Engine Expo
Stand E218

Low-Voltage Hybridisation for Affordable Fuel Economy & Drivability

October 2012

Nick Pascoe, CEO

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Themes

- Convergence of Global standards for fuel economy/CO_2
- Mechanical Energy Recuperation:
  - the next focus for CO_2 reduction
  - ....at 48V?
- Exhaust Gas Energy Recuperation
  - feasibility and benefit validation?

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Company Profile

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CPT Created March 2007

- Products, Technology and Facilities acquired from Visteon Corporation.
- Licence for Switched Reluctance Motors from Emerson Corporation (now Nidec)

Organisation

- Experienced management and technical team, many ex-Visteon.
- German entity created mid-2010.
- VTES (automotive electric supercharger) business sold to Valeo December 2011.
- Post sale to Valeo: 32 employees.

Competencies

- Powertrain development & application.
- Power Electronics development.
- Control Electronics and Software development.
- Automotive Industry Design/Validation.

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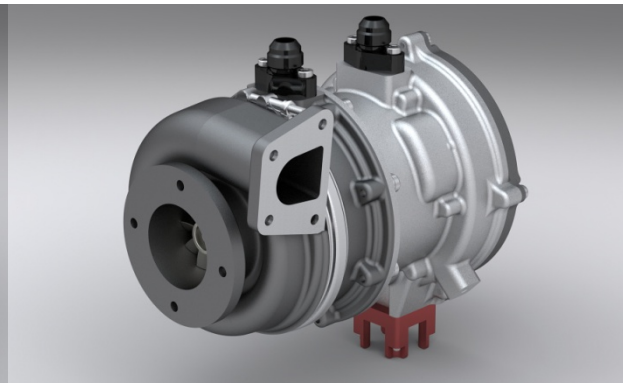
Product Portfolio

COBRA
Heavy Duty, Water Cooled Electric Supercharger

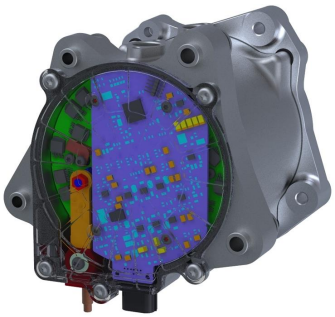
CPT SpeedStart®
Integrated Starter/Motor & Generator

TIGERS
Exhaust Gas Energy Recovery Turbine



Integrated Electronics

- Control electronics
- Power electronics (water cooled)



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Drivers for Change

Legislation

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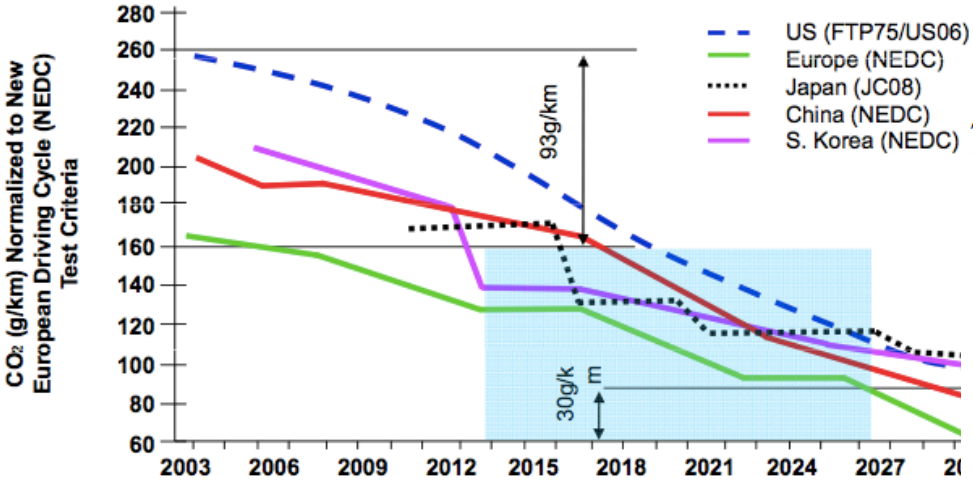
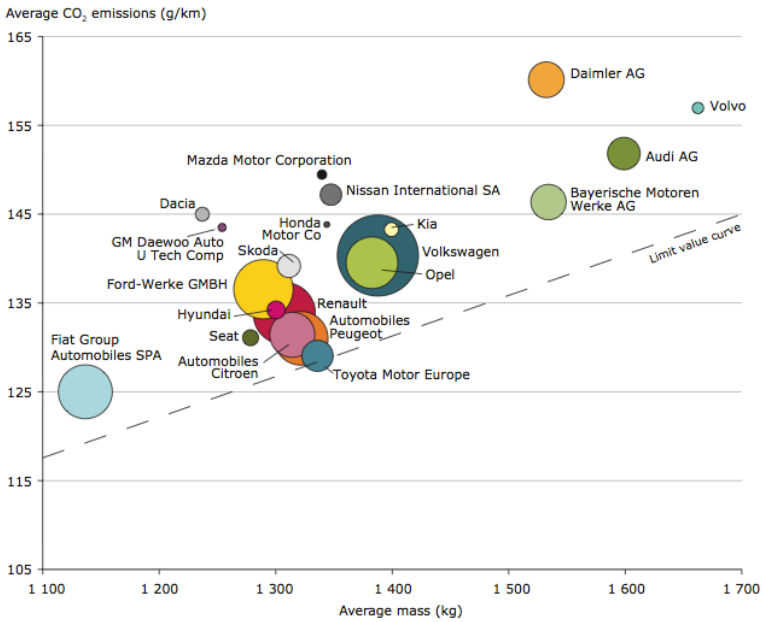


Emission Standards Targets

- Global CO2 emission targets converging.
- 27% further reduction by 2022.
- Larger vehicle brands may not have the benefit of 'Average Mass' skew in the future?



