

Future ICE Developments for High Efficiency AND High Performance

Simon Reader

Director of Engineering Services

MAHLE Powertrain Limited

FPC2026
Future Propulsion Conference



MAHLE
Powertrain

MAHLE Powertrain

A global Engineering Services provider specialising in high performance and high efficiency powertrains



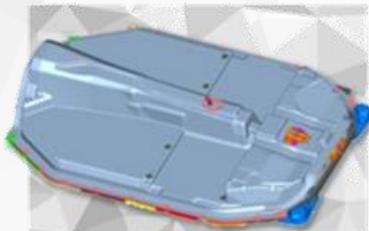
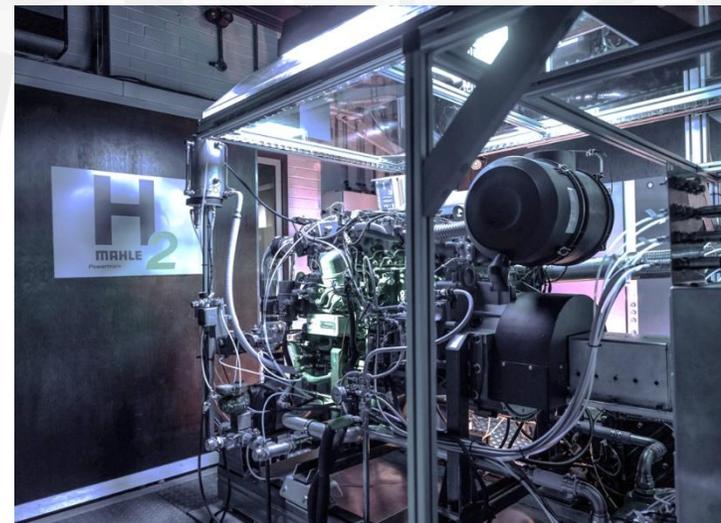
Over 60 years of heritage, innovation and experience



ICE, Electrification and Thermal Management



Whole Powertrain Solutions



Battery Systems

| Simon Reader | MAHLE Powertrain Limited | 25/02/2026



Advanced Engines & Hybrids



Transmissions & E-Axles



Electric Machines



Bespoke Controls & Software

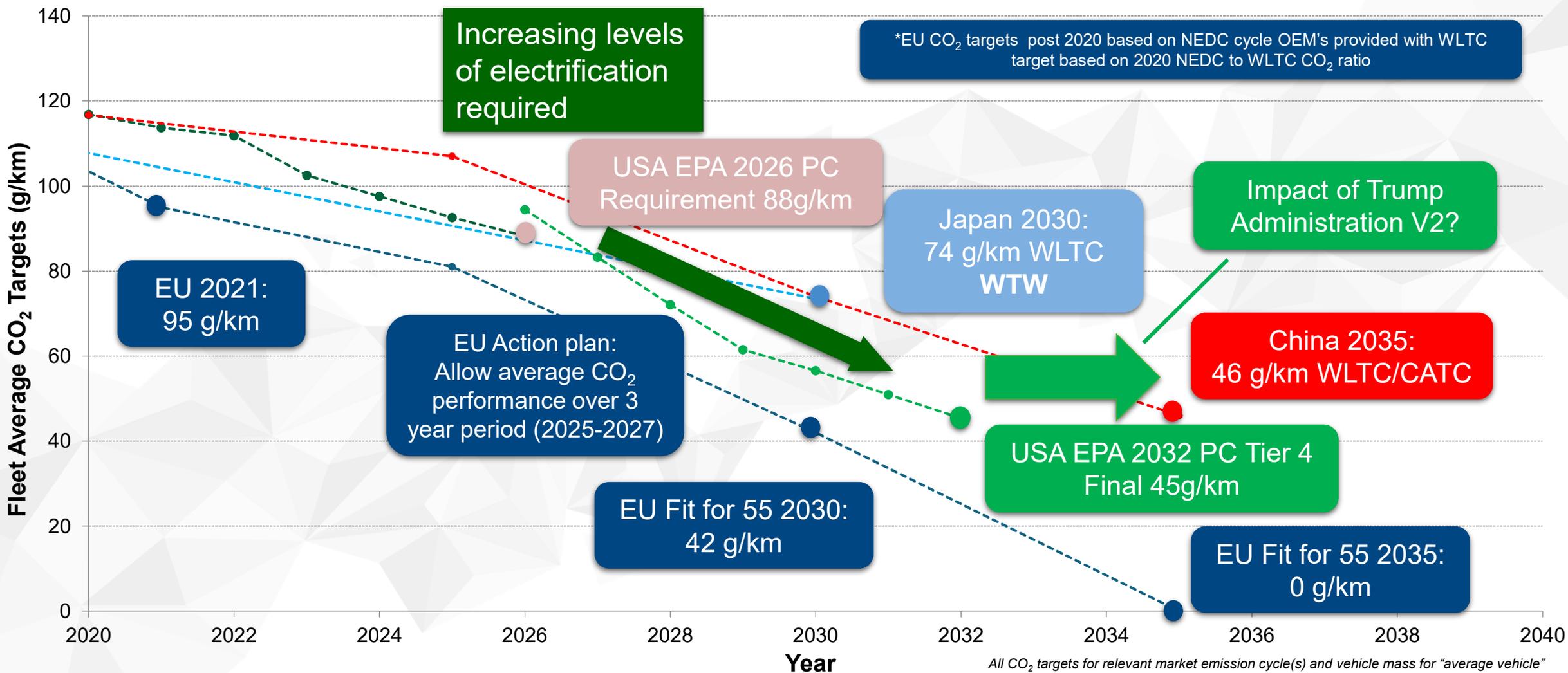


Development & Validation



Vehicle Integration

LDV Global Fleet CO₂ Limits



Source: Japan: <https://www.meti.go.jp/press/2020/12/20201225012/20201225012-2.pdf>

