Meeting Real World Emission Development Challenges for Euro 7 Norms

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Euro 7 – What's New?

European Commission

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What's new in the Euro 7 regulation?

For all cars, vans, trucks and buses

- Limits for emissions from brakes
- Rules on microplastic pollution from tyres
- Vehicles need to comply with emissions rules for longer period
- More effective emissions tests
- Digital monitoring of compliance

  On-Board Monitoring
- Better market surveillance tests

For internal combustion engine vehicles

- Fuel- and technology-neutral emission limits
- Regulating additional pollutants
- On-road tests with broader range of driving conditions

For electric and plugin hybrid vehicles

- Battery durability requirements

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Euro 7 – The Headlines

- **Emission Limits**
  - ❑ **LDV ;** Emission limits as in Euro 6e, except PN10 instead of PN23, no new species, evaporative emission limits tightened from 2.0 g/test to 1.5 g/test
  - ❑ **HDV ;** Tightened limits, especially NOx reduced by 50%, NMOG added (possibly HCHO), NH_3, N_2O_2, PN_{10}
- **Testing Conditions**
  - ❑ **LDV** ; Test methods and CFs(Margin) similar to Euro 6e（WLTP and RDE testing）
  - ❑ **HDV** ; Tests as in UNR49（WHTC/WHSC bench testing and RDE testing, Valid windows for RDE defined as those with average engine power > 6% of max. engine power
- **Extended Lifetime**
  - ❑ Additional lifetime (e.g. Up to 200,000 km for LDV & up to 875,000km for HDV)
  - ❑ Emissions factor of 1.2

Euro 7 – The Headlines

- **On-Board Monitoring(OBM)**
  - OBM system will monitor NOx, NH3(HDV only）, and PM and detect exceedance of 2.5x of emission limits
  - OBM communicate data by OBD port and over the air
  - OBM triggers driver warning system in case of emission exceedances to induce repairs and maintenance
- **Brake Emission Limits**
  - Brake emission limits for LDV only
  - HDV to be decided later
  - Responsibility of vehicle OEM
- **Tyre Emission Limits**
  - Tyre limits will be decided in later stage
  - LDV limits first (C1 type tyre)
  - Responsibility of tyre Tier1 Supplier
- **xEV-Only**
- **Battery & Range Durability**
  - Minimum performance requirements for eLDV (M1 & N1 only) 5yr/100,000km & 8yr/160,000km
  - HDV test method/criteria, will be discussed by the end of 2027
  - SOCE & SOCR “health” and status monitors as part of OBM

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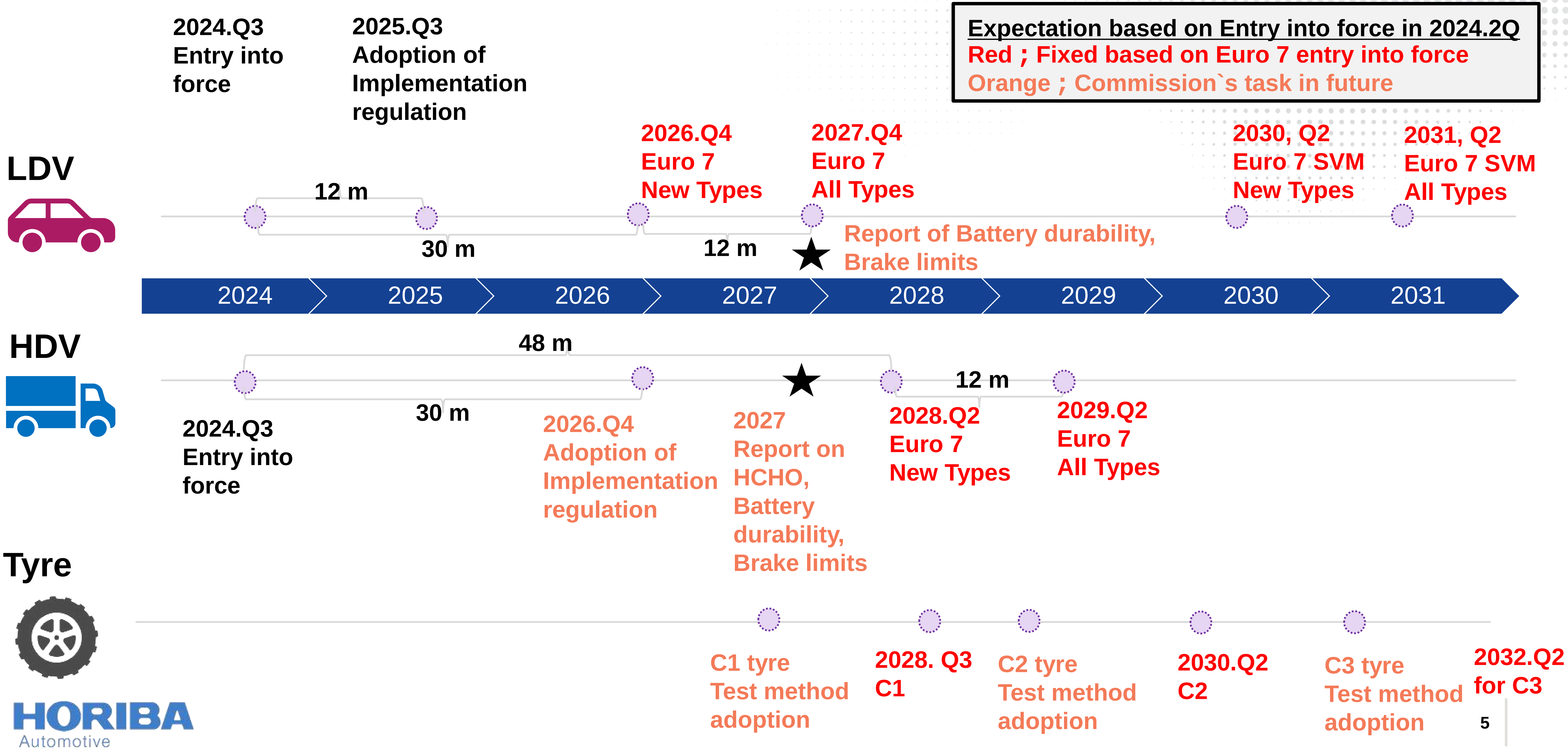
Euro7 Emissions Timeline



