# Heavy Duty Vehicles - Land

ETI10 TEN YEARS OF INNOVATION 2007 – 2017

#ETI10

# Welcome and Introduction

HDV Project Manager
David Butler

# Agenda

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| Introduction and welcome | David Butler (ETI) |
| Programme overview | David Butler (ETI) |
| High Efficiency Selective Catalytic Reduction Project | Professor Graham Hargrave (Loughborough University) |
| Heavy Duty Vehicle Project | Mike Kenyon (Caterpillar) |
| On Highway HDV Efficiency | Simon Mills (AVL) |
| Future Work | Chris Thorne (ETI) |
| Close | |

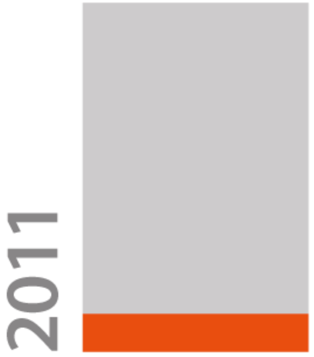
# HDV Land Programme Overview

HDV Project Manager
David Butler

# Agenda

- Why are HDVs important
- Programme Scope
- Programme Objectives and Outcomes
- Projects within the Programme
- Learning opportunities / Outcomes to date

# Why are HDVs important?




8% of current UK $CO_2$ emissions are from HDVs


Proportion is set to increase to approx 30% as other sectors reduce $CO_2$

- Modelled scenarios consistently point to HDV efficiency as cost-effective way to reduce emissions
- Limited options for low-carbon fuel alternatives

# Fuel challenges and emission sources

The ETI is attempting to demonstrate 30% improvement in fuel efficiency before aerodynamic and light-weighting advances

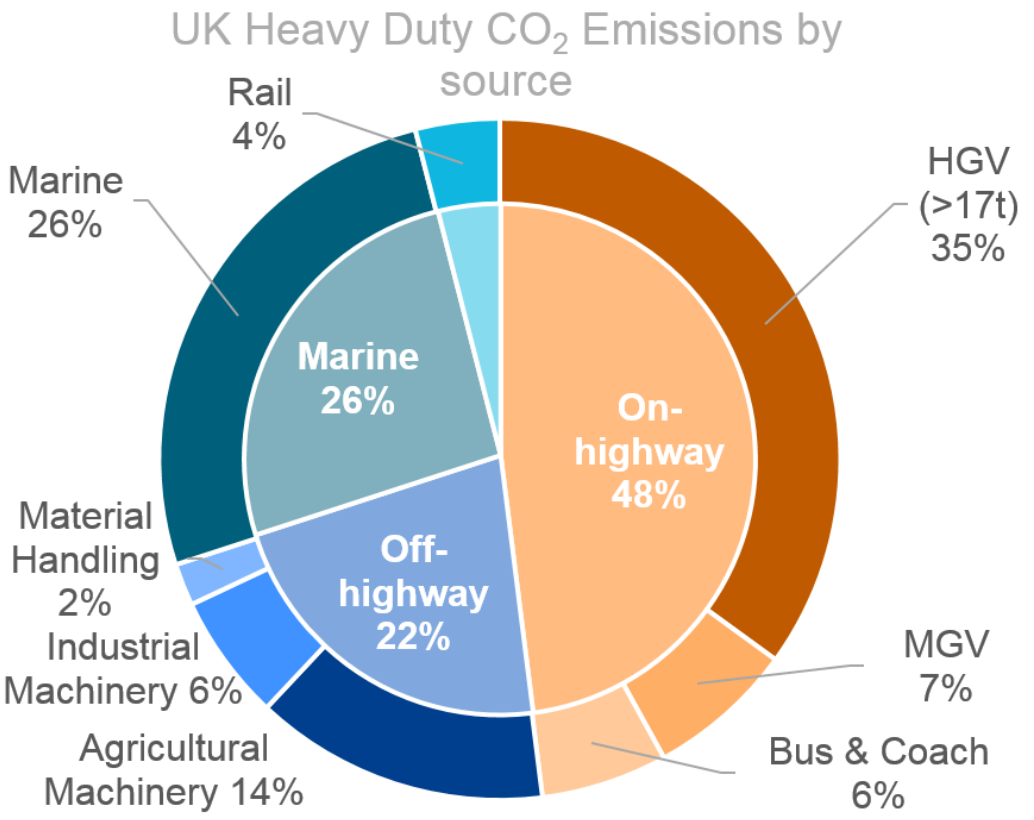
NG

Natural gas and bio-fuels could supplement liquid fuel given compatible vehicles and subject to lifecycle emissions analysis

