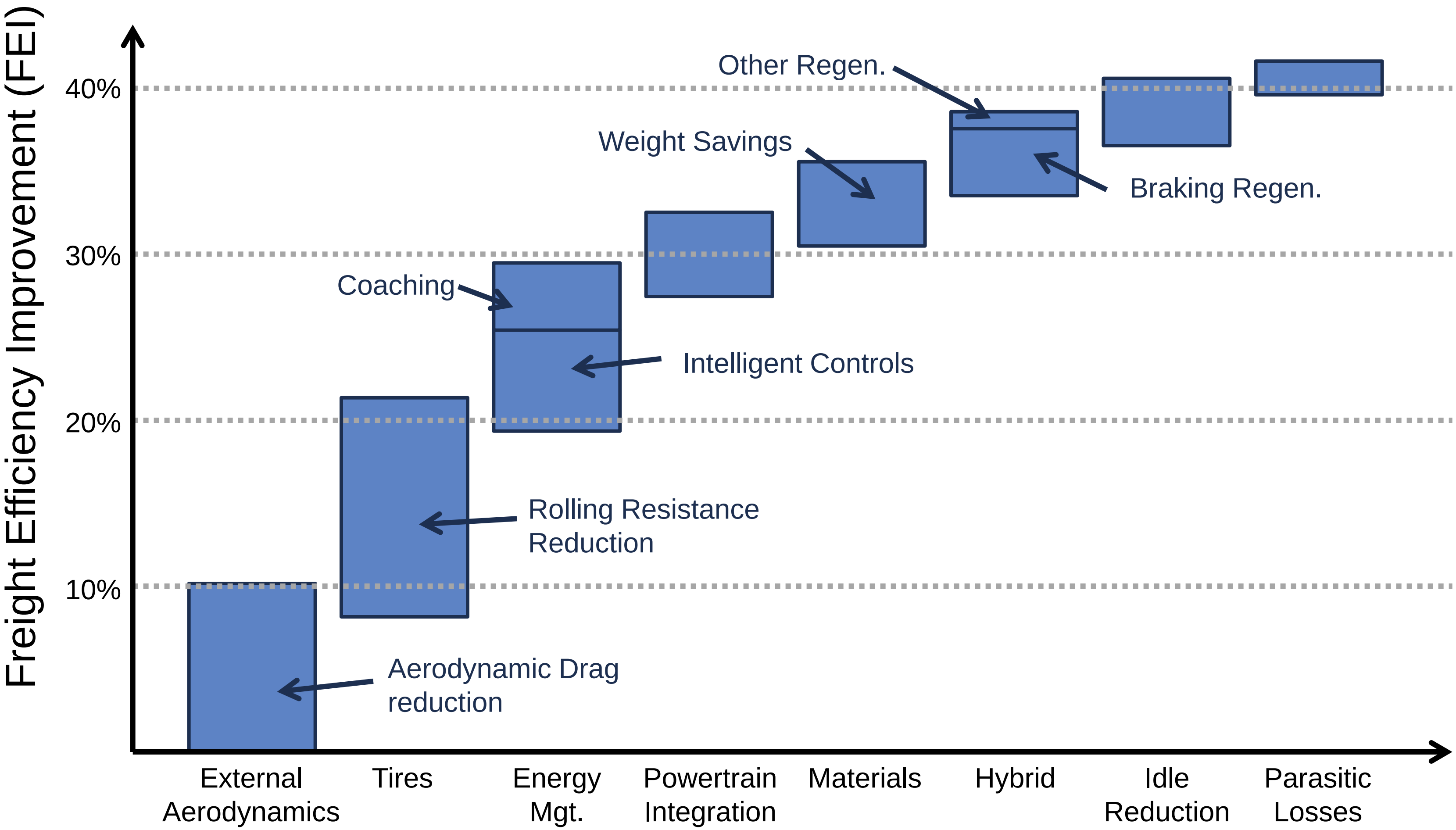
**Fixed Parameters**

| | | | |
|---|---|---|---|
| **Engine** | 15 liter 455/1550 | **GCVW** | 65000 lbs |