2010 OEMs Average Emission and Weight-based Emission Targets 2015
(source: eea.europa.eu)

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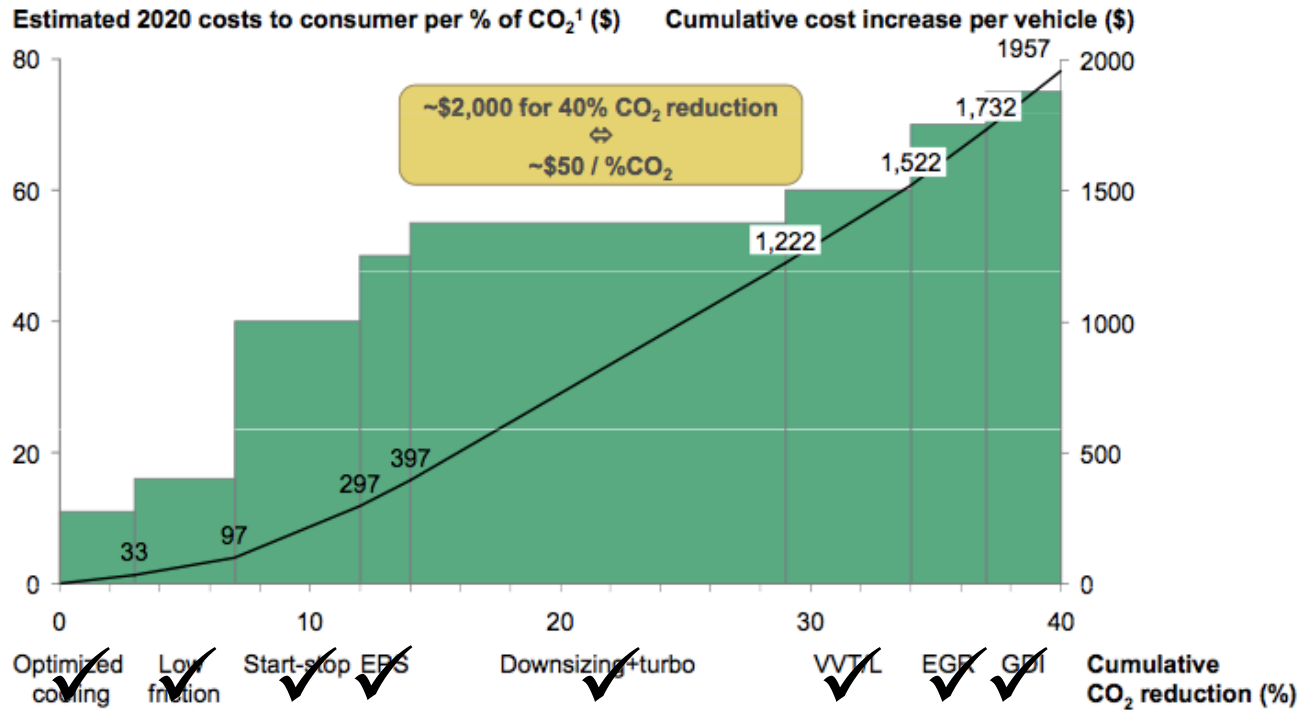
Estimated 2020 Costs to Customer per % of CO2 and Cumulative CO2 reduction (%)



European Status

Average incremental cost per $\%CO_2$	0-10%	10-20%	20-30%	30-40%
	$23	$44	$58	$70

1. Estimated 2020 price to customer before VAT. Assume 1% decrease in manufacturing costs from 2010 to 2020 and OEM mark-up ranging between 50 to 100%; shown for D segment in North America. Expect minor variances by segment and region

Source: Boston Consulting Group, 2011 report "Powering Autos to 2020"

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Hybrid Technology Options

System ▸ Metric ▼	Micro Hybrid	Mild Hybrid	Full Hybrid	Plug-in Hybrid
Voltage	12V	24-130V	200-600V	300-400V
e-Motor Power	3kW	10-15kW		
Regen. Power	0.5-3.0 kW	~10 kW		
Launch Assist	0	<15kW		
e-Drive Range	0	0		
Customer on-cost	$275- 1,240	$1,040 - 6,870	$8,250- 11,000	$16,500 – 20,600
CO_2 Benefit %	4 -7 %	6-10%	10-15%	15%
Customer Cost/ Benefit	$40 - 310/1%	$104- 1,145 / 1%	$550- 1,100 /1%	$1,100- 1,380 /1%

Excludes potential additional engine down-speeding/ down-sizing benefits (eg 30% smaller = -15% CO_2)

Target Market ≤60 volts

future

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Source: Various EU publications/papers with € converted to $

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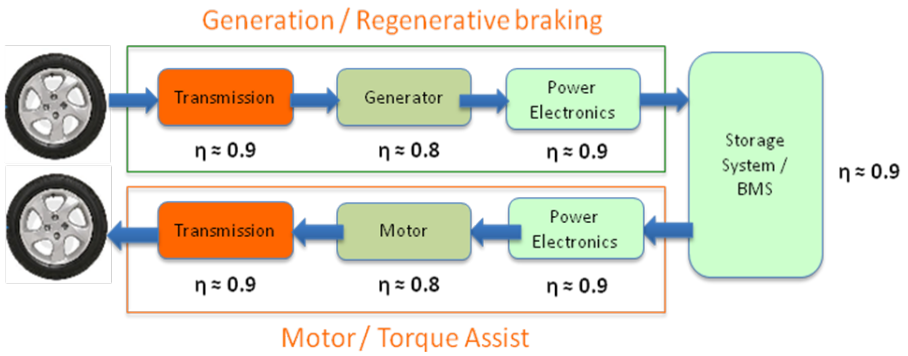
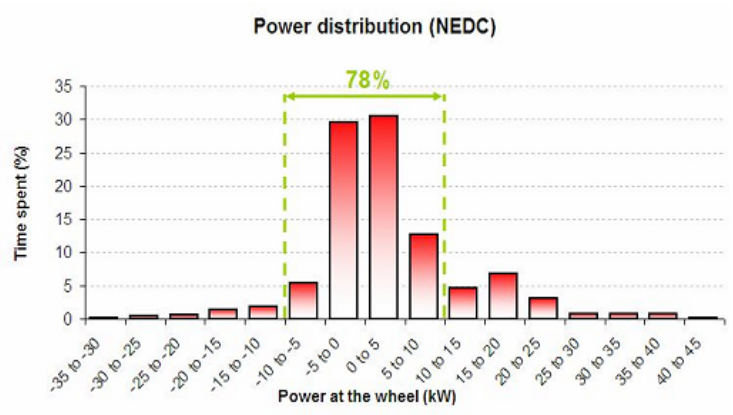
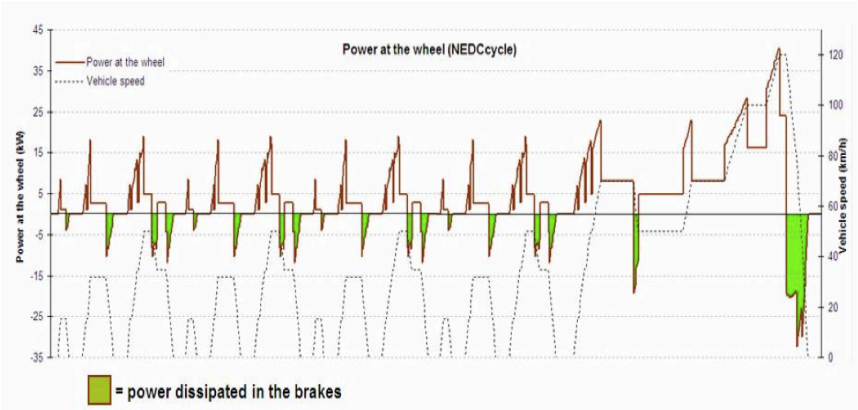
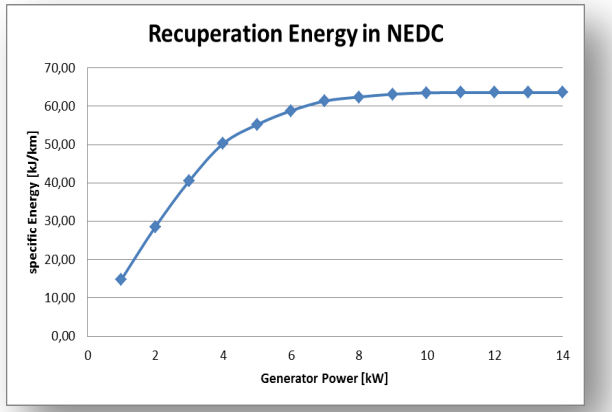
Energy Harvesting & Usage