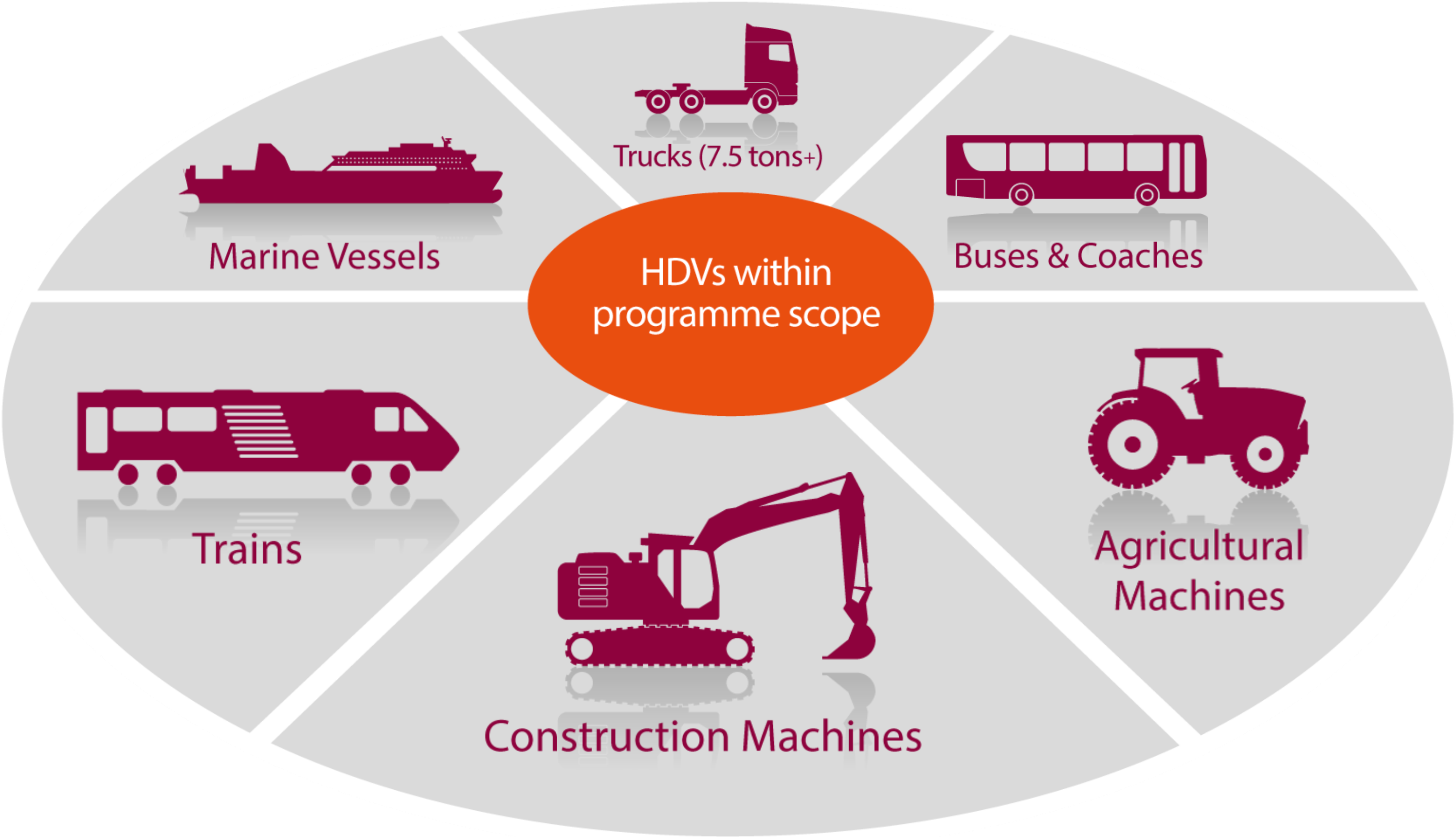
On board storage requirements are challenging as is the ability to support off-highway duty cycles

Hydrogen storage density coupled with fuel cell robustness are major challenges for HDVs

$H_2$



# HDV Programme Scope



# HDV Activities at ETI

**HDV Efficiency**

Technology Development and Demonstration Programme

2012 – 2019

**Gas as a HDV Fuel**

Strategy Phase

2013 – 2018

# Programme Objective

**HDV Efficiency**

Development and Demonstration

2012 – 2019

To bring about a meaningful change to the fuel efficiency and GHG intensity of the UK HDV fleets

1. Develop new **vehicle concepts**
2. Develop new **technologies** to support concepts
3. Produce **demonstration vehicles** that are 30% more efficient
4. **Develop supply chain** to enable meaningful market deployment