EU Fit for 55: EU regulation 2023/851

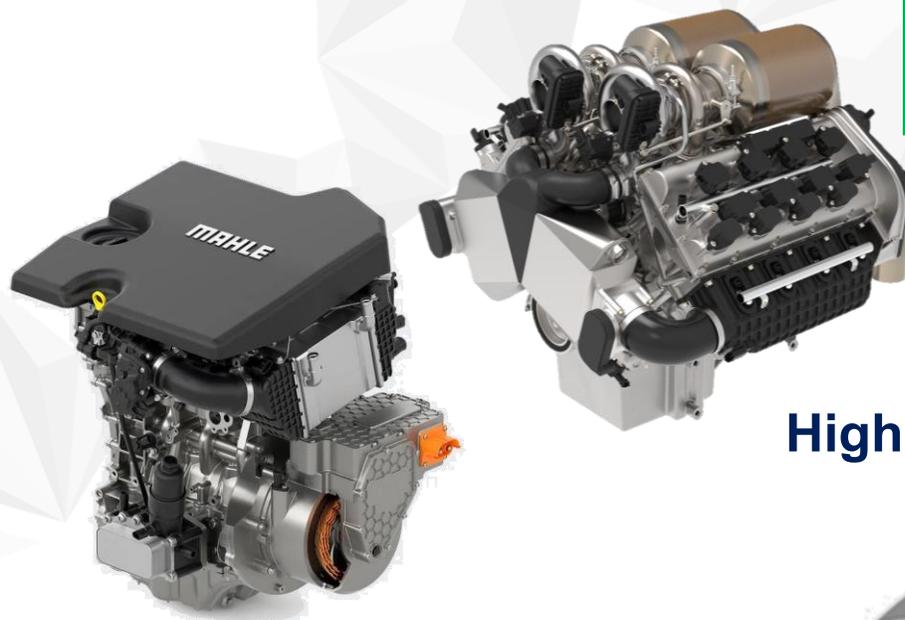
USA: <https://www.epa.gov/regulations-emissions-vehicles-and-engines/proposed-rule-revise-existing-national-ghg-emissions>

Engines are still a key part of electrified powertrains

Emissions compliance and Efficiency are still the key drivers whatever the application

Highly Efficient Range Extenders

High Performance Hybrids



Customer Motivation – China REEV Market

China Market Key Figures and Trends

- **Rapid Growth:** EREVs are the fastest-growing drivetrain in China, with sales rising 83% in 2024¹
- **Market Dominance:** EREVs accounted for nearly 25% of electric SUV sales in China in 2024 and over 60% of large electric SUV sales²
- **Increased Registrations:** In 2024, China registered one million EREV vehicles³
- **Model Availability:** The number of EREV models available in China doubled from 17 in 2023 to 36 in 2024, with more models planned for 2025⁴



Li L8



Deepal S07



Yangwang U8



Leapmotor C11

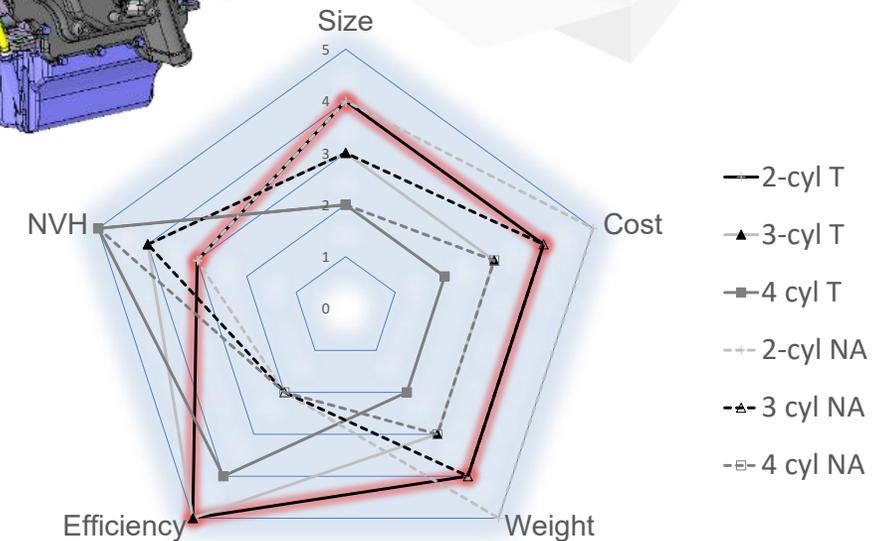
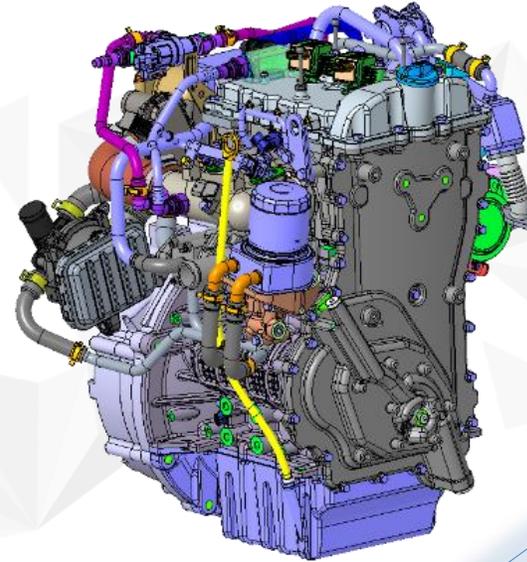