Efficiency of the ISG chain









Recuperation energy potential in NEDC

[vehicle mass 1450kg; parallel braking with travel dead end]

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Electrical Energy Usage

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- Vehicle energy demands already exceeding 12V/3kW alternator.
  - Powertrain & Chassis Systems
  - Passenger Safety, Security & Comfort Systems
- Hybridisation includes the use of controllable, electrical devices to reduce energy demands:
  - Cooling fans,
  - Water pumps,
  - Electric Power Assisted Steering, etc.
- Higher power electrical devices would benefit from higher voltage systems but:
  - >60V requires much greater safety consideration.....
  - ...leading to significant cost increase.

48V provides an ideal compromise for performance and cost.

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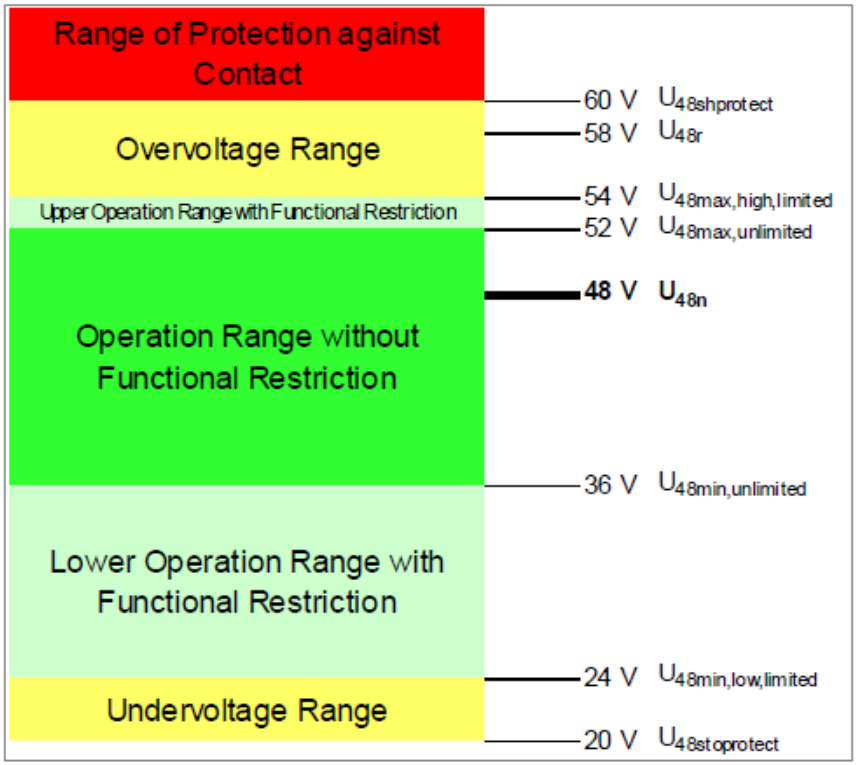
48V Specification for Motor/ generator



VDA | Verband der Automobilindustrie

Specification still evolving but real pressure to conclude quickly.

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CPT SpeedStart®

Mechanical/Kinetic Energy Recuperation

Delivering CO_2 Reduction Technologies

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Overview – 12V

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Features

- 12V High Power, Fully Integrated Belt Driven Starter Generator
- Liquid cooled system including power & control electronics

CO_2/FUEL ECONOMY BENEFITS

- Stop-Start + Efficient Generation: 5 – 20%
- Stop-Start + Regeneration: 8 – 25%

DRIVER BENEFITS

- High Torque, Fast Response
- Desirable, 'Comfort' Stop-Start
- Unique 'Driver Change of Mind' capability
- Efficient, High Current Generator

AVAILABILITY

- 2015

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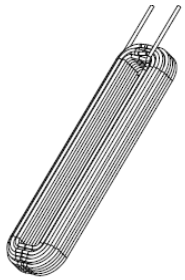
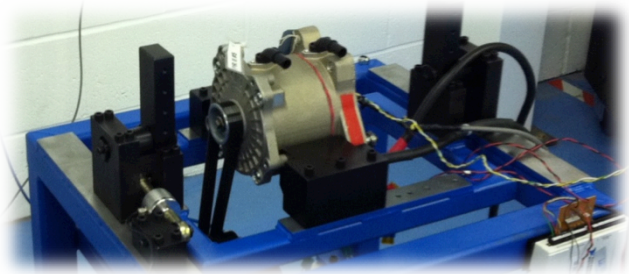
48V Scaled Machine Design

- Designed to be scaled from day one
- Re-use of existing rotor and stator laminations
- Re-use of HPDC housing and cooling system
- Electronics scaled
  - Voltage specification increased (Caps and FETs)
  - Power supply redesigned
  - New op-amps / gate drivers specified
- Nominal Performance Targets at 48V
  - 10kW ~~5kW~~ Generation Power
  - 10kW ~~7.5kW~~ Motoring Power for up to ~~5~~ 30s seconds
  - Up to 95Nm break away torque