Enable substantial reduction in $CO_2$ emissions across sector

# HDV Programme Phases

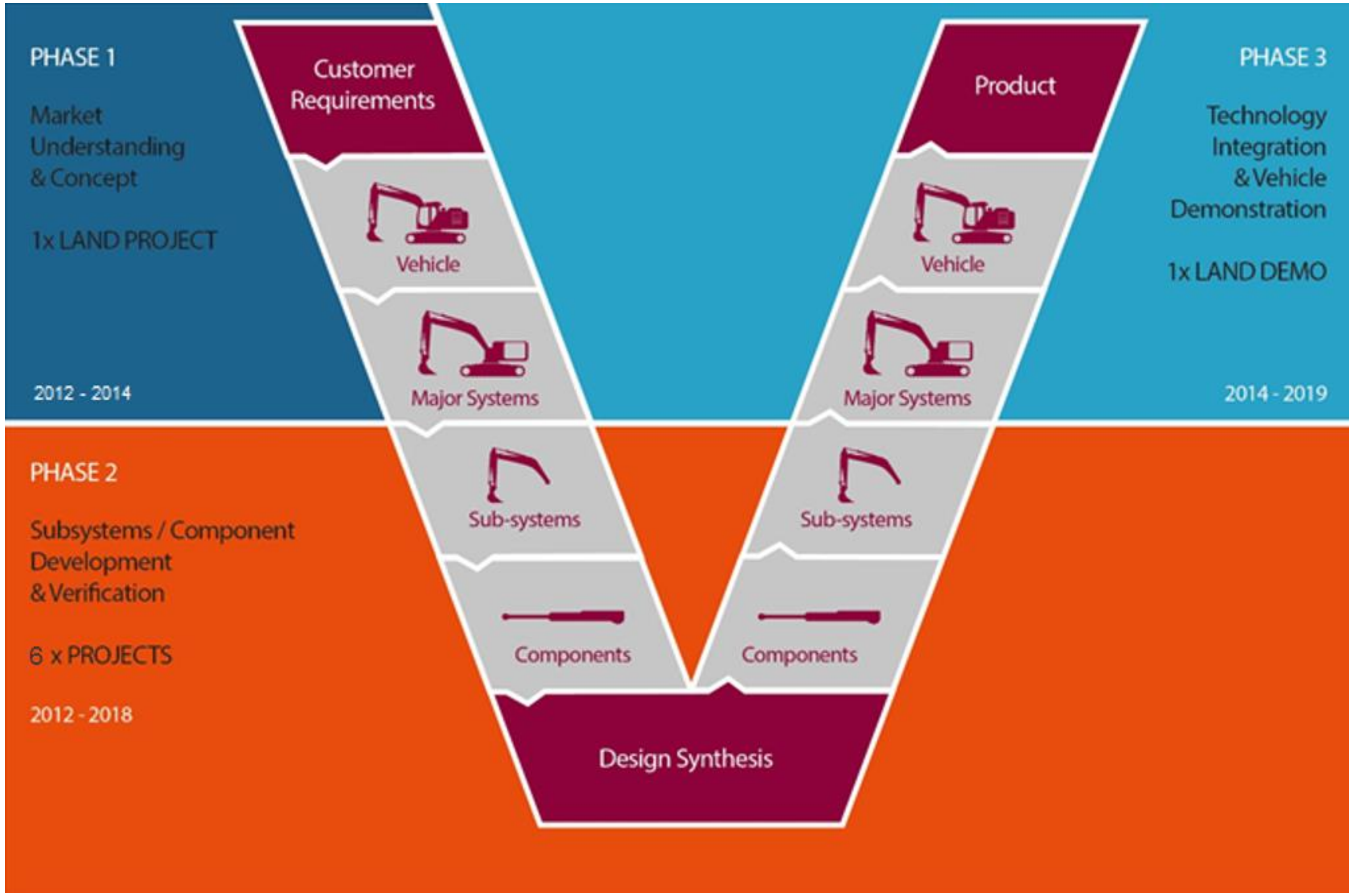
HDV Efficiency

Development and Demonstration

2012 – 2019

Feedback on performance and design

Design requirements




Materials and quantified potential risks

Results and validation issues

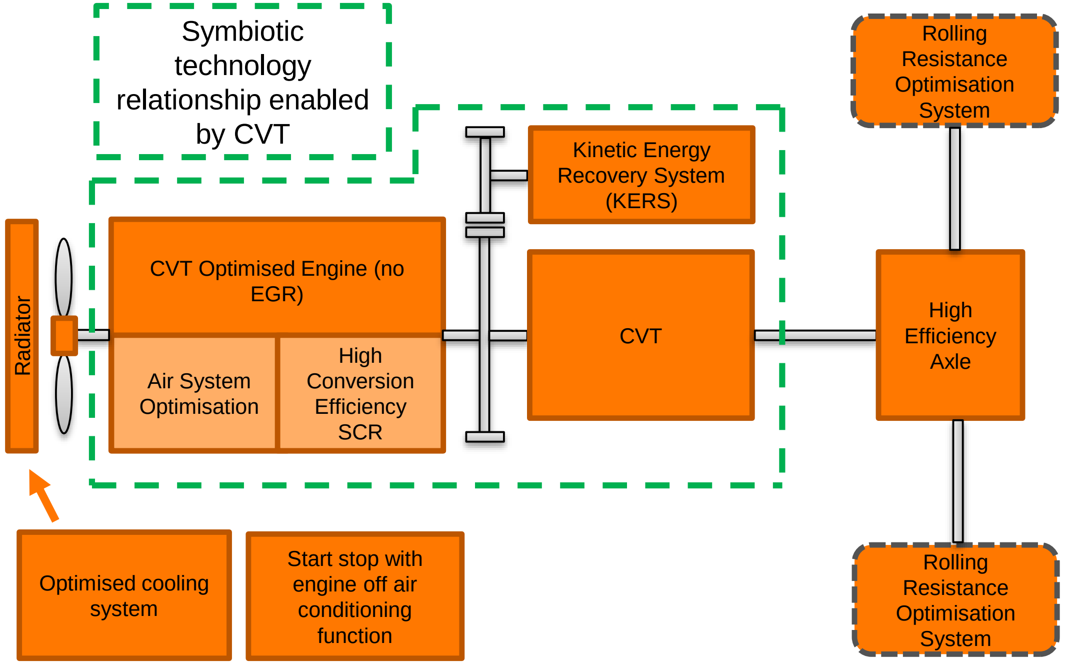
# Phase 1 – System Integration Project


Objectives:

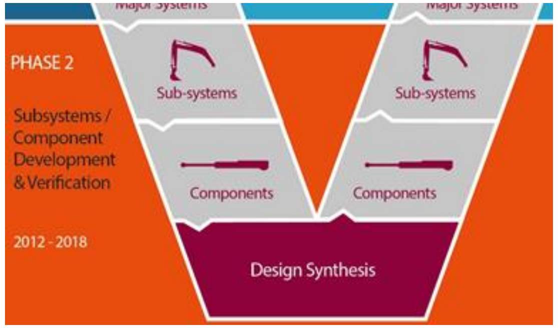
- Develop representative Vehicle models
- Generate a Vehicle concept architecture that will a 30% reduction in fuel consumption (weighted fleet average) over the baseline vehicles
