Enhancing Driving Dynamics whilst halving emissions:

electric Dynamic Control of MIRA Hybrid 4WD Vehicle (H4V)

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Vehicle Dynamics Expo – 18 Jun 2009

Summary

- MIRA’s approach to the integration of Hybrid Technology with Vehicle Dynamics
- Development of the Hybrid 4WD vehicle (H4V)
- Electric Dynamic Control for the Hybrid 4WD vehicle

Hybrid Technology at MIRA

Electric bus fleet trial
Camden London

MGTf 200 HP
All Wheel Drive

Series-Hybrid
Luxury Vehicle

Technology Strategy Board

JAGUAR

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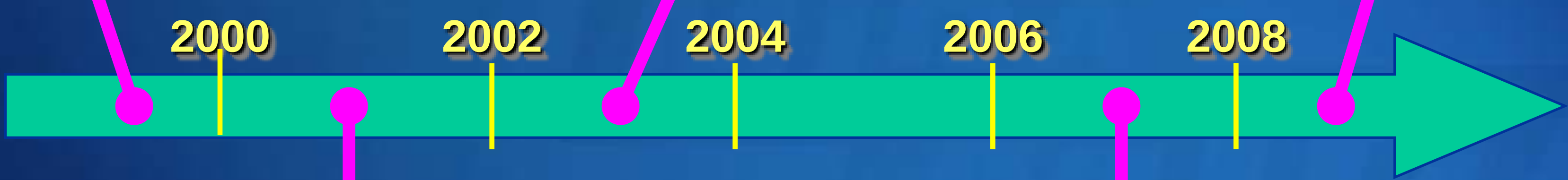

6 electric Porter vans

Hybrid 4WD
Vehicle H4V

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Hybrid Technology at MIRA

- Alternative powertrains
- Vehicle system integration
- Electric motors
- Battery management
- AMT development

Advanced Engineering

- Autonomous and semi-autonomous vehicles
- Drive-by-Wire
- Actuators control
- Advanced sensors
- States observer
- Remote diagnostics

Electrical Engineering

- Vehicle-level attributes setting
- Objective and subjective evaluation
- High-level control algorithms
- Full-vehicle modelling

Dynamics and NVH

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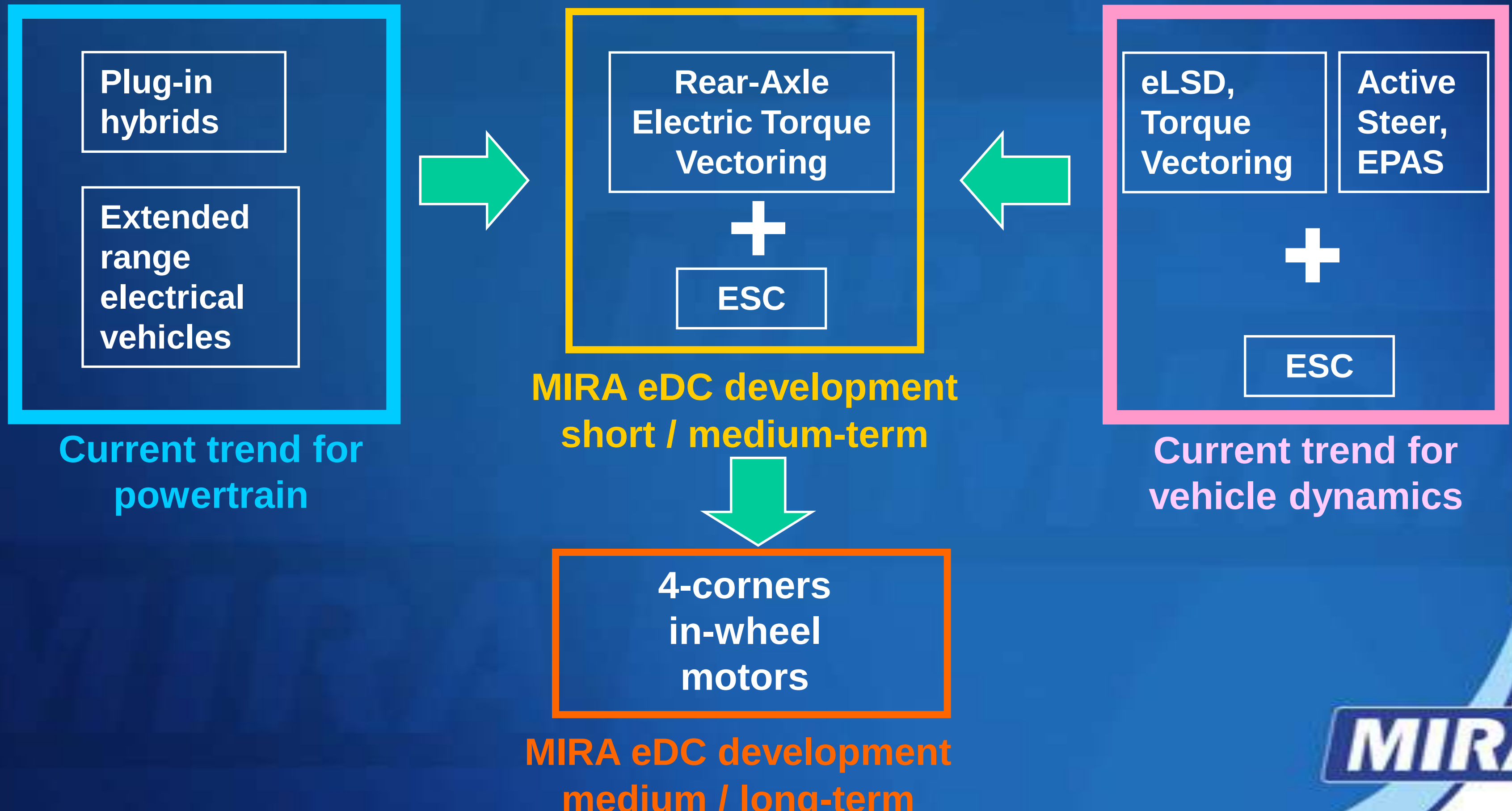
MIRA Electric Dynamic Control