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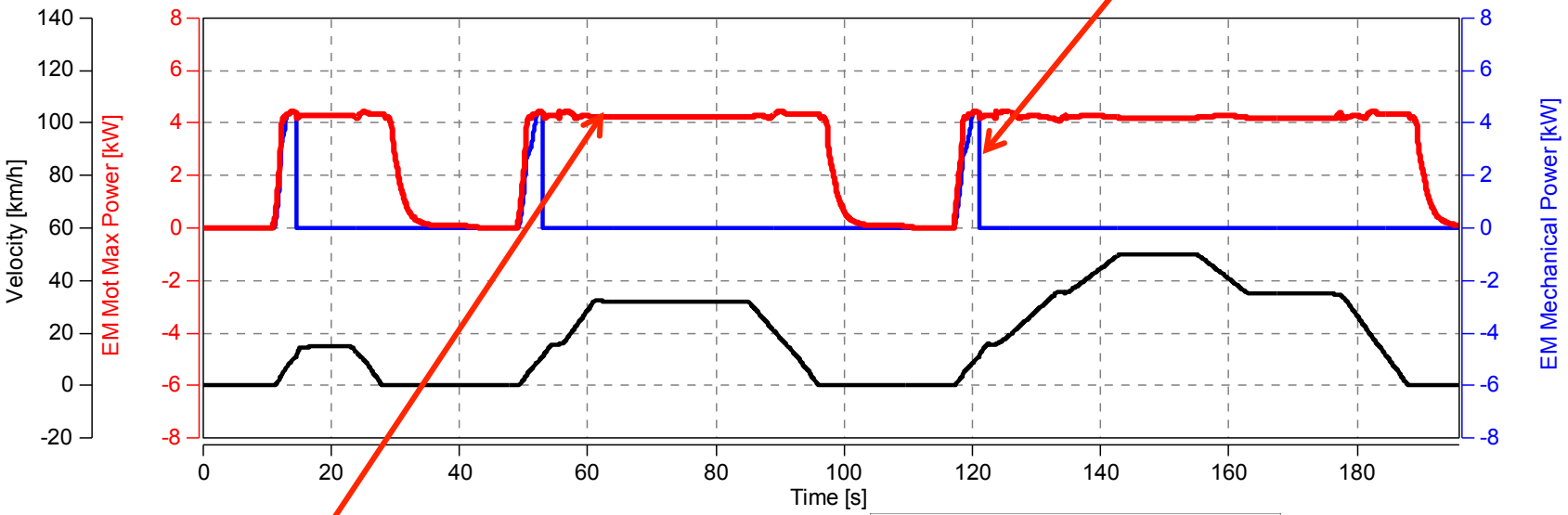
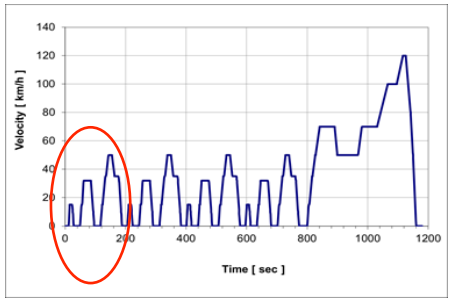
Electric Launch Assist and/or Drive with Load Point Moving

Example for Electric Launch Assist (Acceleration) in NEDC

Selected electric launch events



Threshold for max. E-Machine power



Simulation results courtesy of AVL Schrick GmbH

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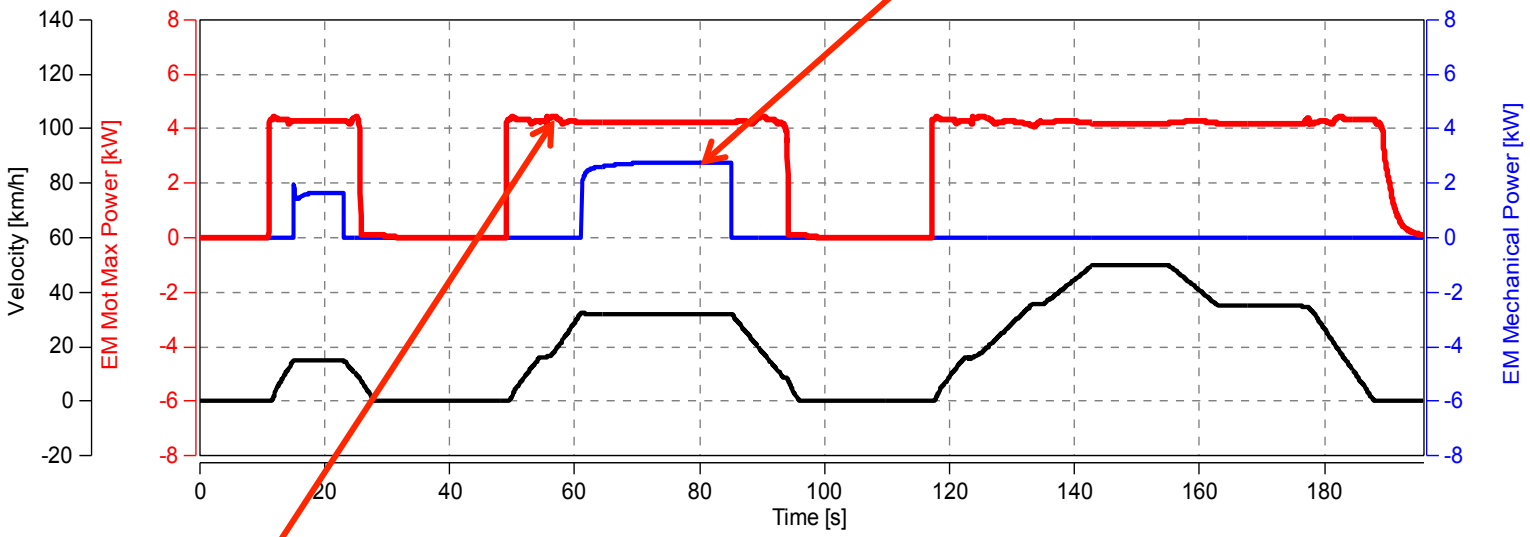
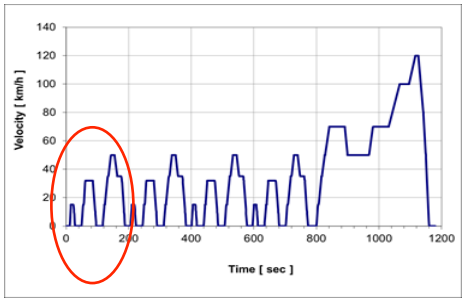
Electric Launch Assist and/or Drive with Load Point Moving