- Identify (and specify) a series of Platform Technologies that support the identified Vehicle concept architecture

Project Lead:

CATERPILLAR®



# Phase 2 – High Efficiency Axle Project

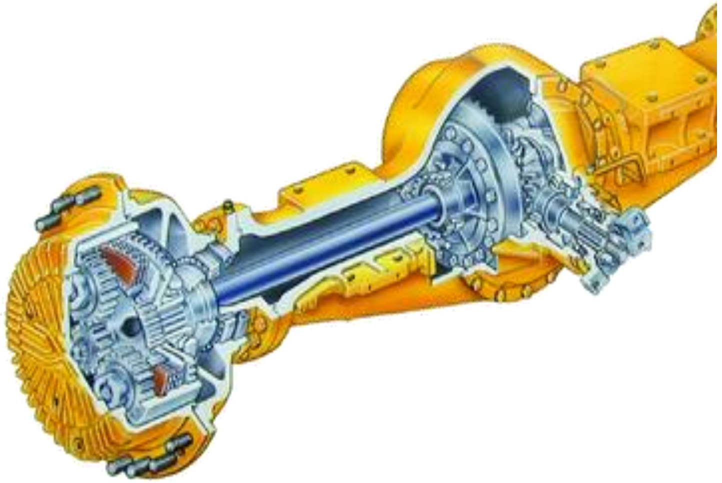



Objectives:

- Reduce energy losses through:
  - Low viscosity Oils
  - Reduce Oil churning / better Oil splash management
  - Reduced sliding friction from better gear design and coating / surface finish

Outcomes / insights:

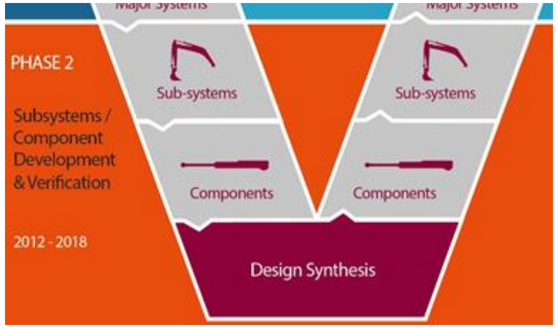
- 50% reduction in losses achieved (key objective)
- Design methodology IP in Romax Designer
- Castrol new oil formulation
- Ansys design / simulation methodology – improved timescales