Euro7 LDV Limits & Test Protocol

Euro 7 Appears Similar to Euro 6e

- ❑ Not technology agnostic
- ❑ No NH_3
- ❑ PN_{10} instead of PN_{23}
- ❑ PN Apply to all PI vehicles (not only DI-PI Vehicles)
- ❑ Test conditions for LDV remains the same as Council's General Approach – Euro6e (**R168**) level.

	Eu6e		Euro 7 Trilogue							
	Gasoline	Diesel	PI				CI			
			M1	N1 (Class I)	N1 (Class II)	N1 (Class III)	M1	N1 (Class I)	N1 (Class II)	N1 (Class III)
	WLTP RDE CF NOx: 1.1, PN: 1.34 only		Refer to **R168**: WLTP, RDE CF NOx: 1.1, PN: 1.34 only + CO and CO2 needs to be measured							
NOx [mg]	60	80	60	60	75	82	80	80	105	125
PM [mg]	4.5	4.5	4.5							
PN [#]	DI only **PN23** : 6×10^{11}		**PN10** : 6×10^{11}							
CO [mg]	1000	500	500	500	630	740	1000	1000	1810	2270
THC [mg]	100	HC+NOx: 170	100	100	130	160	HC+NOx: 170	HC+NOx: 170	HC+NOx: 195	HC+NOx: 215
NMHC [mg]	68	-	68	68	90	108	-	-	-	-
NH3 [mg]	-	-	-	-	-	-	-	-	-	-

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Euro7 HDV Limits & Test Protocol

- New components : NMOG NH3[mg] CH4, N2O, PN10 instead of PN 23
- Formaldehyde(HCHO): to be reviewed by the Commission based on expected use of fuel by Dec 2027
- Test conditions for HDV remains the same as Council's General Approach (R49)
- **New RDE requirements similar to LDV Euro 6e**

	EuroVI	**Trilogue Result**	
mg/kWh	WHTC (CI & PI)	WHSC (CI) and WHTC (CI and PI)	Real Driving Emission (RDE)
NOx [mg]	400	200	260
PM [mg]	10	8	—
PN [♯]	PN23: 6×10^{11}	**PN10** : 6×10^{11}	**PN10** : 9×10^{11}
CO [mg]	4000	1500	1950
THC [mg]	—	—	—
NMOG [mg]	-	80	105
NMHC [mg]	160	—	—
HCHO [mg]	—	?	?
NH3 [mg]	-	60	85
CH4 [mg]	500	500	650
N2O [mg]	-	200	260
ISC	Yes (CF=1.5)	Yes	Yes
RDE	No	-	Yes

Euro7 RDE – LDV & HDV

LDV

- ❑ Testing in accordance with UN R168
- ❑ R168 not yet approved – discussions on-going
- ❑ Carry-over Euro6e but with PN10
- ❑ PEMS margin defined in R168, equivalent CFs: NOx:1.1 and PN: 1.34

HDV

- ❑ Testing in accordance with UN R49
- ❑ Not yet approved – discussions on-going
- ❑ Valid “window” above 6% max. power
- ❑ Proposed CF=1.0

	Condition	Altitude	Temperature
LDV	Moderate conditions	Altitude lower or equal to **700 meters** above sea level.	Greater than or equal to 273.15 K (**0 °C**) and lower than or equal to 308.15 K (**35 °C**).
	Extended conditions	Altitude higher than 700 meters above sea level and lower or equal to **1300 meters** above sea level.	Greater than or equal to 266.15 K (**– 7 °C**) and lower than 273.15 K (0 °C) or greater than 308.15 K (35 °C) and lower than or equal to 311.15 K (**38 °C**).
HDV		≥ 82.5 kPa	- 7°C to around **40℃** (at 1atm)

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Euro7 Brake Particles Emission Limits

All vehicles (incl. Battery Electric Vehicles)

- ❑Conditions for testing is Based on UN GTR on brake emission for LDV.
  - In GTR No.24, PM_{10}, $PM_{2.5}$, PN_{10}, TPN measurement methods are defined
  - New Friction Braking Coefficients agreed to cover mild hybrids
- ❑Test method for HDV should be decided by 30 months after entry into force of Euro 7.
- ❑PM10 and PN limit shall be review by the end of 2027 and new table will be applied from Jan.2030. Brake system test is required for type approval and conformity of production.
- ❑Update in 2030 and another in 2034
- ❑One limit for all powertrain types after 2035

Until 31.12.2029

Emission limits in mg/km per vehicle	M1, N1 vehicles excluding N1 Class III*				
Powertrain technology	PEV	OVC-HEV	NOVC-HEV	FCV	ICEV
Brake particle emissions (PM10)	3	7	7	7	7

*For N1 Class III vehicles, the applicable limits are as follows: PEV 5 mg/km; OVC-HEV, NOVC-HEV, FCV and ICEV 11 mg/km.