**Increasingly aggressive targets**

# Vehicle Simulation Results-Energy Consumption

# Roadmap: Vehicle-Side Technologies



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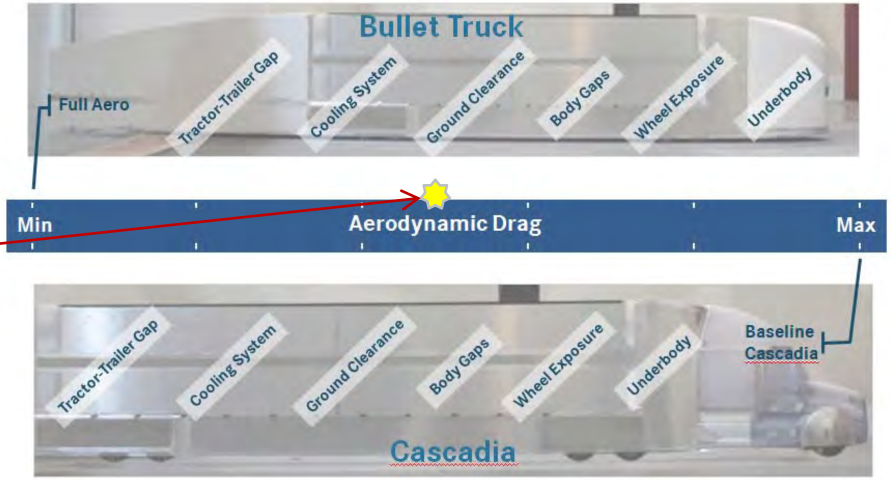
# External Aerodynamic Analysis

## Scale Wind Tunnel Testing

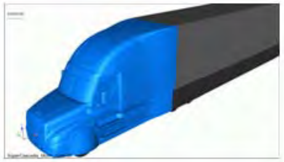
Objective:30% aero. drag reduction over baseline




### Results to Date

- 268 hrs of wind tunnel tests
- Identification of significant parameters

## Computational Fluid Dynamics



50+ full vehicle simulations *(30,000 CPU-hrs)*

- Drag Development
- Visualization

➔NEXT STEPS: lock-in macro tractor-trailer design features, investigate underhood thermal management

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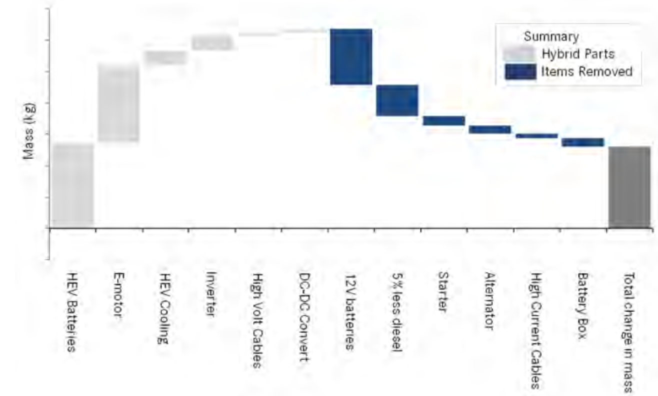
# Hybrid Electric Architecture

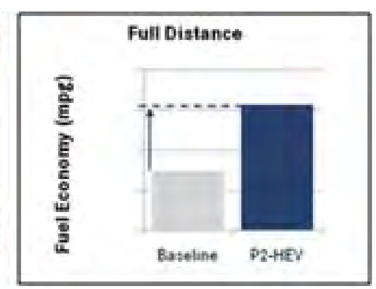
## Proposed Hybrid Architecture

- Parallel hybrid configuration
- Weight advantage
- Enabler for additional features (e.g. anti-idle)