Project Lead: Romax Technology

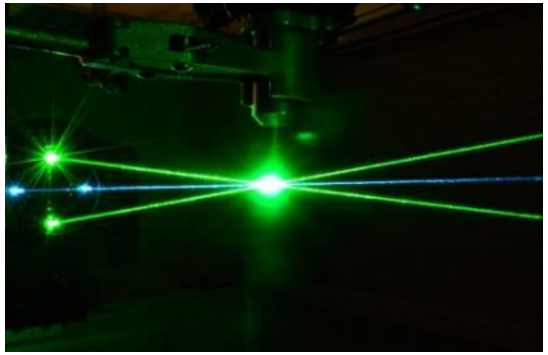
Project partners: ANSYS, Castrol

# Phase 2 – High Efficiency SCR Project



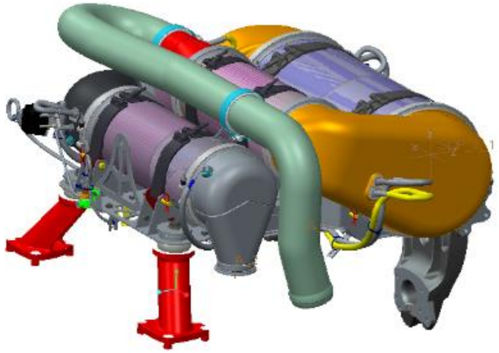

Objectives:

- Achieve Euro VI (On-highway) and Stage V (Off-highway) regulations whilst minimising overall (engine & SCR) system GHG emissions ($CO_2$ and $N_2O$)
- Maintain package size and minimise cost increase (<25%)



Outcomes / insights:

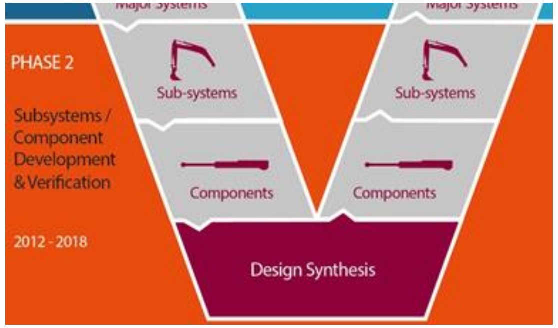
- Euro VI and Stage V cycle average emissions limits achieved
- Cost and package size achieved
- Co-optimisation with engine / engine controls is critical
- Urea deposits are still challenging / limiting on "lower temperature cycle"



Project Lead: Johnson Matthey

Project partners: Caterpillar, Loughborough University

# Phase 2 – Waste Heat Driven Air Conditioning Project




Objectives:

- Design, develop, test and implement ClimateWell's proprietary absorption heat pump technology in the demonstration vehicle

Outcomes / insights:

- Enables the use of start / stop technologies, as engine not required to drive cab cooling / warming
- "Under hood" space is limited thus the "power density" requirements are challenging
- Project did not complete as unable to achieve required power density for package space allocated

Project Lead:

ClimateWell

# Phase 2 – High Efficiency Continuously Variable Transmission (CVT) Project

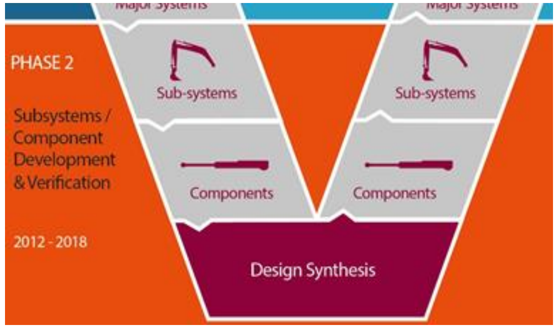
Objectives:

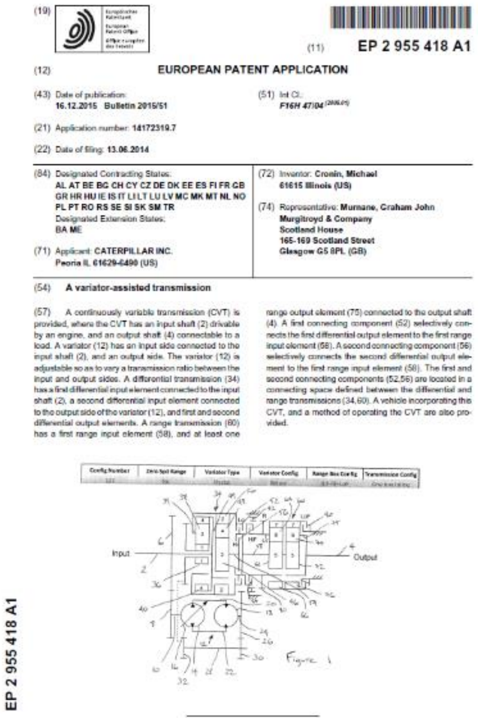
- Minimise energy losses whilst achieving ratio range
- Have suitable torque / power density to achieve current package size
- Minimise cost increase whilst maintaining robustness