Voyah Free

REx Engine Specification

Range Extender Architecture

Parameter	Value
Displaced volume [cc]	996
Bore x Stroke [mm]	79.0 x 101.6
Compression ratio	14:1
Number of cylinders	2
Number of valves per cylinder	4
Power	60 kW @ 3800 rev/min
Torque	151 Nm
Fuel injection system	Port fuel injection
Ignition system	MAHLE Jet Ignition (MJI)
Valve timing	Fixed, Miller cycle valve timing
Turbocharger	Single-scroll, with wastegate



Customer Motivation – Hypercar Market

Key attributes

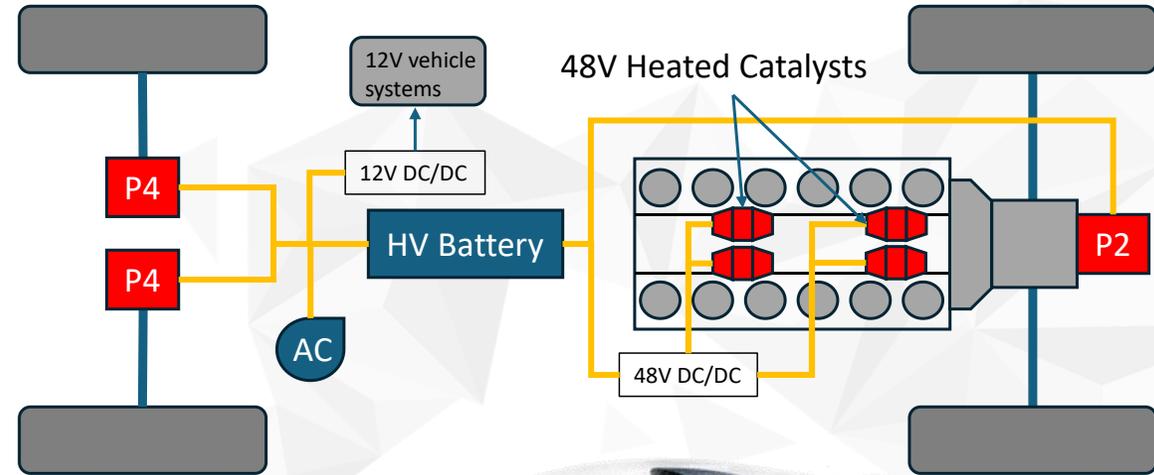
- €3m starting price
- Emotion
- Investment
- Status
- Big numbers! 1000PS and up.



High Performance Hybrid Architecture

Powertrain specification

- 1250PS V12 Engine mid mounted
- 600PS single P2 and twin P4 motors
- 4.1kWh 800v immersion cooled battery pack



High Performance Engine Specification

Hypercar Architecture

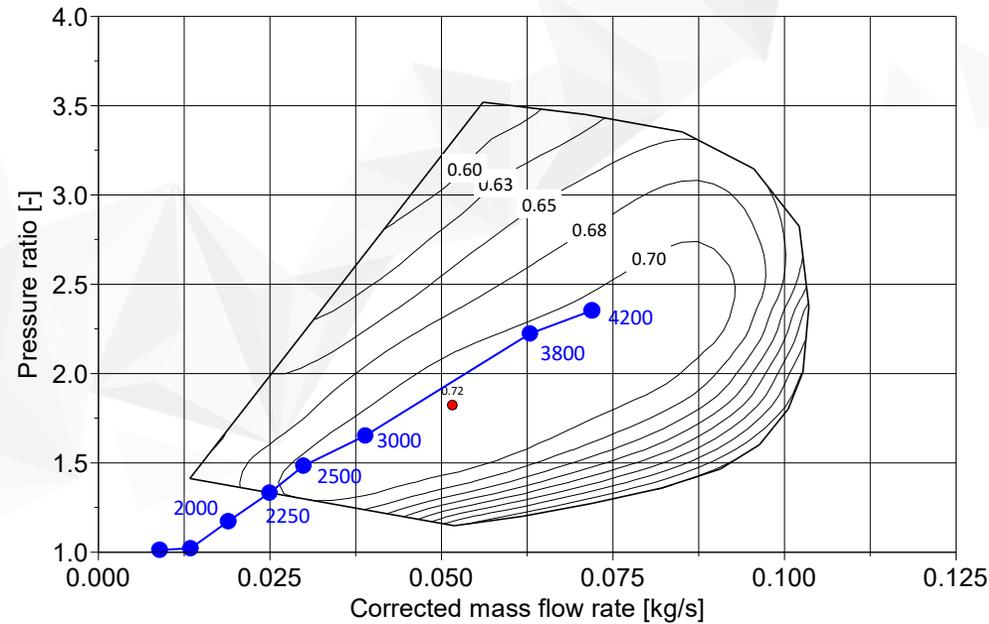
Parameter	Value
Displaced volume [cc]	6600
Bore x Stroke [mm]	96.5 x 75.2
Compression ratio	10.5:1
Number of cylinders	12
Number of valves per cylinder	4
Power	920 kW @ 8500 rev/min
Torque	1200 Nm @4000-7000 rev/min
Fuel injection system	Central direct injection
Ignition system	MAHLE Jet Ignition (MJI)
Valve timing	Inlet and exhaust 40° VVT
Turbocharger	4x ball bearing with electric wastegates