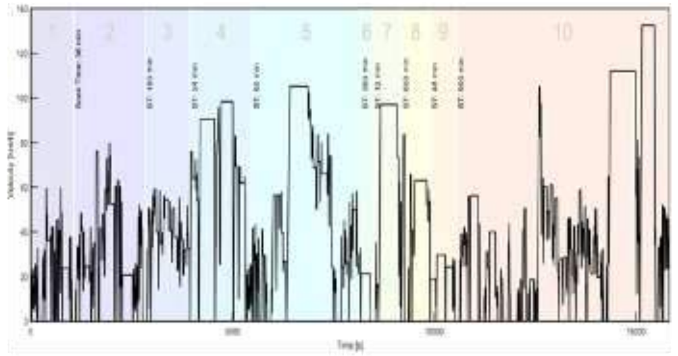
Overview of ECE/TRANS/180/Add.24

Cooling adjustment
- Adjustment of cooling air condition to keep brake temperature within the specified range

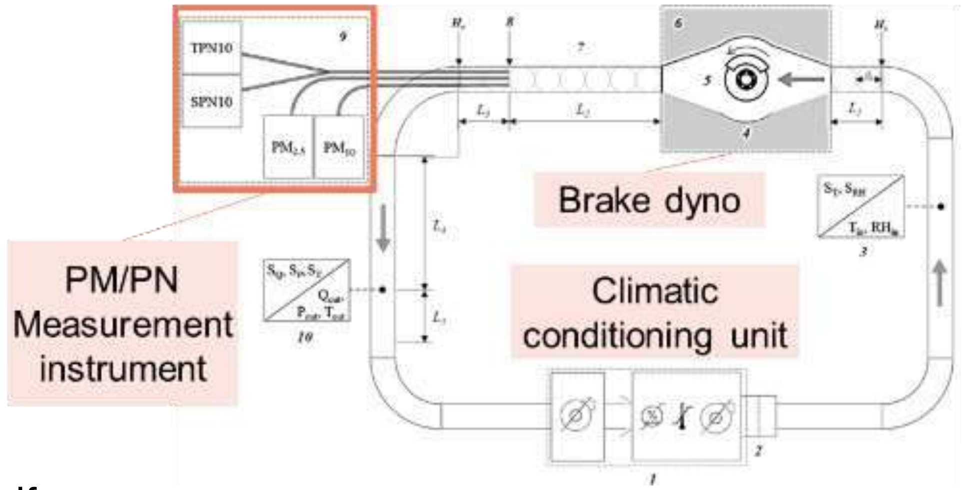
→ **Bedding**
- Stabilization of brake emission through 5 times WLTP brake cycle operation

→ **Emission measurement**
- PM and PN measurement over WLTP brake cycle

WLTP Brake Cycle



Indicative layout for brake emission test in lab



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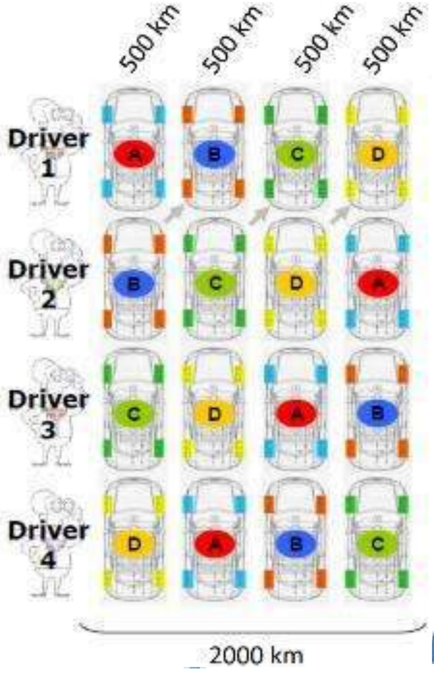
Source：https://data.consilium.europa.eu/doc/document/ST-16960-2023-REV-1/en/pdf

Tyre Abrasion Rate Limits

- ❑Conditions for testing is Based on UN R117 GTR on brake emission for types after 2035
- ❑Implementation follows Euro7 by 18 months
- ❑No firm test protocol decided – lab and road testing considered
- ❑Real-world “Convoy” method preferred



Tire abrasion rate limits (mass lost)	C1 (LDV) tires	C2 (LCV) tires	C3 (HCV) tires
Normal tires – g/1000 km	Not yet specified	Not yet specified	Not yet specified
Snow tires – g/1000 km	Not yet specified	Not yet specified	Not yet specified
Special use tires – g/1000 km	Not yet specified	Not yet specified	Not yet specified

Timing (Article 11, 3a-3c)

Class	C1	C2	C3
New types from	1 July 2028	1 April 2030	1 April 2032
All from	1 July 2030	1 April 2032	1 April 2034
Non-compliant in market until	30 June 2032	31 March 2034	31 March 2036

Battery Durability

Measurement procedure

- Based on UN GTR 22 In-Vehicle Battery Durability for Electrified Vehicles

EU Commission

- Added possibility of additional lifetime up to 8 years or 160.000km

PHEVs and BEVS

- Only energy min. performance requirements defined for M1, N1 vehicles

TBD in Delegated Acts

- Energy min. performance requirements for N2, N3, M2, M3 vehicles and range min. performance requirements for M1, N1 to be defined at a later stag

Minimum Performance Requirements (MPR) for Energy based Battery Durability	To 5 years or 100,000km whichever first	More than 5 years or 100,000km less than 8 years or 160,000km	Vehicles up to additional lifetime
M_1 – OVC-HEV (PHEV's)	80%	72%	Not yet specified
M_1 – PEV (BEV's)	80%	72%	Not yet specified