Outcomes / insights:

- Energy losses minimised through improved arrangement
- Cost and package size achieved
- Co-optimisation with engine / controls is critical to unlocking the greatest fuel savings
- Very high efficiency transmissions are critical for state steady type operation (e.g. HGV)

Project Lead: CATERPILLAR®



(19) European Patent Office

(11) EP 2 955 418 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication: 16.12.2015 Bulletin 2015/51

(51) Int Cl.: F16H 47/04

(21) Application number: 14172319.7

(22) Date of filing: 13.06.2014

(84) Designated Contracting States: AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States: BA ME

(71) Applicant: CATERPILLAR INC. Peoria IL 61629-6490 (US)

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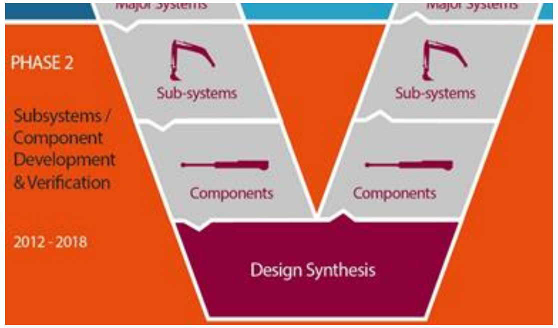
(54) A variator-assisted transmission

(57) A continuously variable transmission (CVT) is provided, where the CVT has an input shaft (2) drivable by an engine, and an output shaft (4) connectable to a load. A variator (12) has an input side connected to the input shaft (2), and an output side. The variator (12) is adjustable so as to vary a transmission ratio between the input and output sides. A differential transmission (34) has a first differential input element connected to the input shaft (2), a second differential input element connected to the output side of the variator (12), and first and second differential output elements. A range transmission (60) has a first range input element (58), and at least one range output element (75) connected to the output shaft (4). A first connecting component (52) selectively connects the first differential output element to the first range input element (58). A second connecting component (56) selectively connects the second differential output element to the first range input element (58). The first and second connecting components (52,56) are located in a connecting space defined between the differential and range transmissions (34,60). A vehicle incorporating the CVT, and a method of operating the CVT are also provided.

# Phase 2 – Rolling Resistance Optimisation System (RROS) Project




Objectives:

- Commercially viable (Capital cost vs user benefit)
- Establish and accurately achieve required tyre pressure
- Maintain (or improve) service life, robustness and reliability

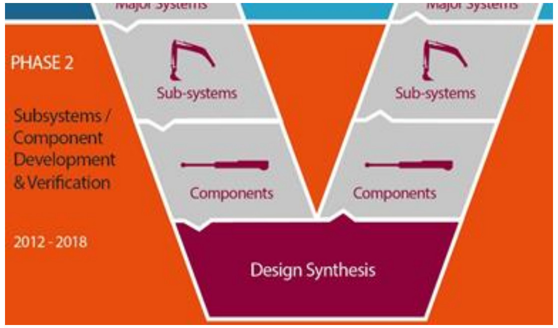
Outcomes / insights:

- On-highway operators are extremely cost sensitive
- Low cost pressure maintenance systems exist for On-highway use
- On-highway systems do not meet the Off-highway requirements

Project Lead:

A HORIBA COMPANY MIRA

# Phase 2 – High Performance Engine Air System (EAS) Project

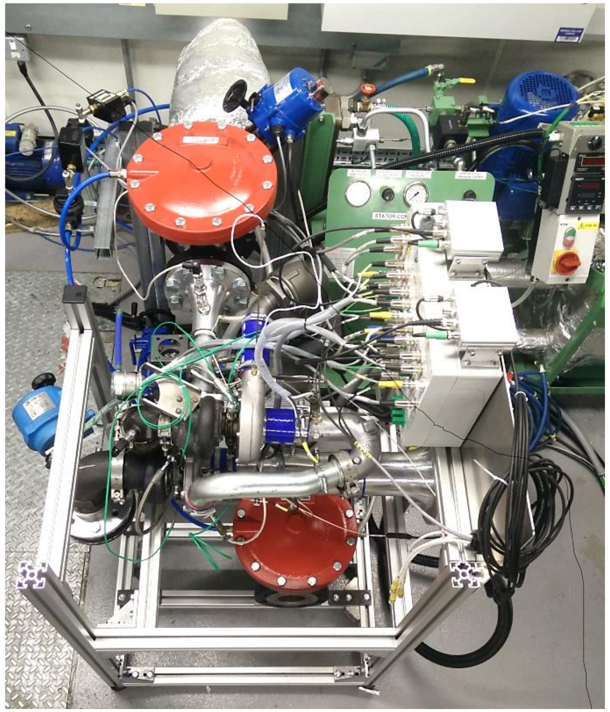



Objectives:

- High pressure ratio over wide operating range with fast response
- Minimal cost increase whilst remaining robust

Current activities / insights:

- Fast response required to support CVT operated vehicle
- Optimisation of existing architectures / technologies gives significant benefits with minimal increase in technical risk
- Innovation and further efficiency gains still possible
- World leading test rig being developed at Imperial College



Project Lead: CATERPILLAR®

Project Partners: Honeywell, Imperial College London

# Phase 3 – System Integration Project


Objectives:

- Maintain and update the vehicle models developed in Phase 1
- Refine the concept developed in Phase 1
- Design, procure, build, test and demonstrate the system concept on a Caterpillar 725 AT

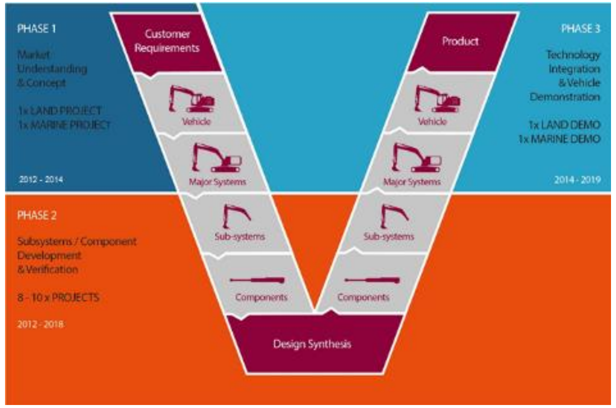
Current activities / Insights:

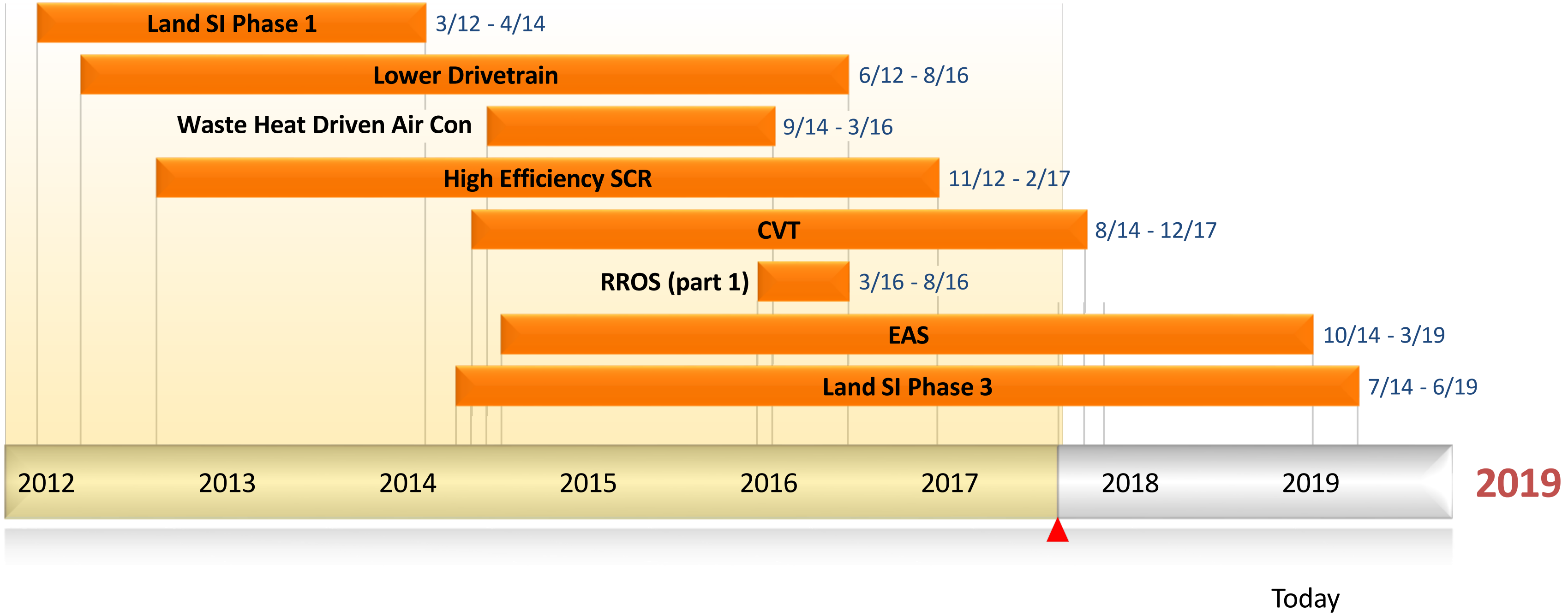
- CVT integrated into vehicle and tested
- CVT, engine, SCR and KERS testing on rig
- Further vehicle build with SCR, CVT and KERS in progress