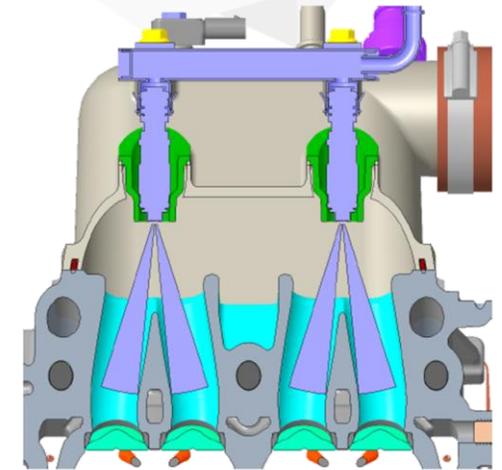
Boosting, Intake and Fuel System

Optimised for Low Cost

- Runner entry bell mouths cast into cylinder head
 - Enables low cost and simple plastic intake manifold design
- CFD Optimised intake system
 - Control of EGR condensate
- Port fuel injected for low cost
- Turbocharger matching required careful attention
 - High boost requirement at low flow
 - Miller cycle
 - Low pressure EGR



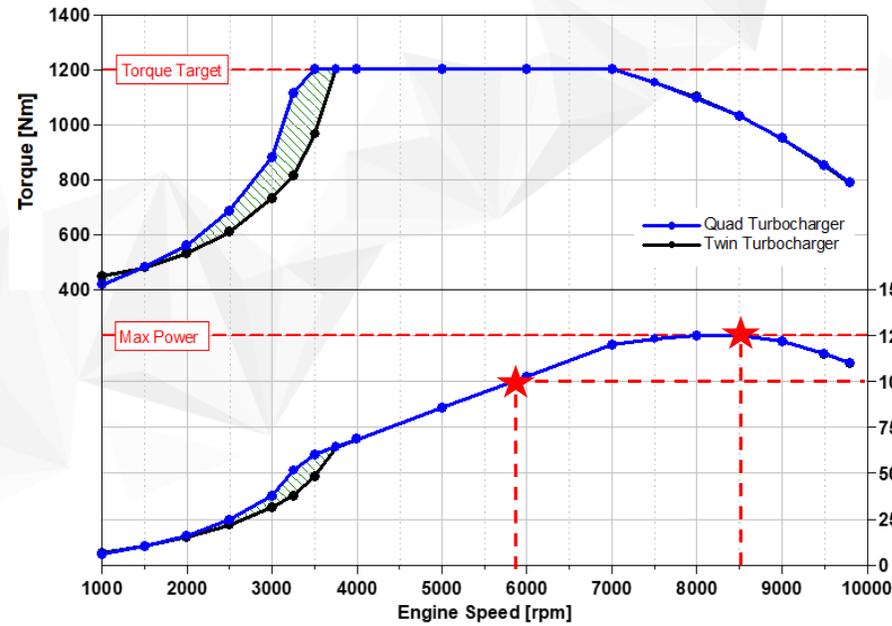
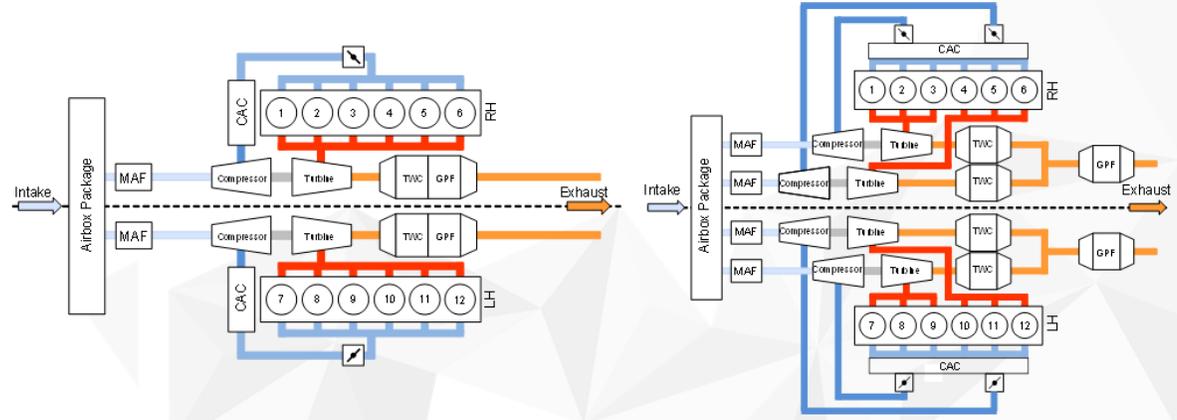
Compressor operation over intended operating locus