## Weight Impact Analysis




## Preliminary Analysis


## Results To Date

- Analysis of various architectures complete
- Simulation on Portland Route indicate sufficient fuel savings to meet target

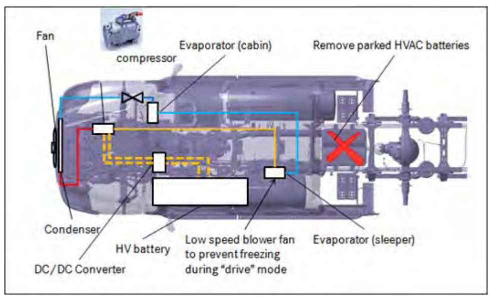
➔NEXT STEPS: Further analysis to size components (E-motor, Battery) and buildup of hybrid system

# Parasitic Losses

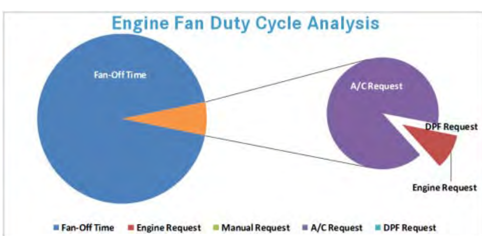
**Objective**: 2% Freight Efficiency Improvement through auxiliary optimization

## Air Conditioning System

- Investigation of Single Circuit Layout



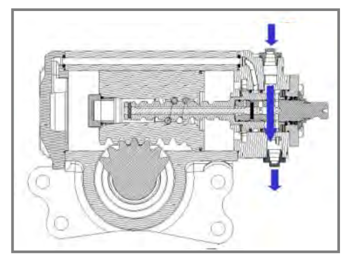

Target: Optimization of power consumer operation (fan, compressor)



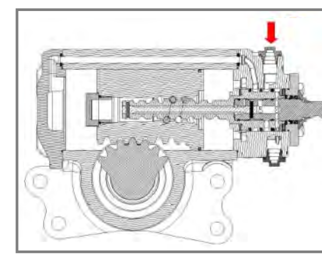

## Power Steering System

- Evaluation of efficient concepts

Open Center



Closed Center



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Open Center:
➔Constant Flow
➔Variable Pressure

Closed Center:
➔Variable Flow
➔Variable Pressure

Target: Minimization of Pump Power & Duty Cycle

➔NEXT STEPS: Evaluation / Selection of preferred concept sizing of system components

# Idle Reduction Technologies

**Objective**: 4% Freight Efficiency Improvement over baseline *(main engine idling)*

## Solid-Oxide Fuel Cell APU

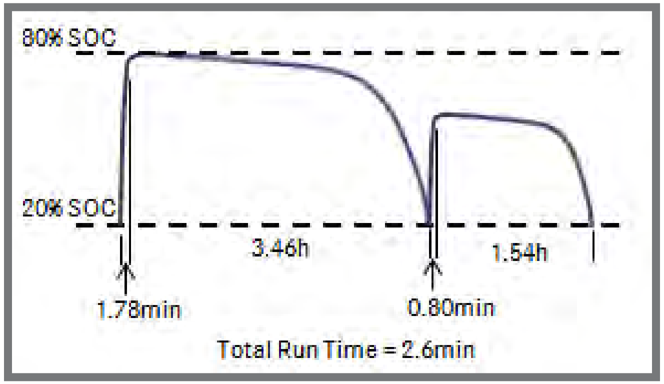
Image shown with permission from Delphi Corporation