(MPR) for range based Battery Durability	To 5 years or 100,000km whichever first	More than 5 years or 100,000km less than 8 years or 160,000km	Vehicles up to additional lifetime
M_1 – OVC-HEV (PHEV's)	Not yet specified	Not yet specified	Not yet specified
M_1 – PEV (BEV's)	Not yet specified	Not yet specified	Not yet specified

Minimum Performance Requirements (MPR) for Energy based Battery Durability	To 5 years or 100,000km whichever first	More than 5 years or 100,000km less than 8 years or 160,000km	Vehicles up to additional lifetime
N_1 – OVC-HEV (PHEV's)	75%	67%	Not yet specified
N_1 – PEV (BEV's)	75%	67%	Not yet specified

(MPR) for range based Battery Durability	To 5 years or 100,000km whichever first	More than 5 years or 100,000km less than 8 years or 160,000km	Vehicles up to additional lifetime
N_1 – OVC-HEV (PHEV's)	Not yet specified	Not yet specified	Not yet specified
N_1 – PEV (BEV's)	Not yet specified	Not yet specified	Not yet specified

On-Board Monitoring Overview

OBD

OTA

Consistent Monitoring

- ❑ NO_X
- ❑ PM
- ❑ NH_3(HDV only)
- ❑ Battery SoH
- ❑ 1Hz frequency
- ❑ Sensor and/or model
- ❑ **TBD?**

EEDWS Excess Emission Driver Warning System

- ❑ Past 1000km data and recent [n] trip
- ❑ Threshold < Limit × 2.5
- ❑ (OBM must not substantially underreport RDE)

EEDWS Status

- **Normal**
- **Intermediate**
- **Error**

ISC In-Service Conformity

- ❑ RDE Test
- ❑ Test result ⇔ OBM result
- ❑ LDV & HDV CFs
- ❑ Lifetime requirements

RDE ISC Test

- Normal condition
- Some special condition
- Inducement must be triggered “should not endanger road safety”

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Euro 7 – The Outlook

LDV – "a mixed bag"

- ❑ Emissions & RDE carry-over Euro6e
- ❑ New Challenges:
  - ❑ OBM – e.g. PM monitoring and battery state of health (SOH) monitoring
  - ❑ Brake emissions – completely new area for Tier1s and OEMs
  - ❑ Tyre emissions – new field and responsibility for Tier1s – very little definition
  - ❑ Battery durability – ultimately not helping drive down battery cost

HDV – "a bag of challenges"

- ❑ **Tougher emissions, new species and RDE …… business as usual!**
- ❑ **New Challenges**
  - ❑ All the same new challenges that are impacting LDVs
  - ❑ OBM
  - ❑ Brake & tyre emissions
  - ❑ Battery durability
  - ❑ Much more detail to be discussed and agreed
  - ❑ Much less clarity
  - ❑ Later introduction (+2 years on LDV)

BS 7 – The Outlook

Is BS7 Carry-Over Eu7?

- ❑ Implementation likely 2029-30?
- ❑ Emissions & RDE could be carry-over BS6 Level 3 (Eu7 is carry-over Eu6e)
    - ❑ Allows fundamentally carry over powertrain system technology
    - ❑ Delivers significant air-quality improvement
- ❑ Will the New Challenges be included?
    - ❑ OBM / Brake Dust / Tyres / Battery & Range Durability
- ❑ Carry Over RDE and ISC in both LD & HD will drive the need to consider real-world scenarios – not just one cycle!
- ❑ Indian RDE environment is more challenging
    - ❑ Higher max temperature & altitude
    - ❑ Tougher driver styles and environment
- ❑ Consideration of renewable fuels – Ethanol, H2 – a back-drop of decarbonisation