- On-going electrification opens novel opportunities for Vehicle Dynamics control and integration



MIRA Electric Dynamic Control

AWD functions
(single e-motor)

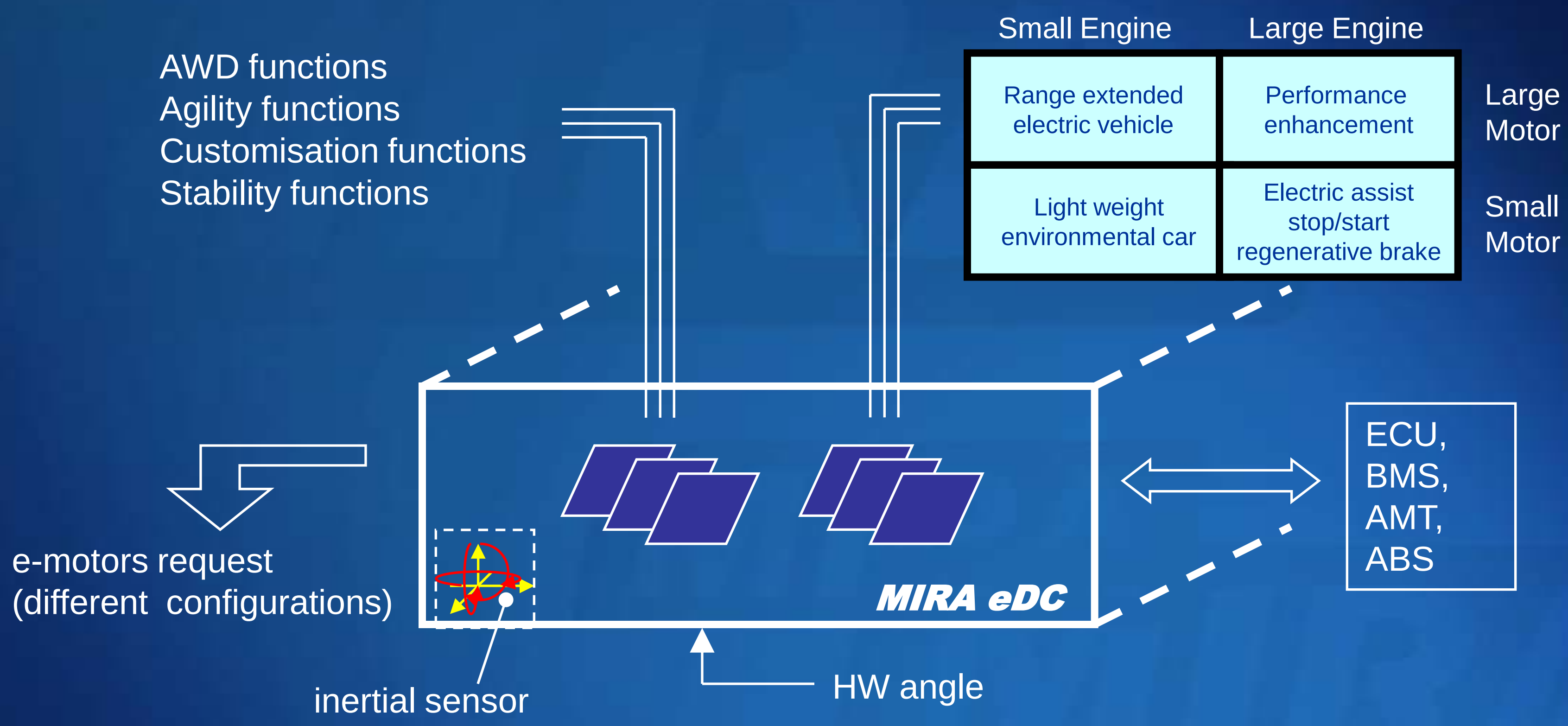
Yaw-Rate functions
(rear twin in-board motors)