Boosting, Intake and Fuel System

Optimised for best performance

- Hot vee approach
- Quad turbochargers
- Hot side throttles
- Integrated CAC to intake manifold.
- Cross over concept to give bank to bank balance
- CFD Optimised
- MJI and central DI – Lambda 1 full area map capable
- Turbocharger matching required careful attention
 - Maximise boost response



MAHLE Jet Ignition (MJI) Pre-chamber Based Combustion System

Passive MAHLE Jet Ignition

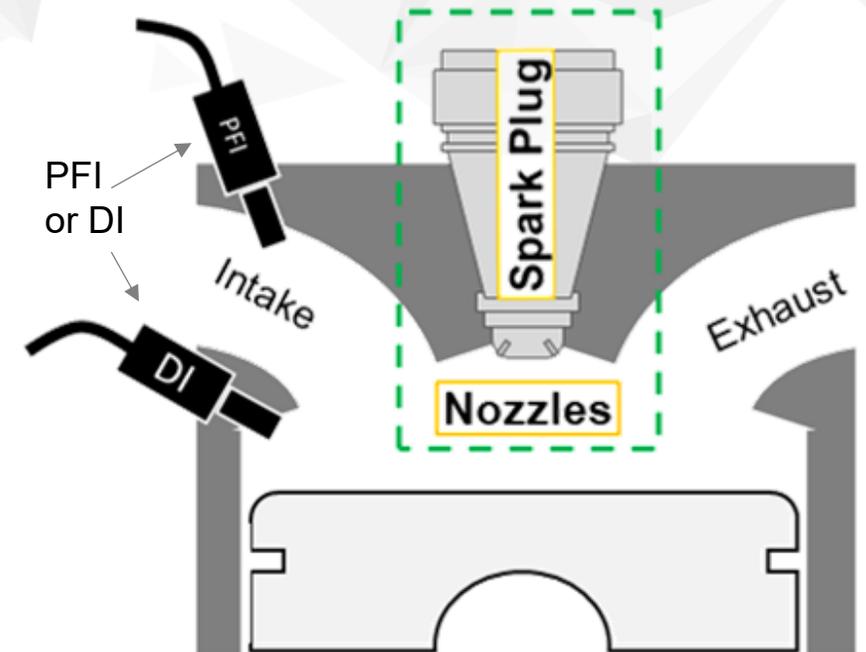
- Pre-chamber ignition systems are not new
 - **Recent renewed interest for high efficiency**
 - Key challenges
 - Whole map operation
 - Cold start
- Passive pre-chamber concept
 - Small chamber for spark-plug
 - Linked to main chamber via several small nozzles
 - Creates multiple ignition sites in main combustion chamber

Passive Layout:

- 1 Injector
- $\lambda=1$
- Conventional After-treatment

Key Benefits:

- Knock Reduction
- Faster more Stable Combustion
- EGR Tolerance



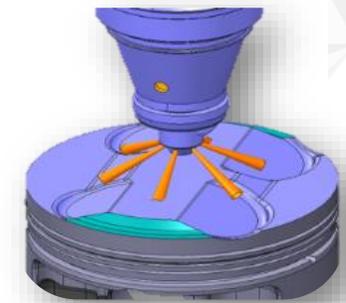
MAHLE Jet Ignition (MJI) Pre-chamber Based Combustion System

Combustion Comparison with Conventional Spark- plug

- Passive MAHLE Jet Ignition (MJI)
 - No additional fuel injector
- Rapid combustion
 - Increased CR capability
 - Excellent EGR tolerance
- Improved stability

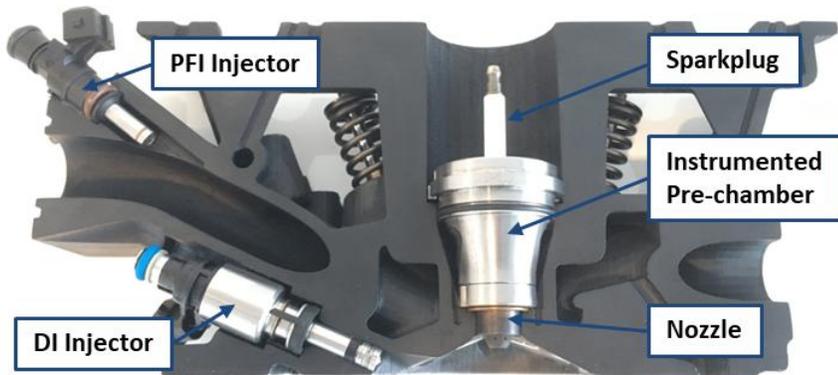


	CSP	MJI
MFB 50%	17.4	8.6
10-90% Burn Duration	25.9	15.4
PMax	71.2	90.9
RMax	1.98	5.2
COV NMEP	2.54	0.85