Euro 7 Example: Combine simulation & test to cover regulatory envelope

Achieve sufficient coverage using predictive simulation

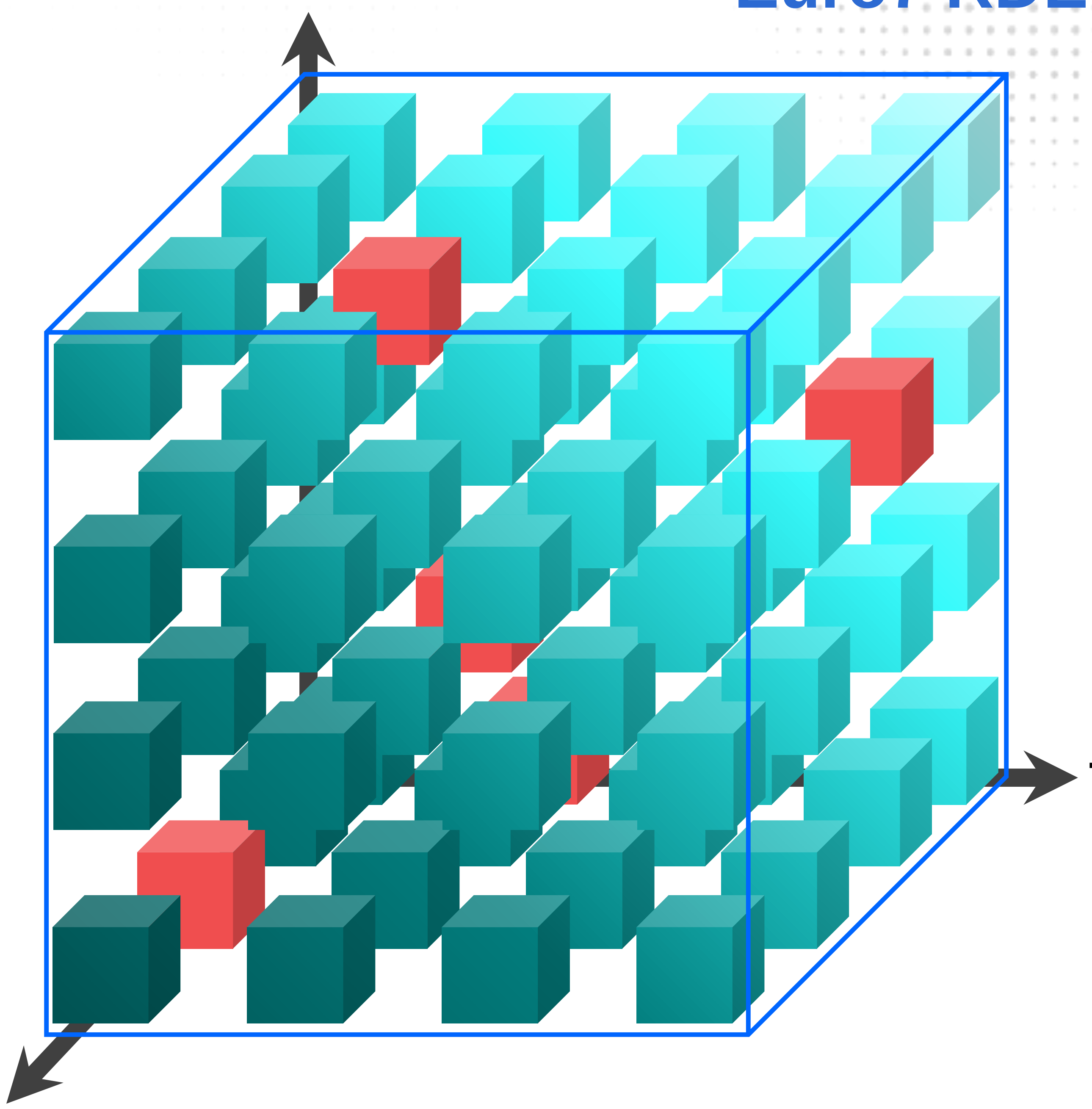
- Almost “infinite” drive-case scenarios in Euro 7
- Impossible to physically test and validate all drive cases

Solution

- Use EDT & simulation to identify worse cases
- Physically test worst cases only (far fewer tests)
- Use EDT & simulation to populate the validation

- **Physical** ‘Worst case’ Road test
  Lab Replication & Emulation
- **Simulation** Empirical Digital Twin
  + Co-simulation

Euro7 RDE Envelope



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EDT Case Study – Identify "Hot Spots"

Project *ViVID* 2020-23

- Use of advanced digital engineering methods on new vehicle development
- Demonstrated EDT on PHEV powertrain
- Won UK Innovation Award in 2023

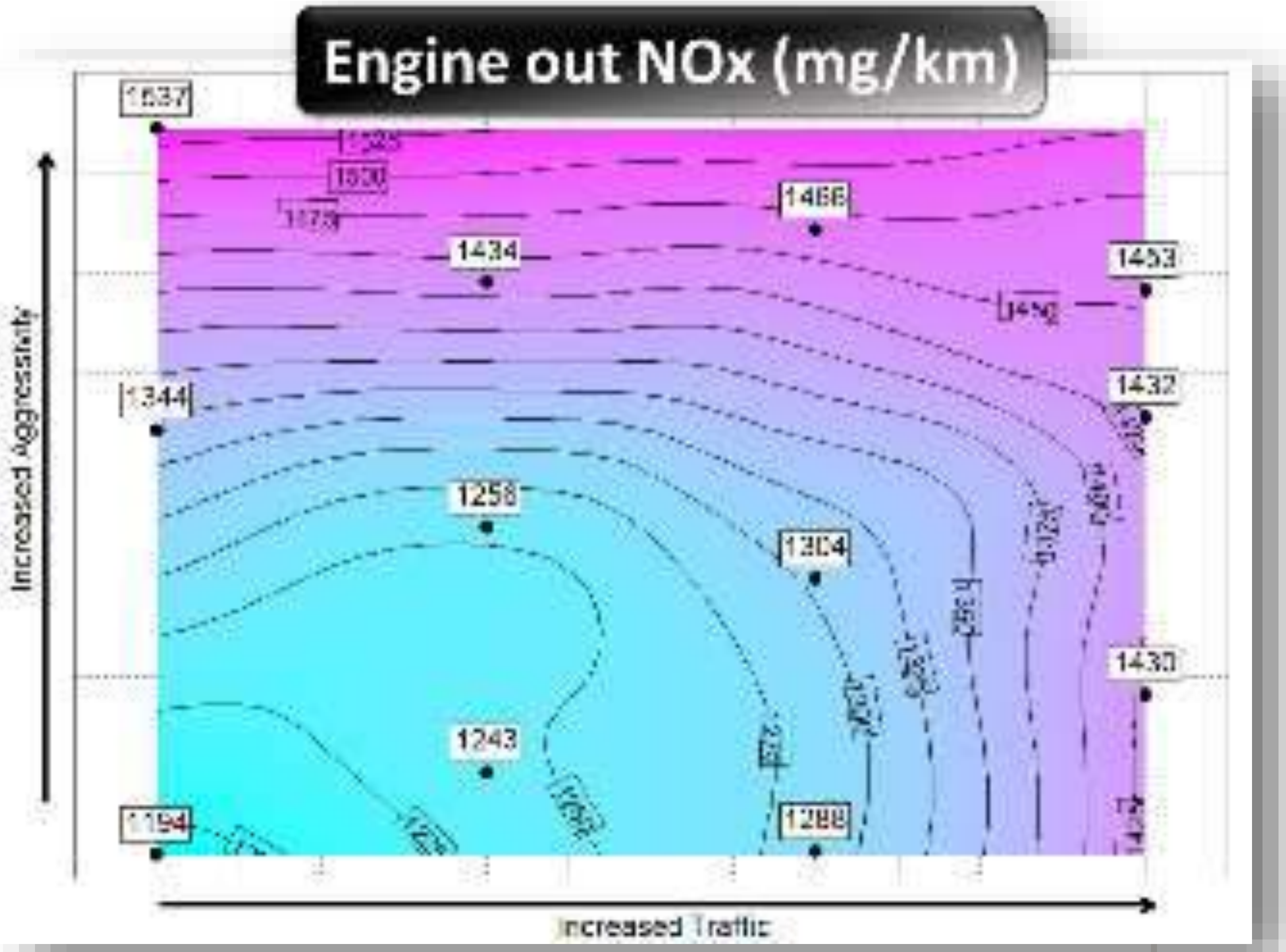
HORIBA's EDT process can find areas of concern or non-conformity quickly to help focus development resources