Rear twin (in-wheel?) motors +
ESC integration

4-corners in-
wheel motors

- Objective: progressive development of hardware and software within same architecture

MIRA Electric Dynamic Control



- Flexible architecture for different hybrid configurations
- Integrated 6DoF inertial sensor

- MIRA’s approach to the integration of Hybrid technology with Vehicle Dynamics
- Development of the Hybrid 4WD Vehicle (H4V)
- Electric Dynamic Control for the Hybrid 4WD Vehicle

H4V: Project Background

Motivation

- **Energy Saving Trust:** To demonstrate what can be achieved in CO_2 reduction by applying advanced technology to a conventional mid-sized car
- **MIRA Ltd:** To produce a practical demonstration of MIRA's vehicle engineering capability and direction (that is not covered by usual customer confidentiality)

Basic Concept:

- Retaining the front wheel drive engine and gear box
- Re-engineering of the engine to deliver more torque over a tighter speed range, whilst engaging the gears through a MIRA controlled AMT
- Support acceleration and braking using high torque rear wheel motors
- An Integrated Generator (IG) to charge the advanced batteries, when the engine is ON
- Acceptable EV mode when the engine is OFF
- Improve aerodynamics, rolling resistance, and thermal management

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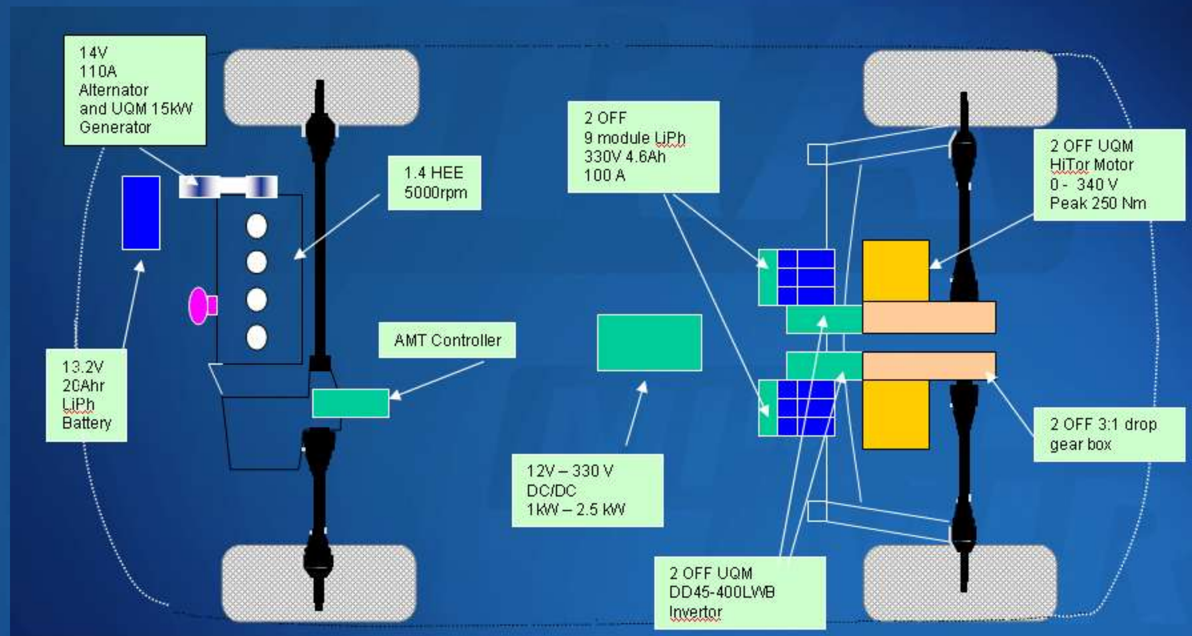
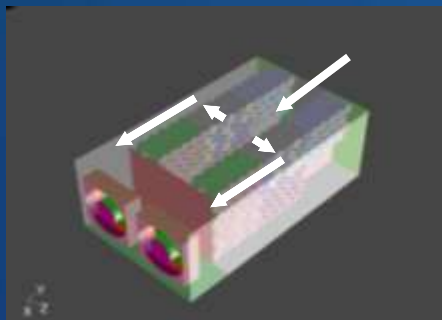
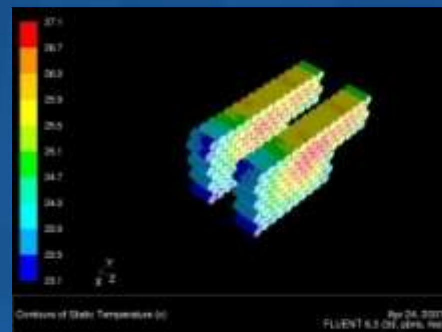
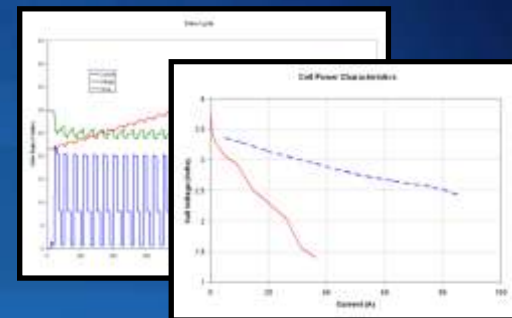
H4V Powertrain Layout