**Results:** SOFC-APU installed & tested on Cascadia, fuel measurement

**Characteristics**:

- Enables full-engine off Operations

## Hybrid System




**Results:** concept defined, preliminary energy calculations completed

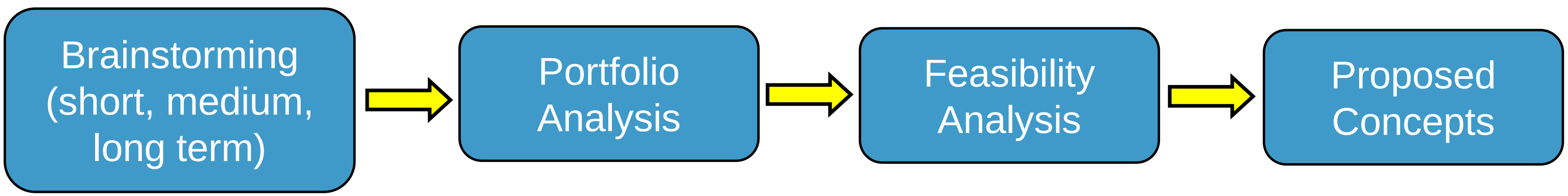
**Charactersistics:**

- Fast on/off time
- No dedicated added weight

➔NEXT STEPS: evaluation / selection of preferred SuperTruck concept based on representative test cycles

# Investigation Phase – Portfolio Analysis

- A portfolio analysis was performed to identify potential weight reduction concepts
- Concepts were discussed and grouped according to short / medium / long term
- Certain concepts were further investigated by a feasibility analyis.



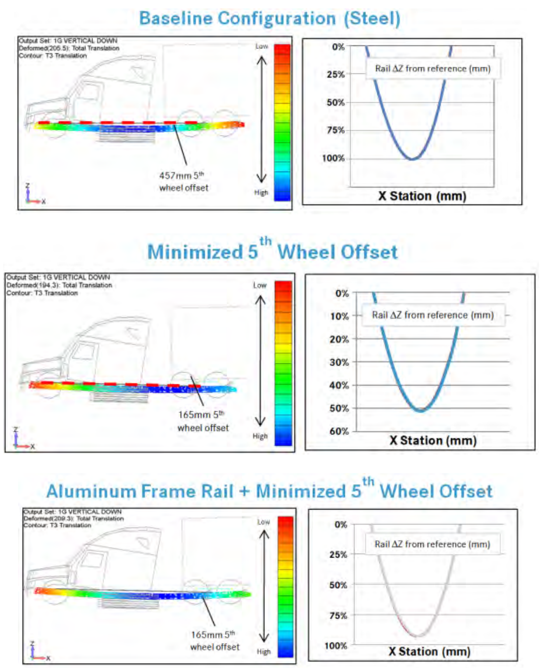

- Some of the proposed concepts include:

| | |
|---|---|
| Aluminum Frame Rails | Lightweight MMC components |
| Horizontal tailpipe | One-piece driveshaft |
| Load optimized frame rail | Multi-link suspension |
| Composite fuel tanks | Integrated suspension/ airbag system |
| Load optimized $5^{th}$ wheel approach | Spaceframe chassis concept |

# Chassis – Load Sensitivity / Optimization Study

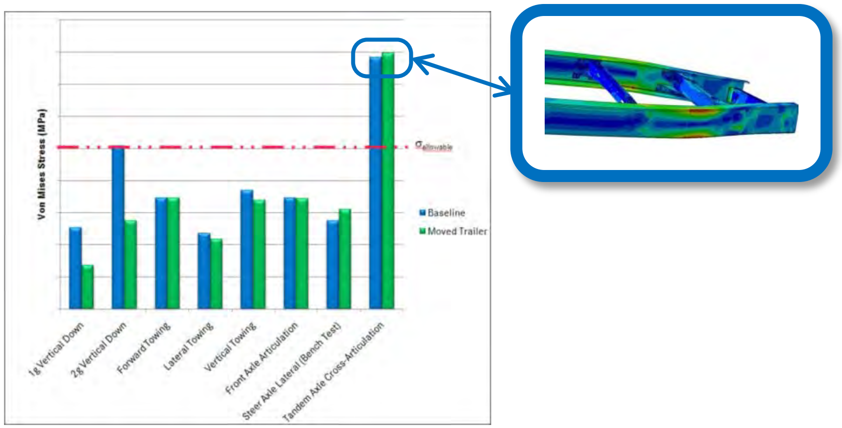
**Objective**: to save 1000 lbs while meeting loading criteria using innovative chassis design and new materials