Run Vehicle Simulation with EDT

Generate vehicle scenarios with **simulation** & combine with **EDT**

Predict "Hot Spots"

- Predict performance, efficiency or emissions
- Identify **"hotspots"** – problem areas that need to be worked on
- Rapid eliminate hot spots in the calibration



Empirical Digital Twins: Bringing trust to simulation workflows

Accurately predict: Fuel, Air, Exh Temp, NOx, PN, Range, Efficiency, ADAS, Functional Safety responses

Create Empirical Digital Twins of critical, complex systems

Especially suited to complex or non-linear

Powertrains

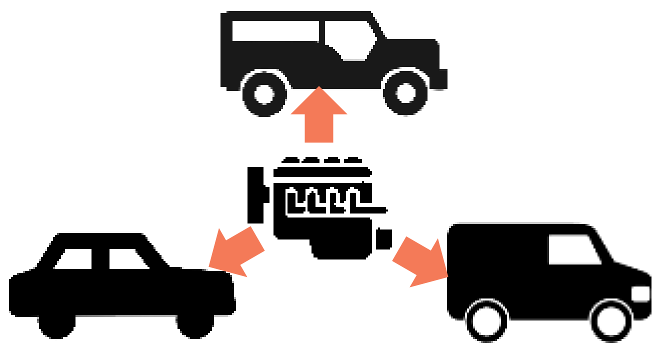
ECT and Thermal

Sensors

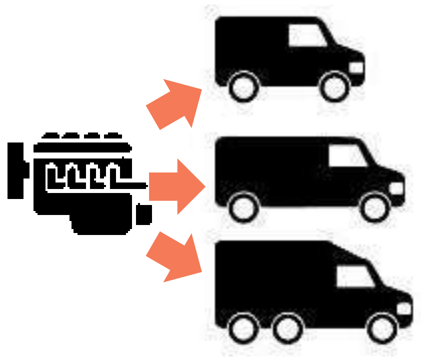
Brake Dust

Analyse 1,000s of scenarios and model combinations

Models