Measured results for 4000 rev/min
& 18 bar BMEP

Example: Passive MJI and CSP operation at
4000 rev/min and 18 bar BMEP

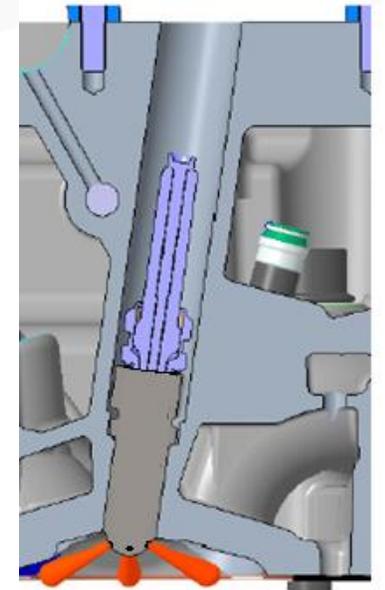
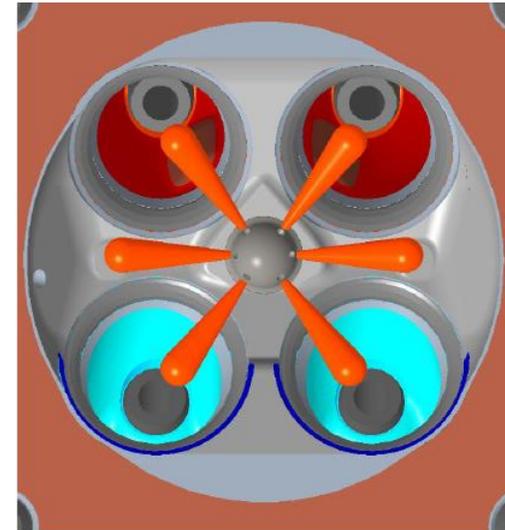
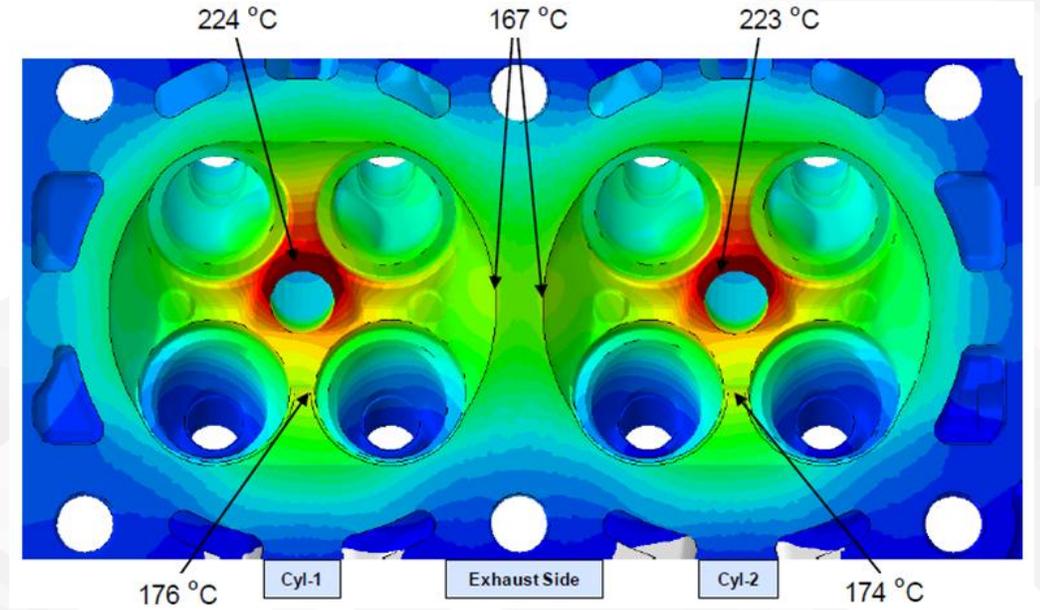
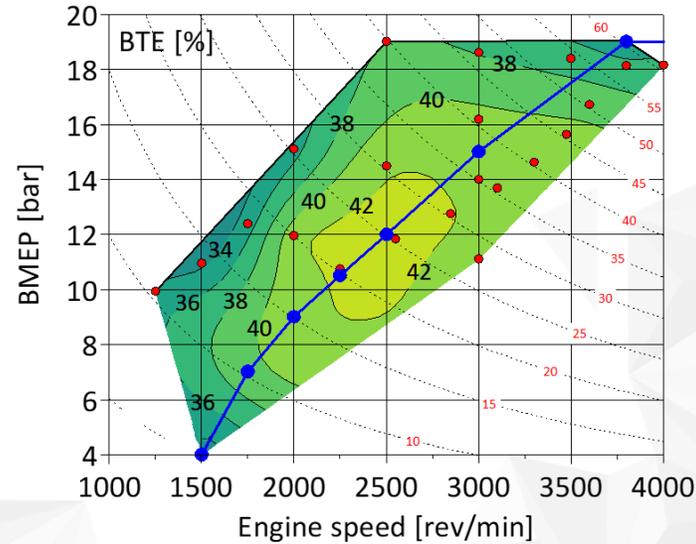