## Conventional Frame




➔NEXT STEPS: Evaluate cross-sectional geometries to meet deflection criteria with standard 5th wheel position

## Load-Optimized Frame

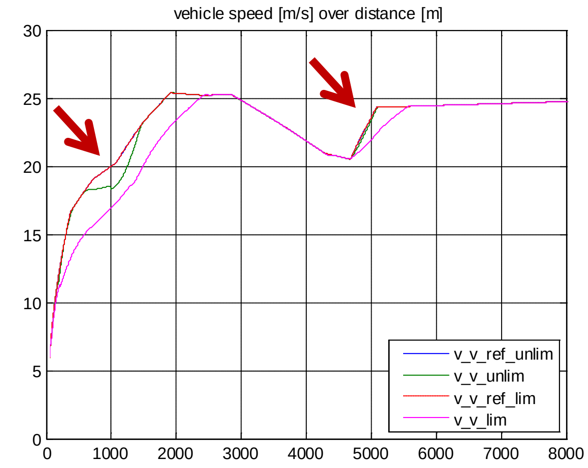



➔NEXT STEPS: Concept development and load path analysis based on Topology Optimization.

# Energy Management

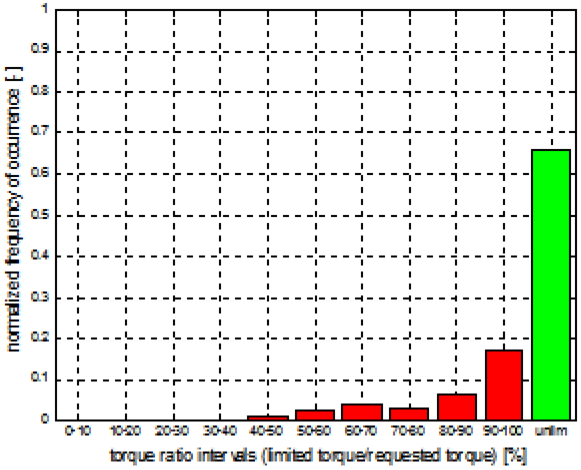
## Predictive Torque Management

- Limits torque based on vehicle mass and road grade to limit excessive accelerations.
- Torque Limit applied using J1939 TSC1 message.




## Results To Date

- Simulations shows fuel saving based on limiting factor, terrain & driving behavior
- Prototype hardware installed and functional in vehicle




➔NEXT STEPS: Conduct a fleet trial to evaluate 'real-world' performance and driver feedback, define calibration levels

# Summary and Future Work

## First Year of SuperTruck Complete

- Baseline vehicle & route specified
- Completed baseline testing
- Definition of technical measures on a system basis
- Vehicle improvement targets defined based on simulation
- Key accomplishments for concept development
  - Hybrid & Energy Management Simulation
  - FEA of Lightweight Frame
  - Aerodynamic and CFD Analysis

## Future Work for 2011

- Complete high-level SuperTruck vehicle specification,
- Resolving technology conflicts
- Complete digital mockup
- Build up prototype systems for performance evaluation on 3 ‘tinker’ trucks
  - Hybrid, powertrain, chassis, aerodynamics

# Collaboration and Support

## Oregon State University

- Composite Frame Analysis
- Fuel Efficient Routing

## Schneider National / Walmart

- Fleet Partner – Technology Evaluation

## Great Dane

- Trailer Lightweighting & Aerodynamics

## ARC

- Aerodynamics

## Department of Energy Head Quarters

- Gurpreet Singh
- Roland Gravel
- Carl Maronde (NETL)

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