Example for Electric Drive Event in NEDC

Selected electric drive events



Threshold for max. E-Machine power



Simulation results courtesy of AVL Schrick GmbH

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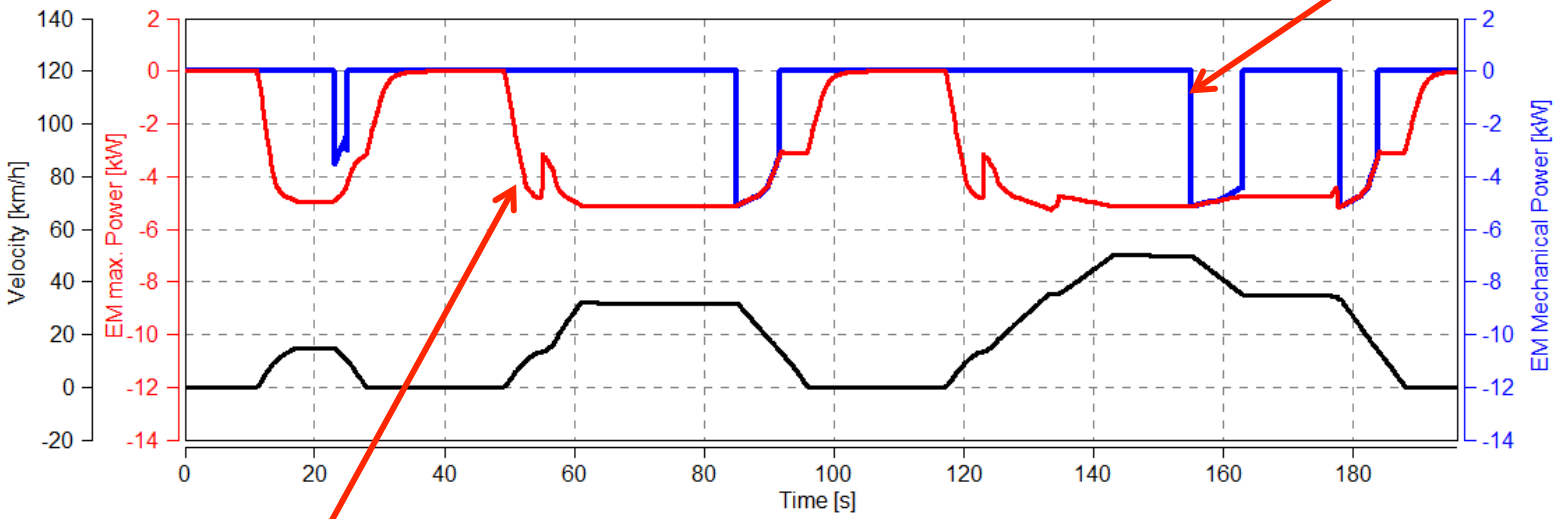
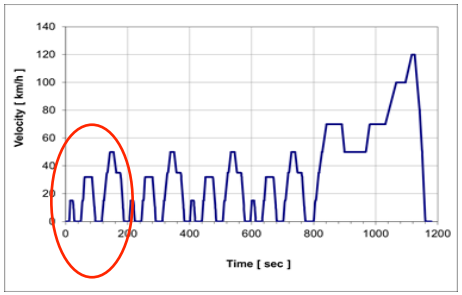
Recuperation by Electric Brake Assist

Example for Recuperation in NEDC

Simulated electric brake assist



Threshold for max. generating power



Simulation results courtesy of AVL Schrick GmbH

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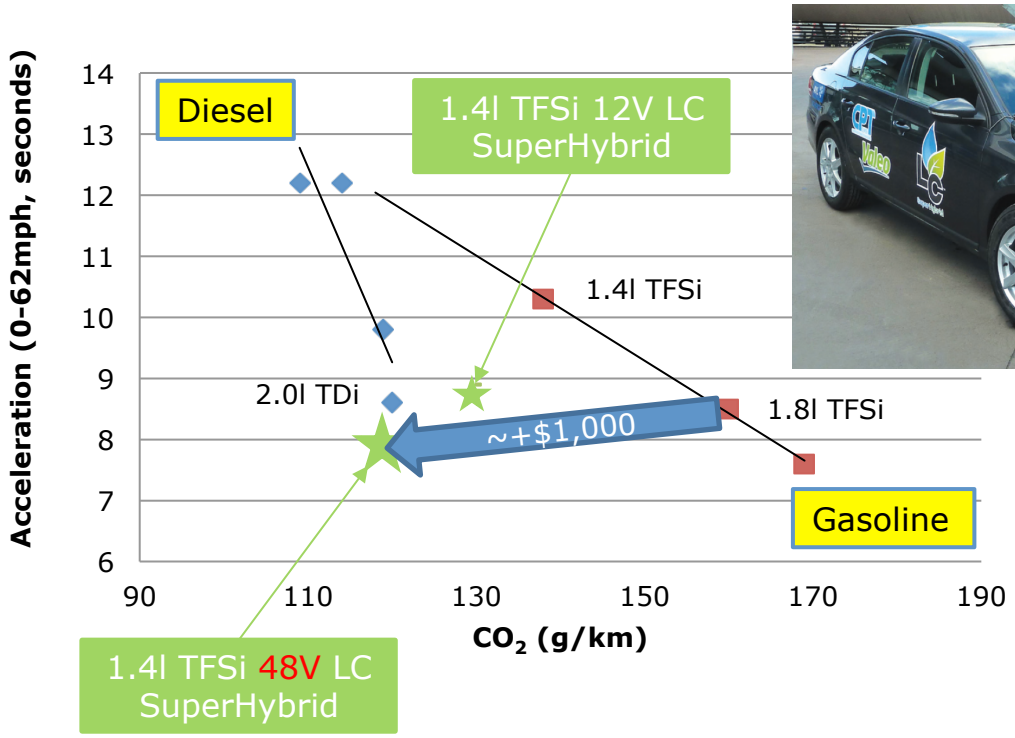
ALABC/LC SuperHybrid