Research engine installation for both
passive & active MJI

High Efficiency MJI Installation

MJI Installation

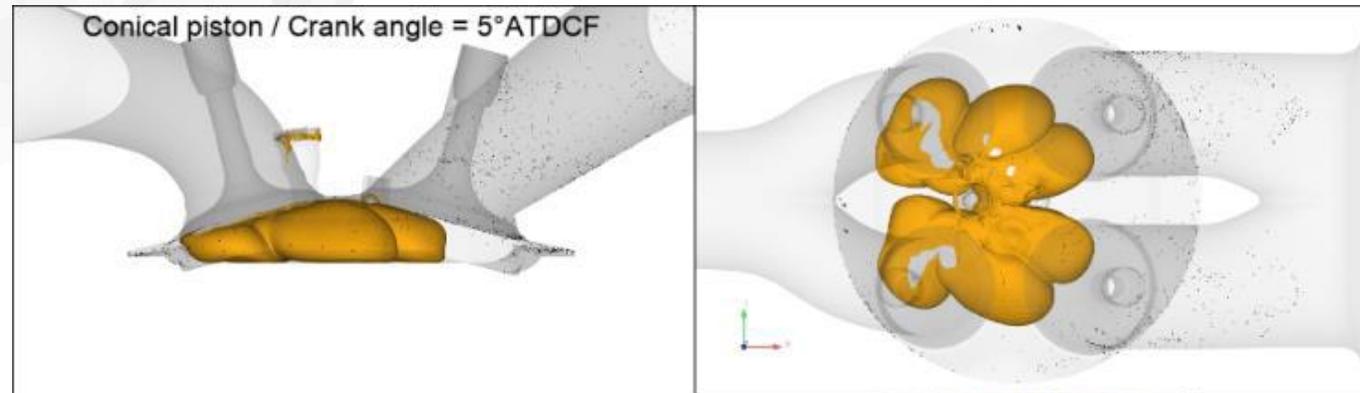
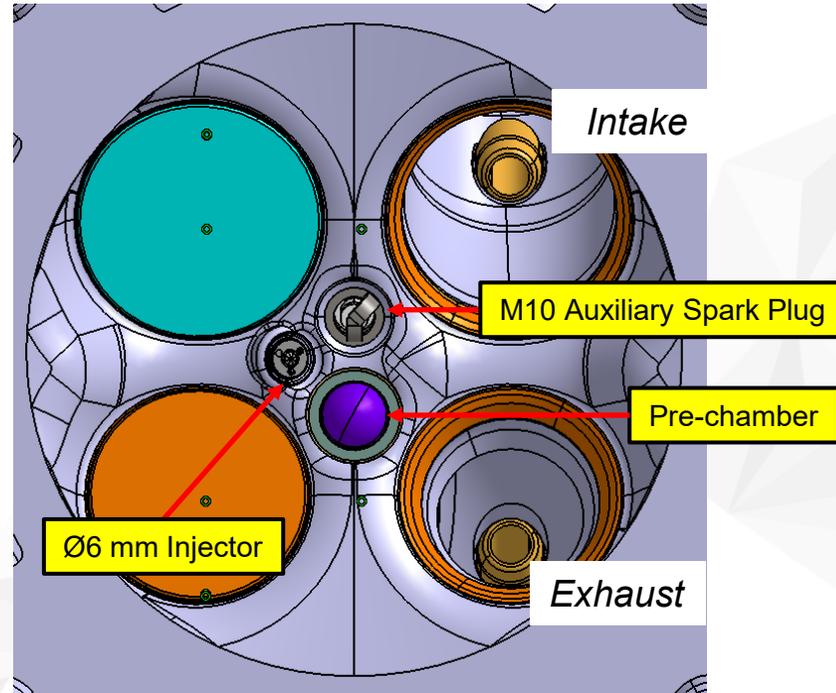
- Steel MJI insert press-fitted into head from above
- Detailed mechanical analysis conducted
 - Interference to ensure pre-chamber retention at hot conditions
 - Not over-stressing head parent metal when cold
- Thermal analysis validated
 - Max head temp: 233°C
 - Spark-plug also sufficiently cooled