Series/Parallel
Petrol/Electric
Hybrid layout

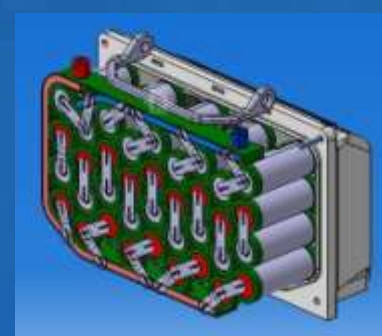


- Front:
  - Retained 1.4 litre petrol, 60kW, re-mapped ECU
  - Retained gearbox, MIRA controlled AMT
  - Engine generator, Heat store, EHPAS
- Rear:
  - Twin in-board 37kW electric motors
  - Li ion 330V battery packs
  - DC-DC converter

Examples of Design and Build

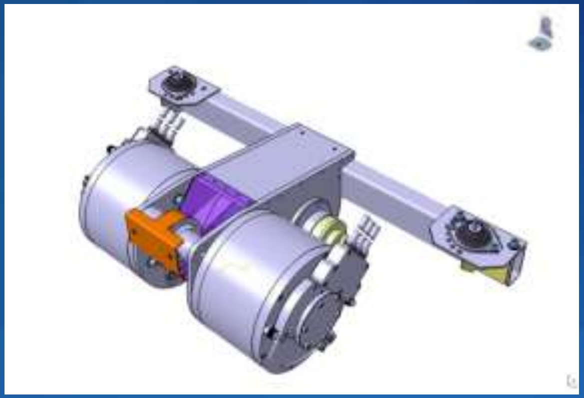




- 330V Traction cassettes pack design and management system


- 12V HighPower LiPh ISG battery

Examples of Design and Build



- UQM HiTor 37kW motors

- New Twist Beam incorporating drive-shafts

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Examples of Design and Build

- Aerodynamic Case Study:
  Front Bumper & Rear Spoiler
  - 3D Laser scanning
  - Base CAD creation using Geomagic Studio
  - New part design using Catia V5
  - Prototyping template design
  - Clay modelling
  - Finished product

- Engine Development
  - Pi Shurlock - Open ECU control module
  - Transient over-fuelling removed

- Vehicle System Integration

H4V Hybrid Powertrain: Results

- 40% reduction in CO_2 during EC drive cycle giving 104gCO_2/km
- Fuel economy <= 4.4 l/100km (baseline 6.7 l/100km)
- In charge depleting mode (mains re-charge), 67gCO_2/km and 2.85 l/100km
- 8% Drag Coefficient reduction
- Lowered rolling resistance
- 10% Engine efficiency improvement
- Comparable performance to base vehicle

- MIRA’s approach to the integration of Hybrid technology with Vehicle Dynamics
- Development of the Hybrid 4WD Vehicle (H4V)
- Electric Dynamic Control for the Hybrid 4WD Vehicle

H4V eDC: Principle

- Motivation:
  - To implement vehicle dynamics features using H4V rear twin motors
- Expected points of strength:
  - Yaw authority in all driving conditions
  - Fast response time
  - Highly controllable
  - No negative feedback to driver