Performance vs Fuel Economy



SuperHybrid

Low Cost

Low Consumption

Low CO_2

Life-Changing

Lead Carbon Batteries

Source: Company websites & LC SuperHybrid testing & simulation

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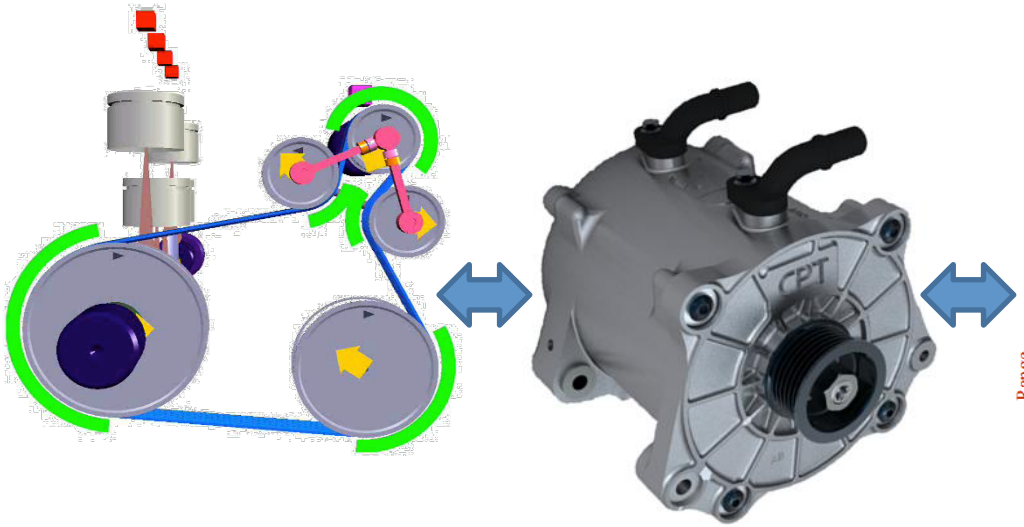
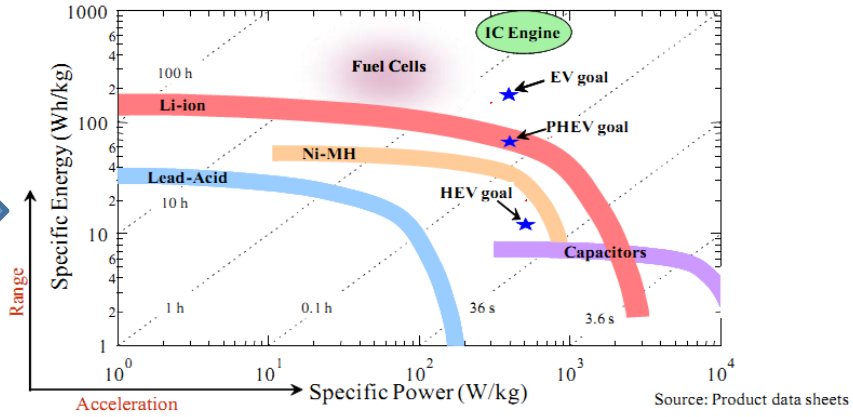
System Level Constraints





Belt Drive

- Belt & Tensioner technology.
- Dynamic response.
- Cold temperature performance.
- 48V torque/power capability.

Battery/Energy Storage

- Cost
- Weight
- Recuperation characteristic.
- Durability

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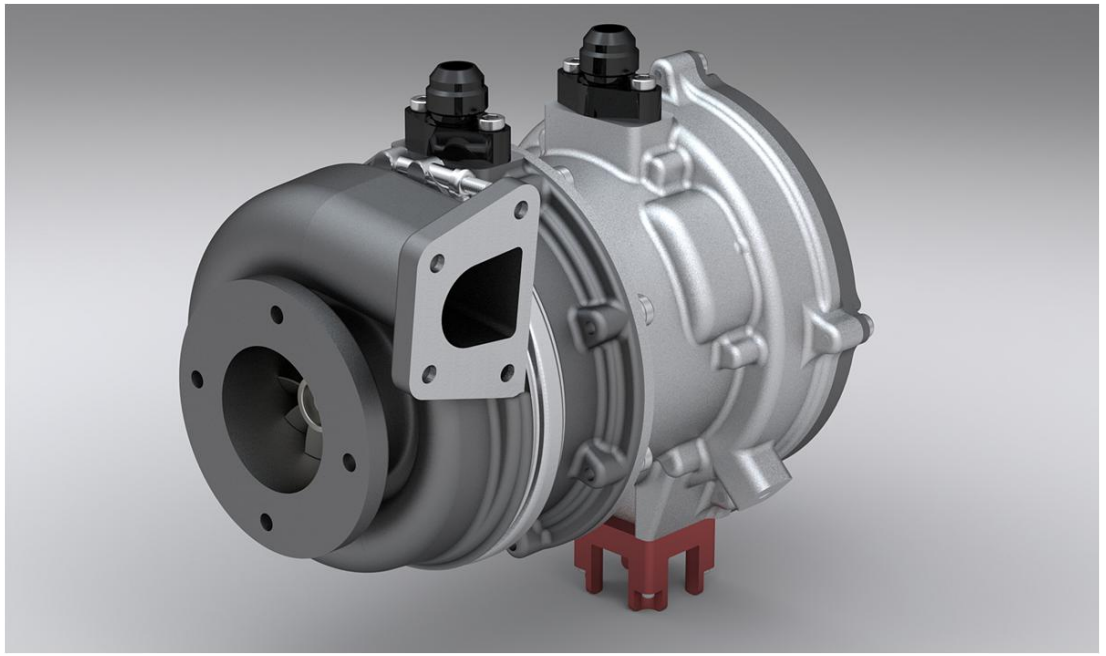
CPT TIGERS



Exhaust Gas Energy Recuperation

Delivering CO_2 Reduction Technologies

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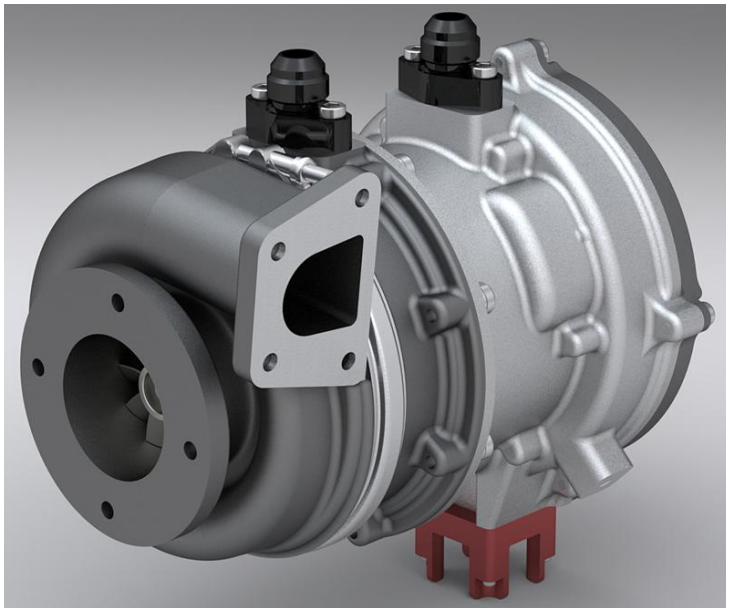
TIGERS Design Challenges