High Performance MJI Installation

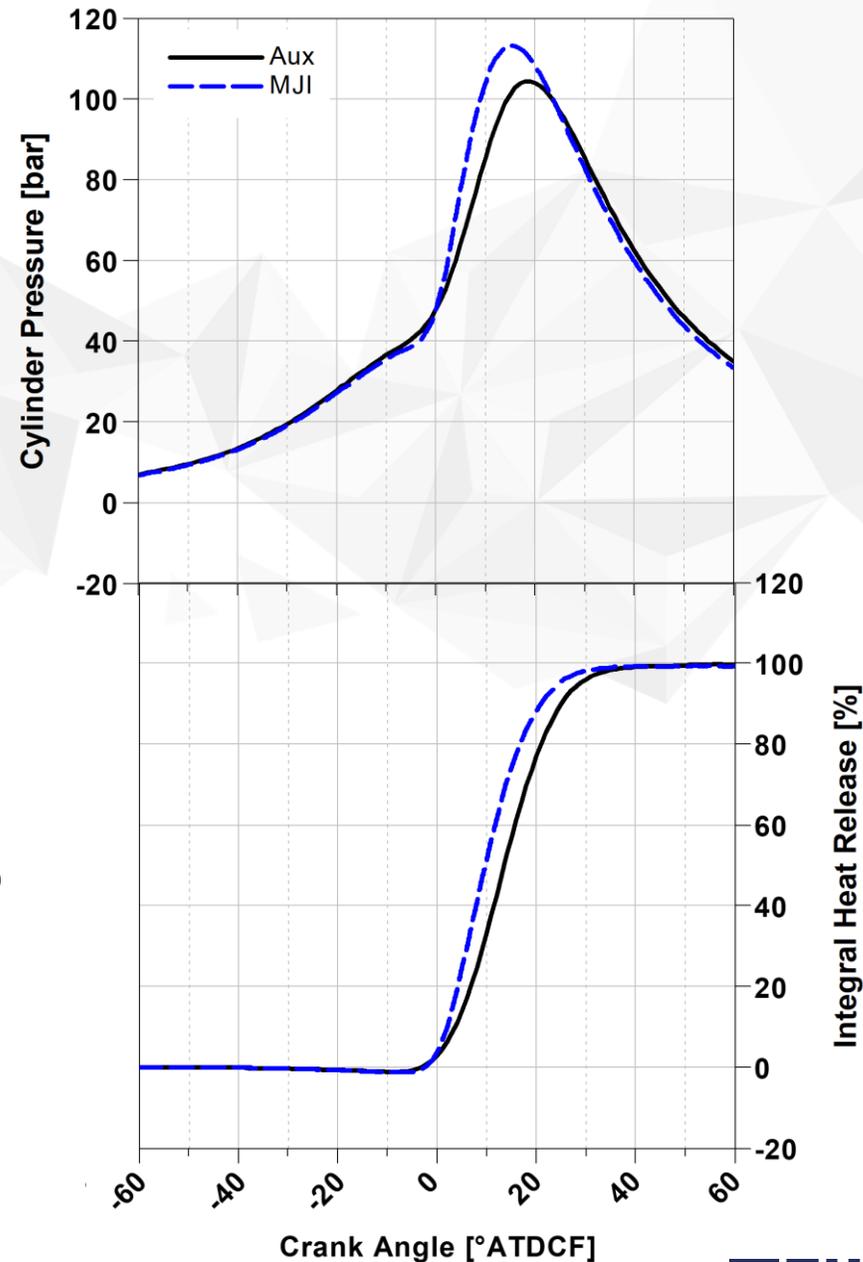
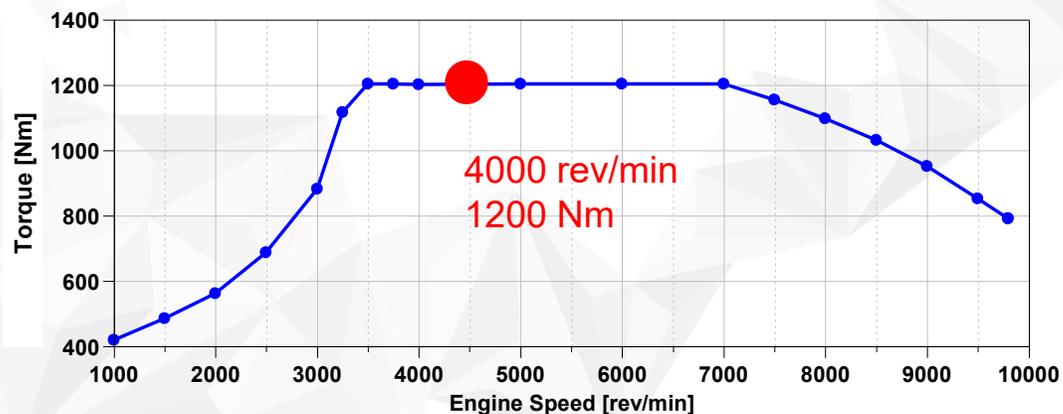
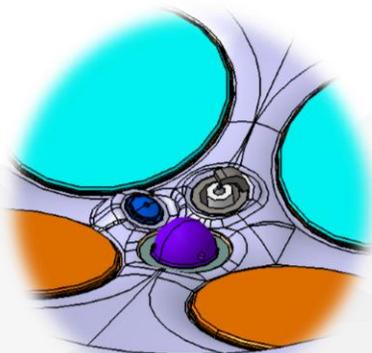
MJI Installation

- **Patented prechamber design** ensures excellent cooling of chamber and spark-plug
- Centrally located pre-chamber, auxiliary spark-plug and central DI fuel injector
 - Packaging challenge!
 - Auxiliary plug used due to high speed ratio operation range of engine



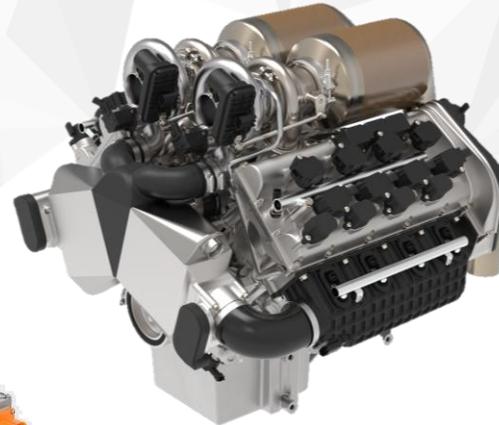
Zenvo Engine Combustion with Auxiliary Spark Plug Vs MJI

MJI Performance



Conclusion

- Markets and regulations are very dynamic currently
- Highly efficient powertrains will be required for the foreseeable future globally
- Development of new technologies for ICE is important
- Technology selection for performance **and** efficiency is key
- MJJ can provide an enabler for both



Thanks for your attention



MAHLE

Powertrain

Simon Reader

Director of Engineering Services
MAHLE Powertrain Ltd.

Costin House, St. James Mill Road, Northampton NN5 5TZ, Great Britain

Mobile: +44 (0) 7990 551435

simon.reader@mahle.com,

<https://www.mahle-powertrain.com>

Enquiries: powertrain@mahle.com

www.mahle-powertrain.com

MAHLE

Powertrain