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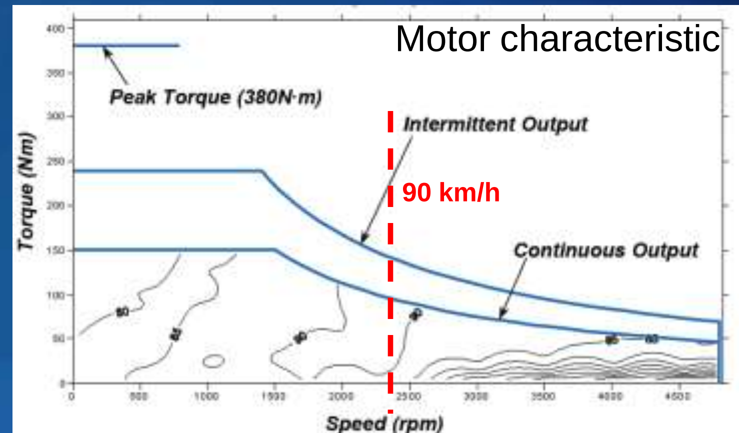
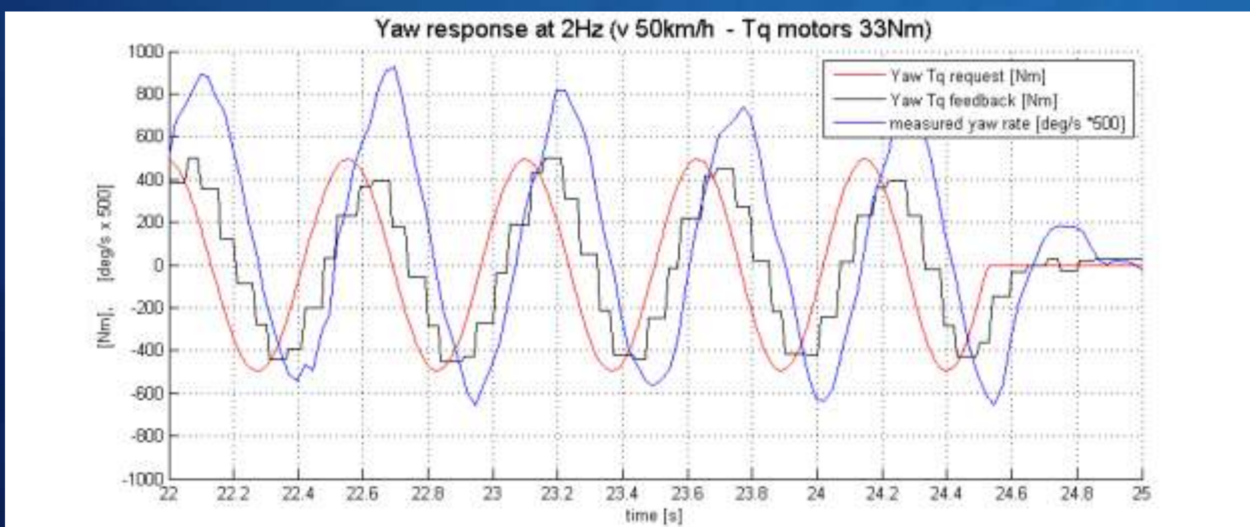
H4V eDC: Yaw Authority