High/Limited Speed Shaft ~ 60k rpm

Heat Dissipation from Motor Core



Integrated Power/ Control Electronics temperature Limited ~ 120 Deg C

Very Low Back Pressure Expander

Bearings temperature Limited ~ 190 Deg C

HOT GAS ~ 800 Deg C

Windings temperature Limited ~ 180 Deg C

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Initial CPT modelling

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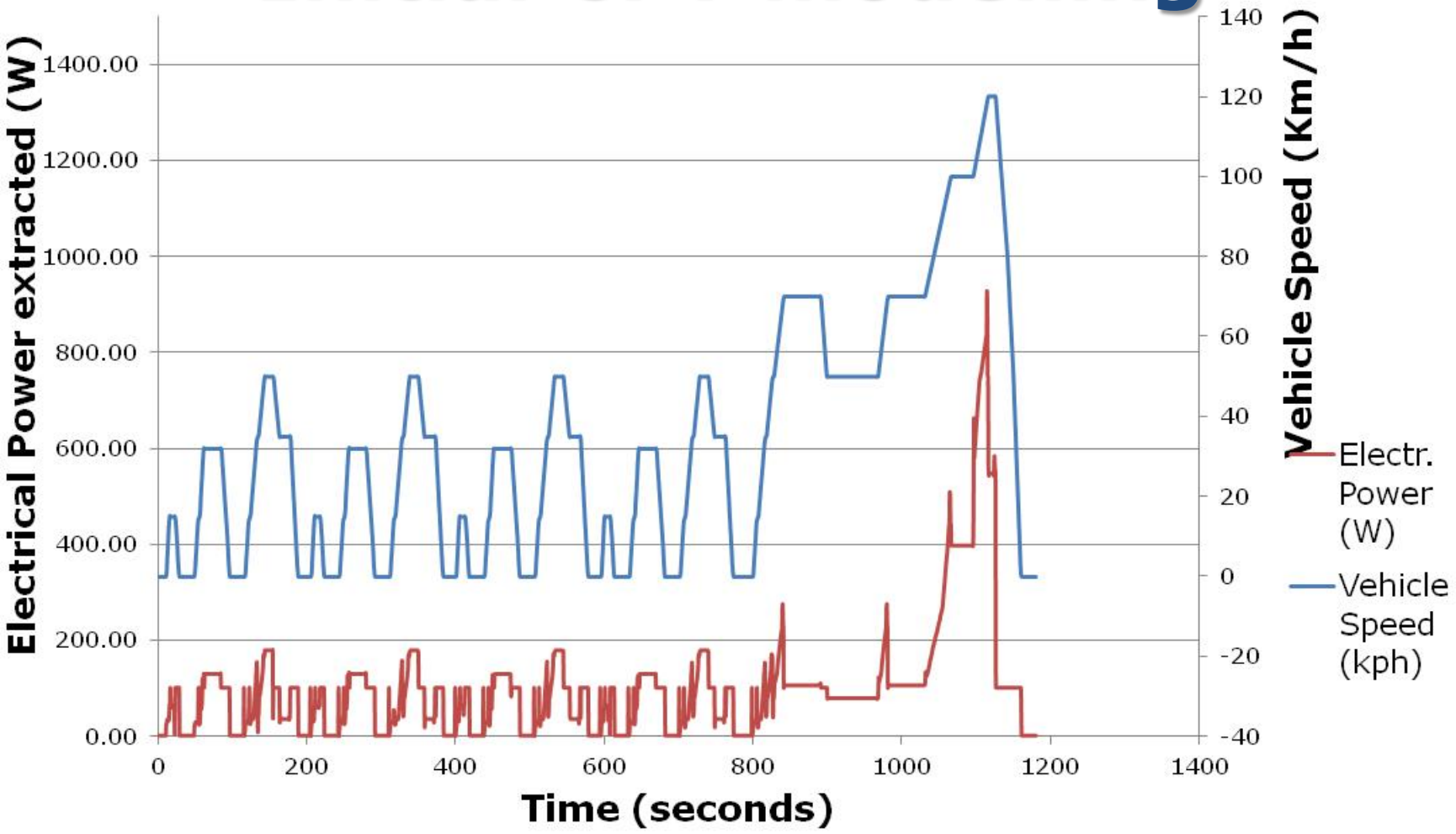

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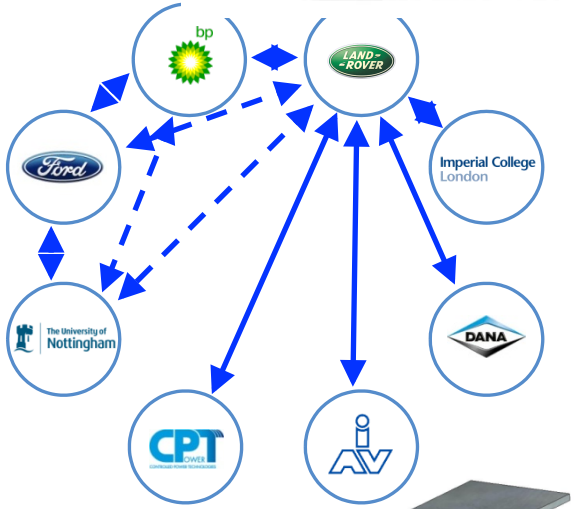
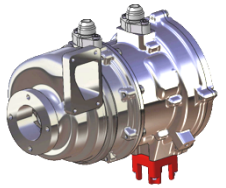
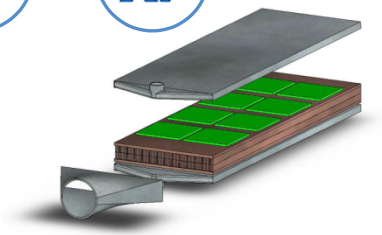
UK TSB funded 'VIPER' Project

- TIGERS targeting 2-4kW.
- Comparison with Thermo Electric Generators (TEGs) – system cost for TEGs remains a major issue .
- TIGERS-V platform will be used to develop:
  - Sensing system capability study
  - Stator and rotor design for steady state
  - Low Pressure Ratio High Efficiency Turbine optimisation
  - Bypass system design and development