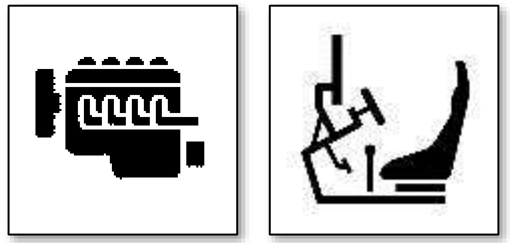


Variants



Scenarios

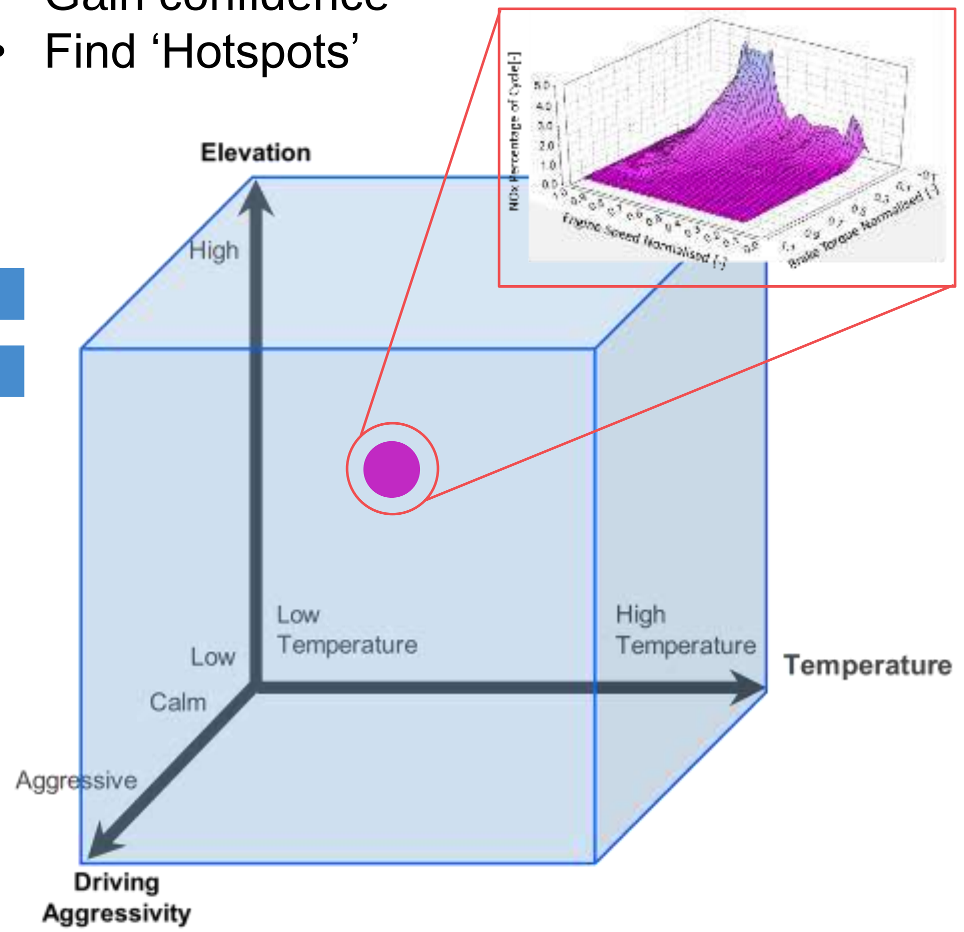
Departments



Accurately predict responses

Explore the Operational Design Domain

- Demonstrate coverage
- Gain confidence
- Find ‘Hotspots’



EV Vehicle-in-Loop (ViL), 4WD e-Powertrain

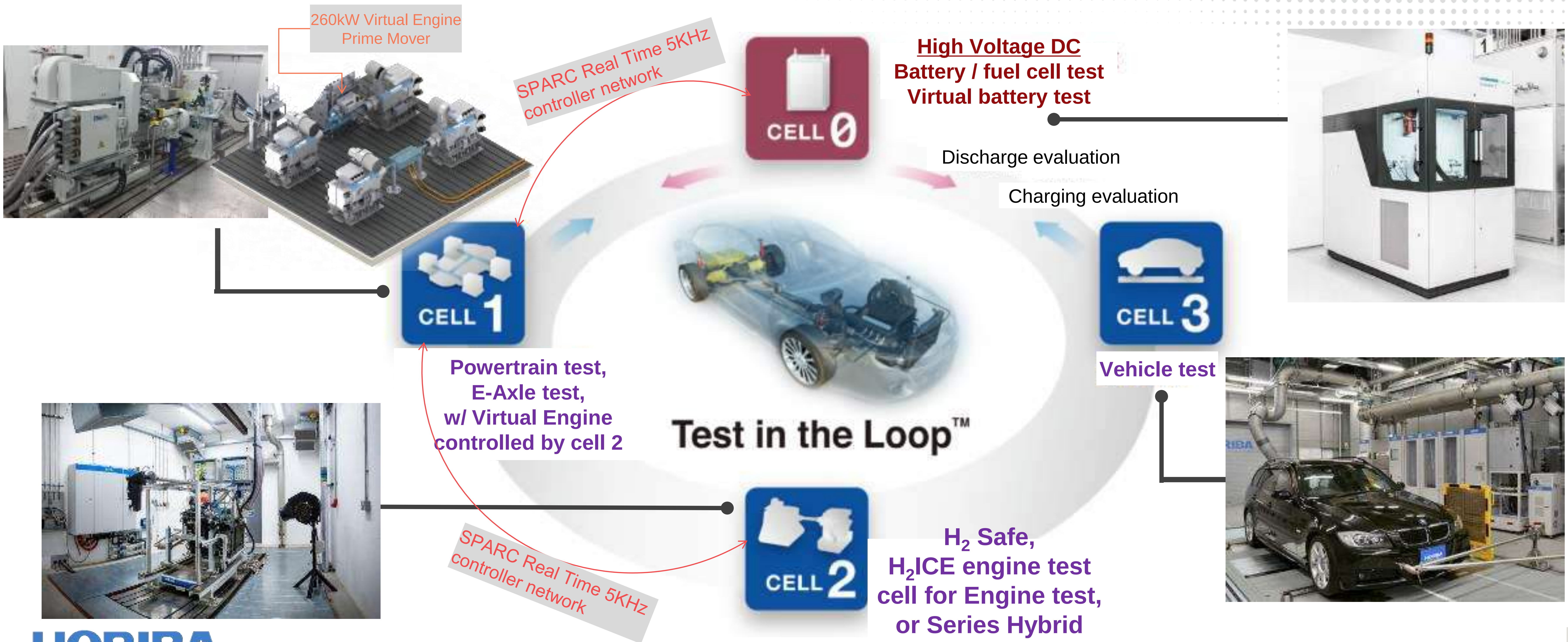
- HORIBA's exclusive robust, AC induction, low inertia wheel dynamometer capable of wheel slip simulation

- Vehicle Support by Wheel (VSW) - emulates Chassis dyno testing but without the tractive effort limitation

- Vehicle Support by Lift (VSL) - provides the ultimate reduction in set up time when testing multiple BEVs

Test in the Loop™

Providing an XiL platform to develop complex propulsion solutions and their control systems together