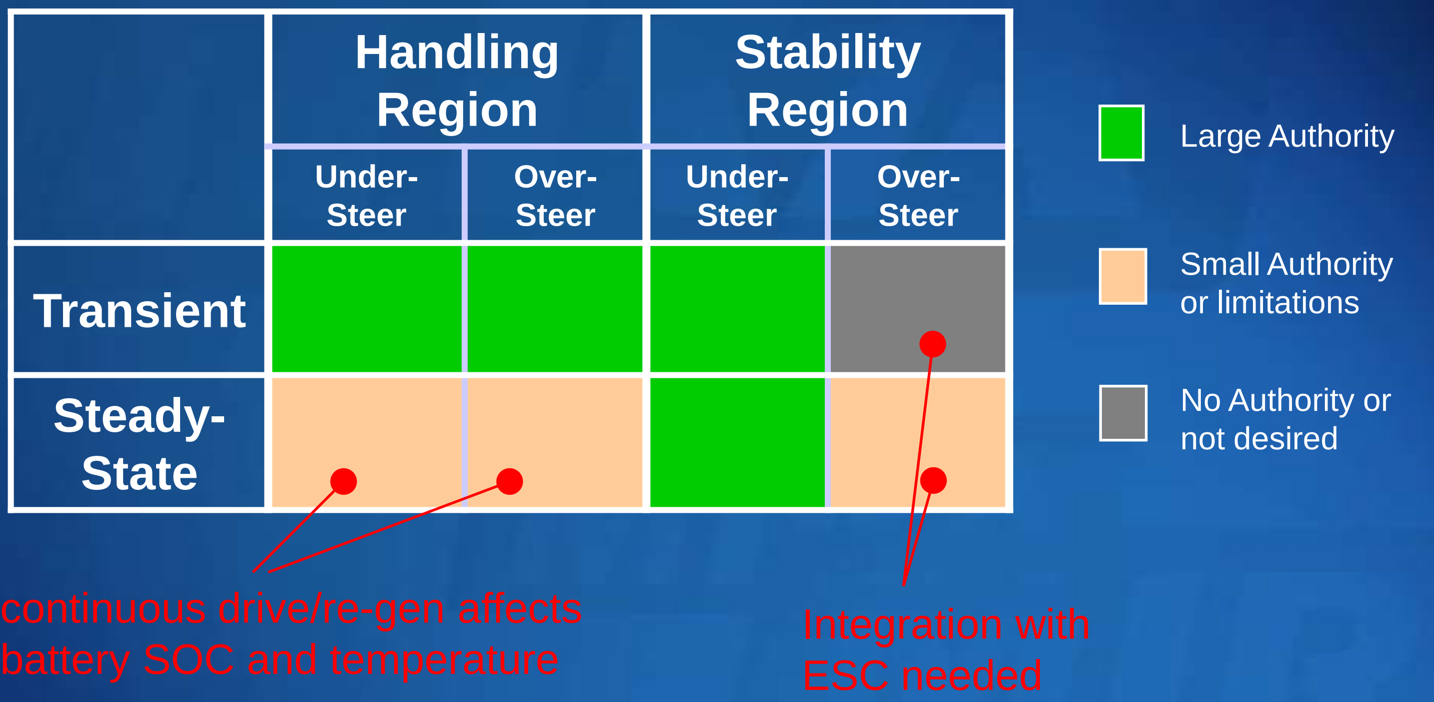


- max Yaw Torque at 90km/h: ~2000Nm



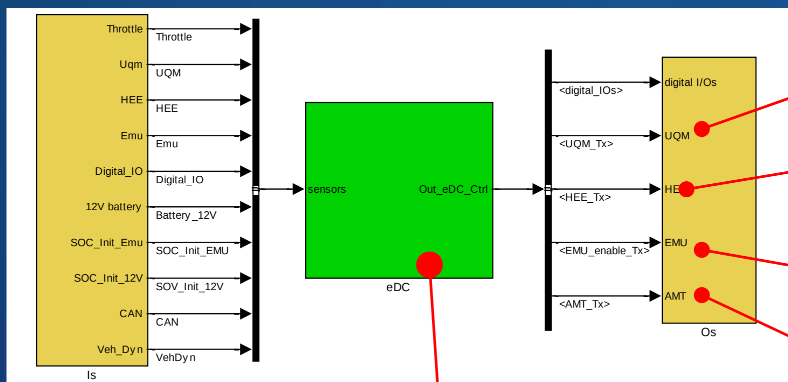
- Fast Yaw-response

H4V eDC: Yaw Authority



- Versatile system which can be used in both Handling Region (tyres not saturated) and in the Stability Region (tyres close to saturation)

H4V eDC: Rapid Control Prototyping

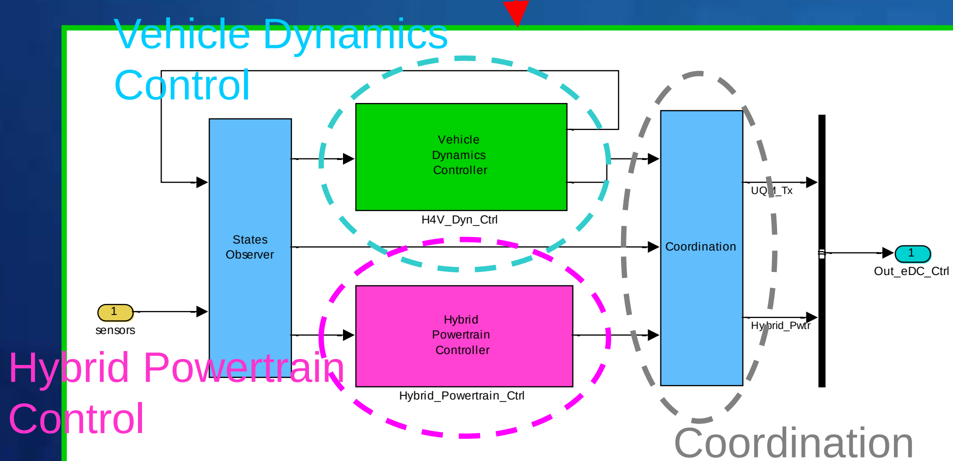


E-motors requests

High-Efficiency-Engine requests

Battery Management override

AMT requests



Vehicle Dynamics Control:
- States Observer
- Targets generation
- Vehicle Yaw-Control
- Wheel Torque control

Hybrid Powertrain Control:
- E-motors target torque
- HEE target torque
- AMT arbitration
- Battery monitoring

- Controller in Simulink
- dSpace MicroAutoBox

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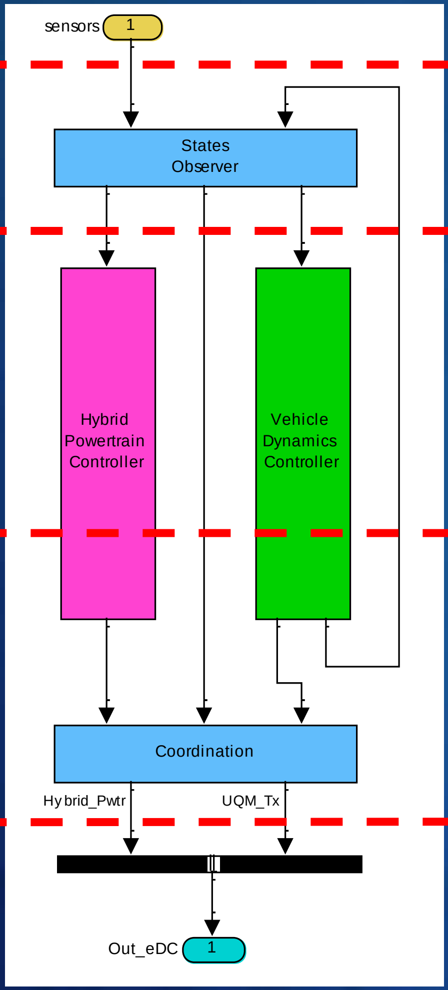
H4V eDC: Control Architecture