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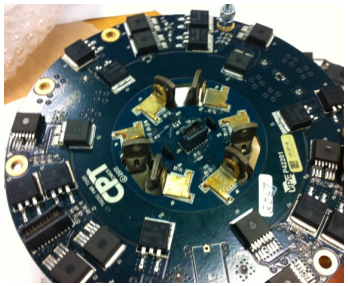
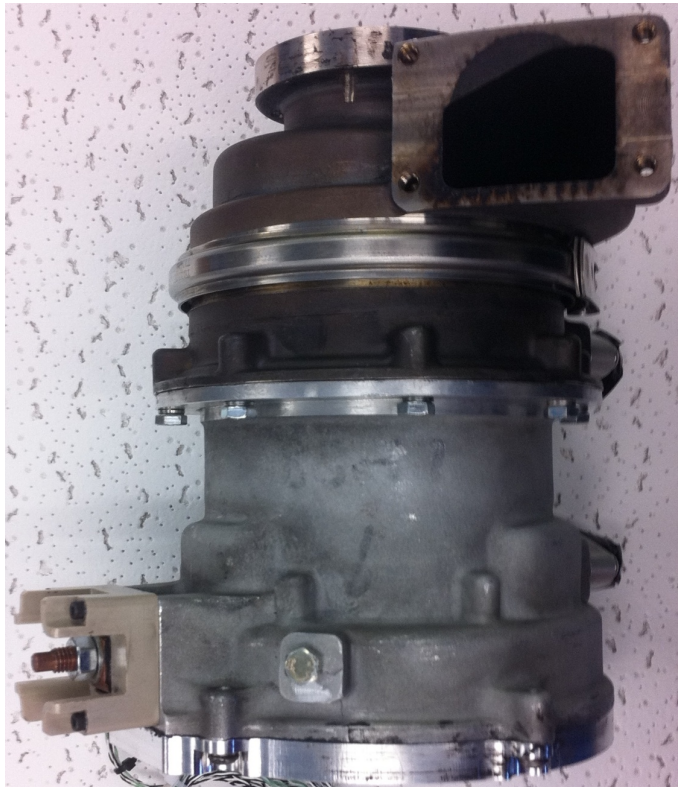
TIGERS Design Specification

Design Specification	TIGERS-H	TIGERS-V
Maximum Speed	63,000 rpm	
Peak Shaft Power	1kW	2kW - 4kW
System Voltage	12v	12v/24v/48v
Generating Efficiency	>70%	
Bearings	Sealed for life rolling element	
Rotor Position Control	Digital	
Machine Weight	~10kg	
Machine Length	~150mm	
Cooling System	Engine coolant	
Power Electronics & Control	Integrated	
Bypass System	Full flow	





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Current Status

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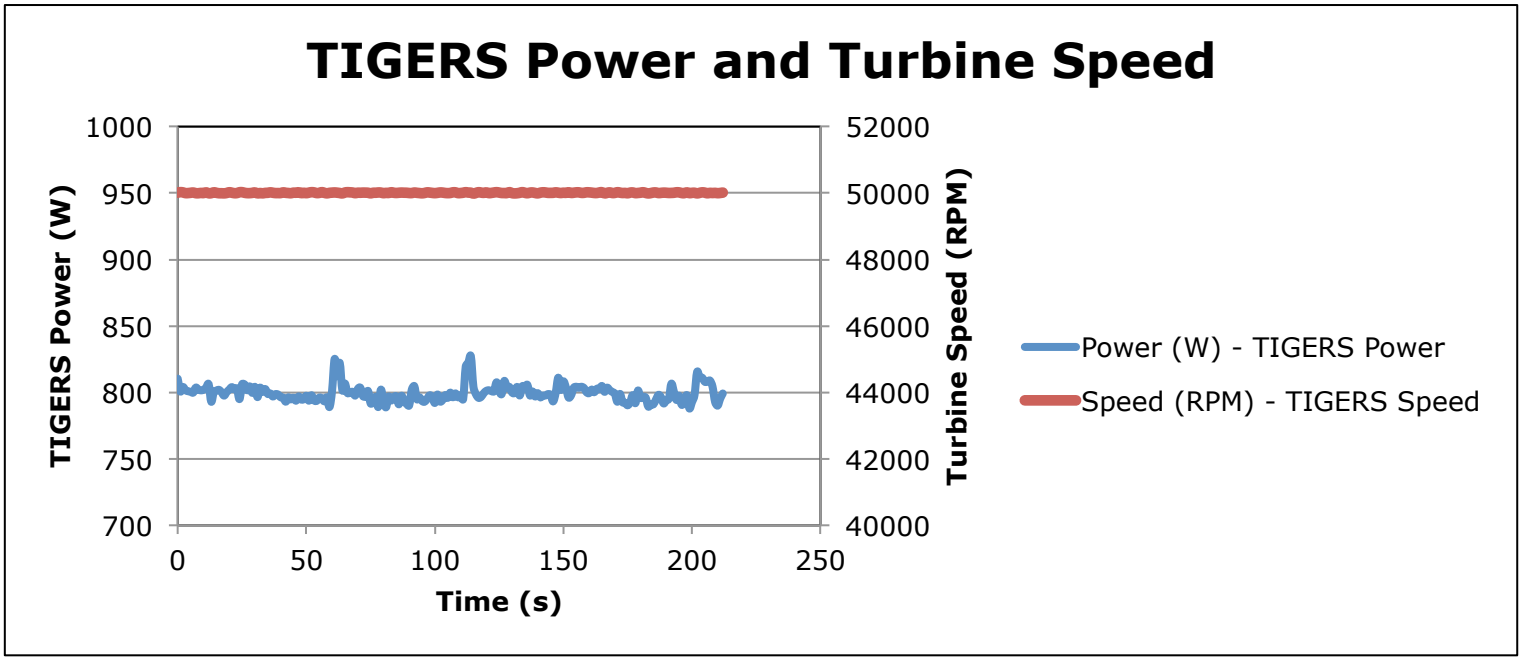

- Validating simulation results.
- Developing by-pass and control system.
- Preparing for vehicle installation (February 2013)

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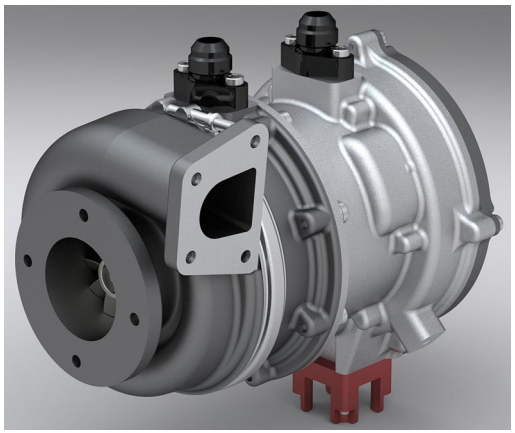
Considerations for Recuperation

- Operating Cycle
  - Validation
  - Certification
  - Customer value
- Requirements definition
- Electrical Architecture
  - Voltage
  - Energy storage technology
- Control System Integration
- Thermal management



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CPT POWER
CONTROLLED POWER TECHNOLOGIES

Low-Voltage Hybridisation for Affordable Fuel Economy & Drivability

October 2012

Nick Pascoe, CEO

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