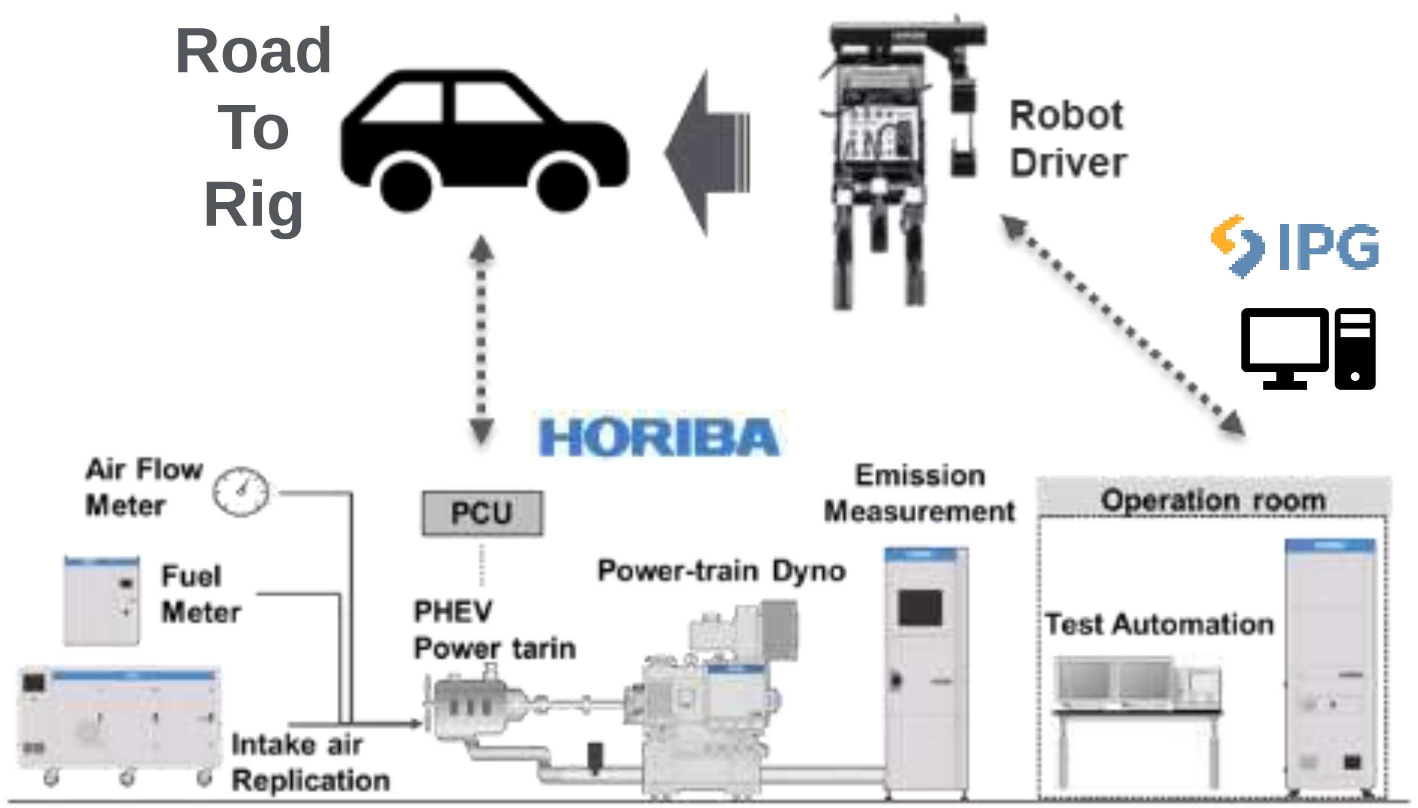


Whole Vehicle Digital Development

- The integration of simulation, digital twins, hardware-in-the-loop and road-to-rig enables full digital development of a vehicle using the DMU (digital mock-up)
- Ride & handling, performance, efficiency, range, emissions, ADAS can all be developed in the virtual domain

Powertrain Propulsion Centre

MIRA



Powertrain-in-the-Loop

Driver Simulator Centre

MIRA

VI-GRADE

IPG

The Future – Be Pragmatic Not Dogmatic

- A multitude of renewable energy vectors and new propulsion solutions
- An amazing collection of new tools and processes

Energy

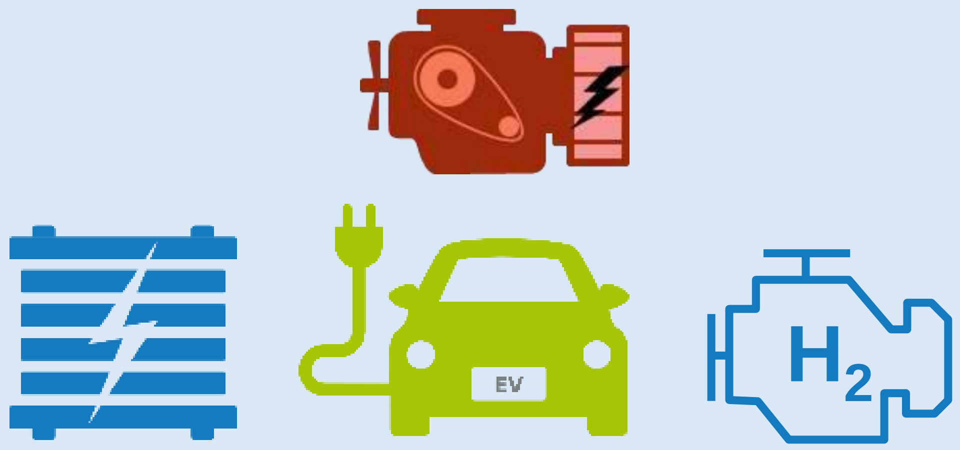
There are a myriad of new “fuels”, each with their own optimal applications.

All options should be supported

Propulsion

Propulsion technologies exist in readiness to exploit all energy vectors and comply with air-quality regulations

All options should be supported



Development

Development capability exists to deliver NPI in all sectors

Digital Engineering methods deliver accelerated NPI

Each solution needs the best energy & propulsion, and a fast road through development

It is the Most Exciting Time! Please join us on this journey

Thank you

Cảm ơn

감사합니다

ありがとうございました

Dziękuję

धन्यवाद

Grazie

Merci

谢谢

நன்றி

ขอบคุณครับ

Gracias

Obrigado

Σας ευχαριστούμε

Děkuji

Teşekkürler

شكرا

Tack ska ni ha

Danke

Большое спасибо