Environment + Vehicle

1 - Observer

Plausibility checks, engine/AMT/SOC states, vehicle/tyre states, driver recognition

2 - Vehicle Control

Target motion generation,
Yaw-rate control,
Longitudinal acc. control

3 - Wheel Control

Wheel torque mapping, Traction control, anti-lock control, co-ordination

Electric Motor requests

- Parallel blocks to allow by-pass
- Layered structure

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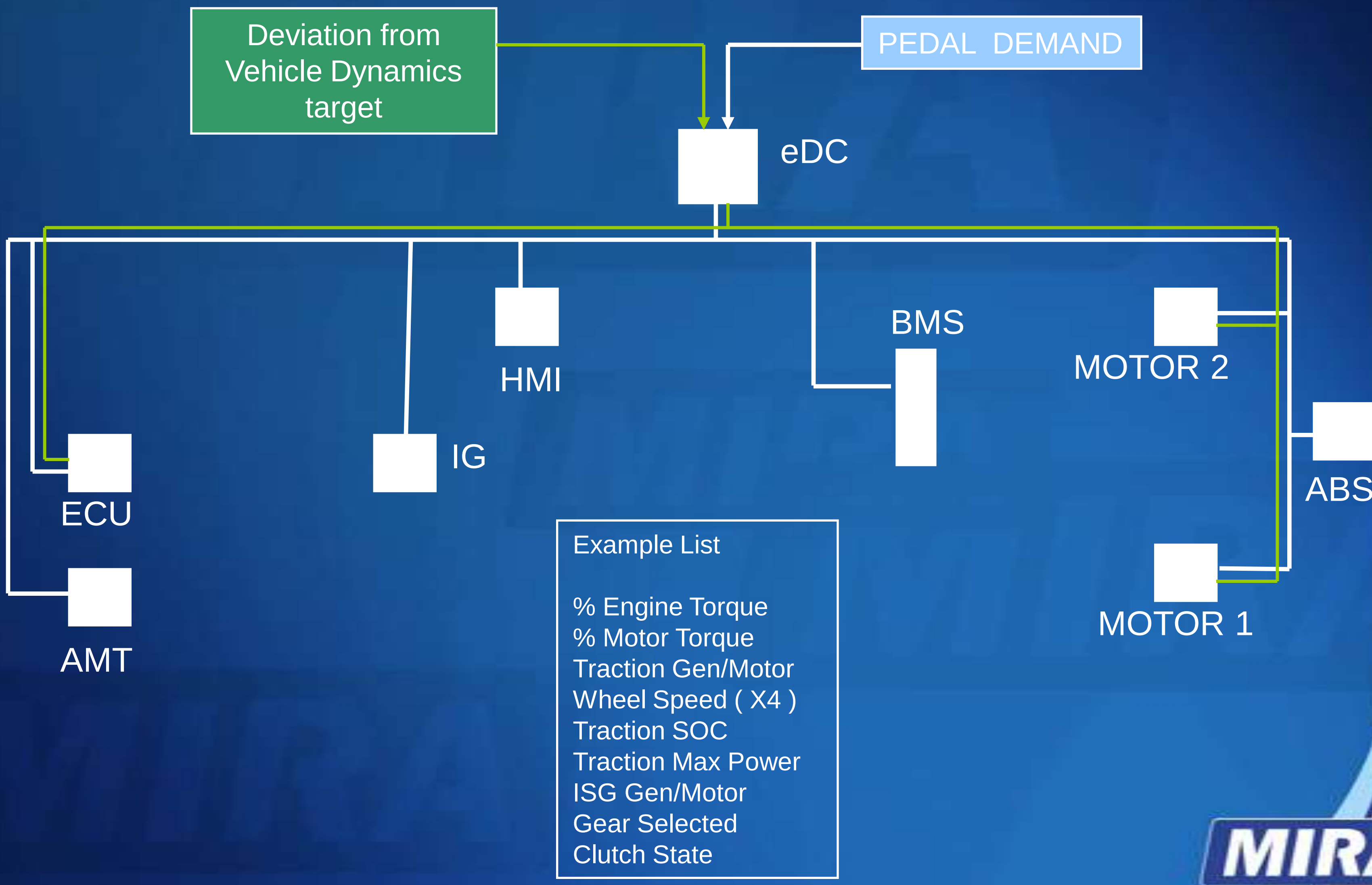
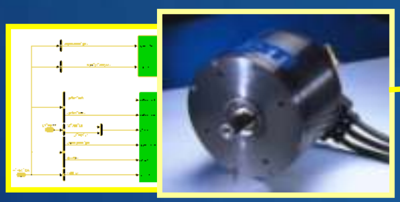
H4V eDC: Information Flow