Project Lead:

CATERPILLAR®

# HDV Land Efficiency Programme Timeline




Programme length is comparable to a vehicle development Project, however, starting and finishing Technology levels have been lower

# Phase 3 – On-Highway Simulation Support Project


Objectives:

- Develop Baseline & ETI Concept models for HGVs
- Provide independent assessment of the ETI Concept against current industrial efforts

Outcomes / Insights:

- Benefit on ETI concept highly drive cycle dependent
- Transmission efficiency is critical for most drive cycles
- Power management control / optimisation is complex and critical

Project Lead:

AVL

# Data Analysis & Optimisation Project

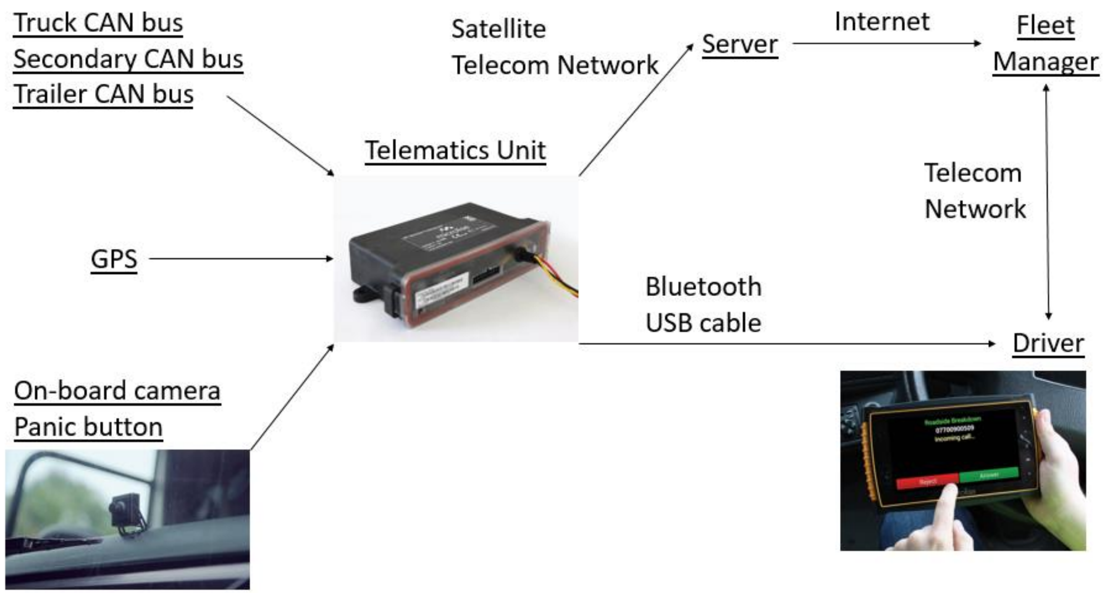
HDV Efficiency

Development and Demonstration

2012 – 2019

Objectives:

- To use existing real world telematics data to understand UK HGV usage patterns
- Develop a method to create representative drive cycles using telematics data
- Create an algorithm to calculate real world truck resistance coefficients




Current activities / insights:

- Data from over 5000 vehicles covering the UK fleet
- High frequency logging enabled characterisation of vehicle parameters

Project Lead:

element energy

Project Partners:

microlise

icct THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

# HDV Activities at ETI

**HDV Efficiency**

Technology Development and Demonstration Programme

2012 – 2019

**Gas as a HDV Fuel**

Strategy Phase

2013 – 2018

# Gas Well to Motion Project

**Gas as a HDV Fuel**

**Strategy Phase**

**2013 – 2018**

Objectives:

- Develop a model that will estimate:
  - Total GHG emissions for different gas production pathways
  - Overlay differing vehicle storage and engine technologies


Outcomes / insights:

- Economics for gas in HGVs hinges upon the stability of the fuel duty differential to enable market confidence
- Natural Gas can reduce “pathway” GHG by 13% - 24%
- Using “best practices” at fuel stations are important
- Current engine and catalyst technologies mean real-world in-vehicle methane emissions can be poor – Addressing this is key!

Project Lead: elementenergy

Project Partners: cng services ltd, strateco, UCL

# Learning opportunities / Outcomes to date

- Heavy Duty Vehicles are assets and are “sweated”
  - Commercial thinking underpin most decisions
  - Reliability is critical
  - Customer risk appetite is low (innovation is challenging)
- Platform technology approaches work, but there are limits
  - Understanding customer drivers are key
  - Appreciate technology limits
  - Module sharing needs to be identified at the concept stage
- The way a vehicle is operated / utilised has a significant effect
  - Intra Vs Inter city operation
- Ownership model have an impact
  - Owner / Operators Vs Rental
- Inter phase specification and communication is key