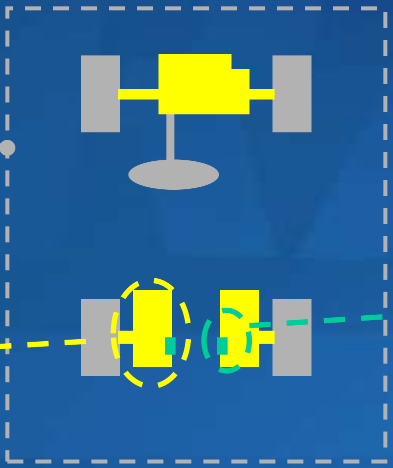


H4V eDC: Simulation Model

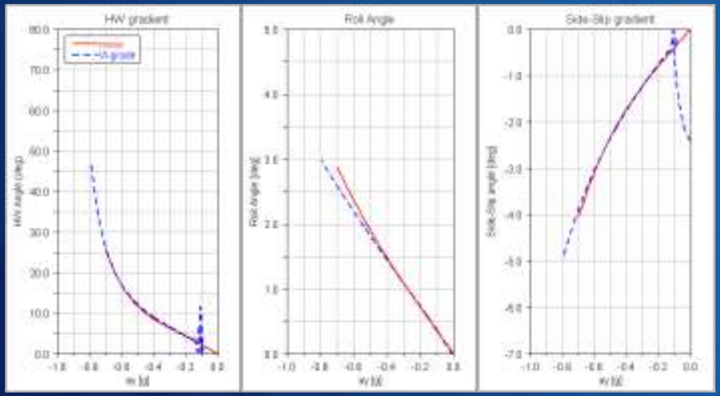
Vehicle plant model (VI-Grade)



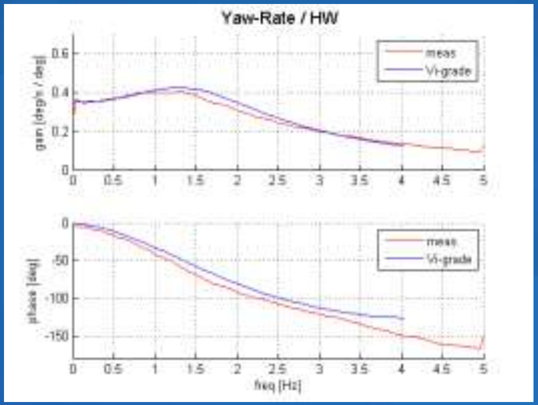
Hybrid powertrain (Simulink)



eDC (Simulink)

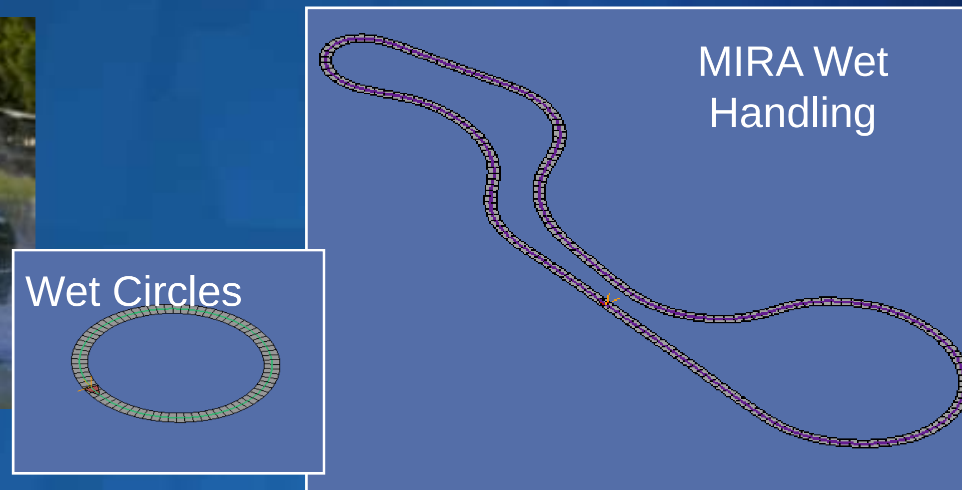


Example correlation:
33m Constant Radius cornering



Example correlation:
Frequency-Response test

H4V eDC: Testing Environment



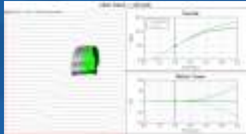
- Controller to be mainly demonstrated on MIRA wet facilities:
  - Wet Cornering Facility
    - Sand asphalt
    - Bridport pebble
    - Basalt tile
  - Straight Line Wet Grip
    - Six surfaces from μ=0.10 to μ=0.75 nominal
    - μ-split test available
  - Wet Handling

H4V eDC: Vehicle Dynamics Features

- Traction Control

play animation

- Under-steer Control

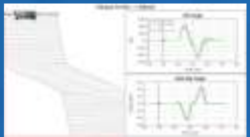


play animation

- Over-steer Control

play animation

- Agility Enhancement



play animation 1
play animation 2

- Stability Control

play animation

- Power-slide

play animation

eDC - Next Steps

- 2009
  - H4V eDC: on-vehicle demonstration
  - Tri-axial inertial sensor installation
- 2010
  - (in-wheel motors?)
  - Integration with ESC


Thank You
Questions?