

Sub-Zero Cold Start of a Novel 6.6ℓ H2 PFI V8 Engine: Experimental Assessment of Coordinated Ignition and Injection Strategies

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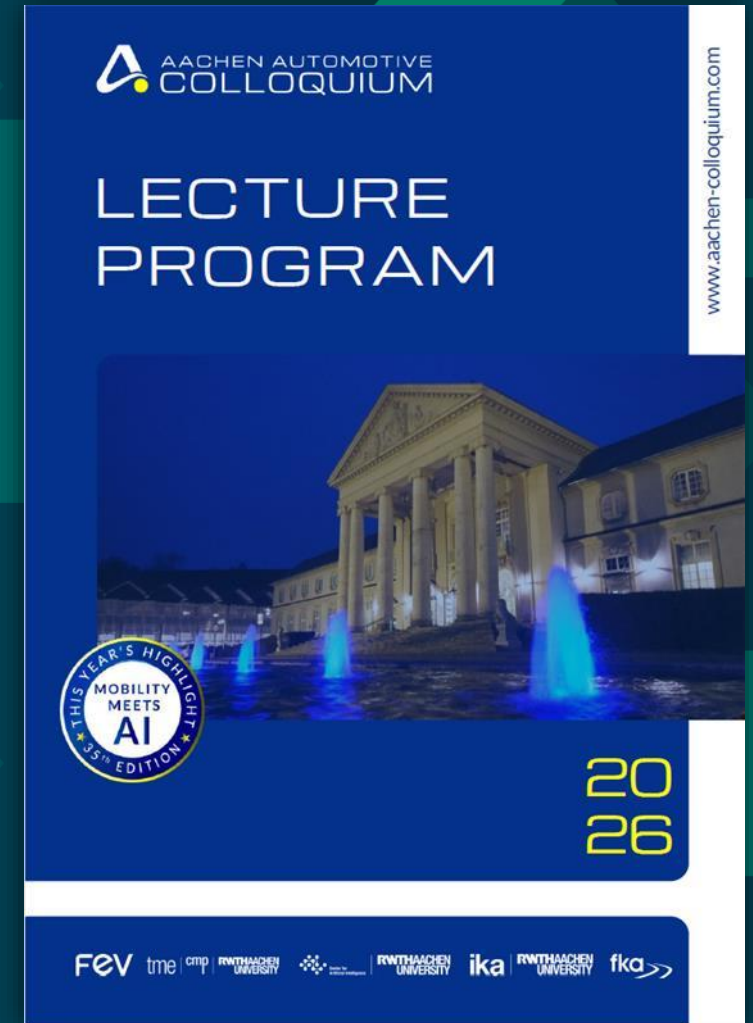
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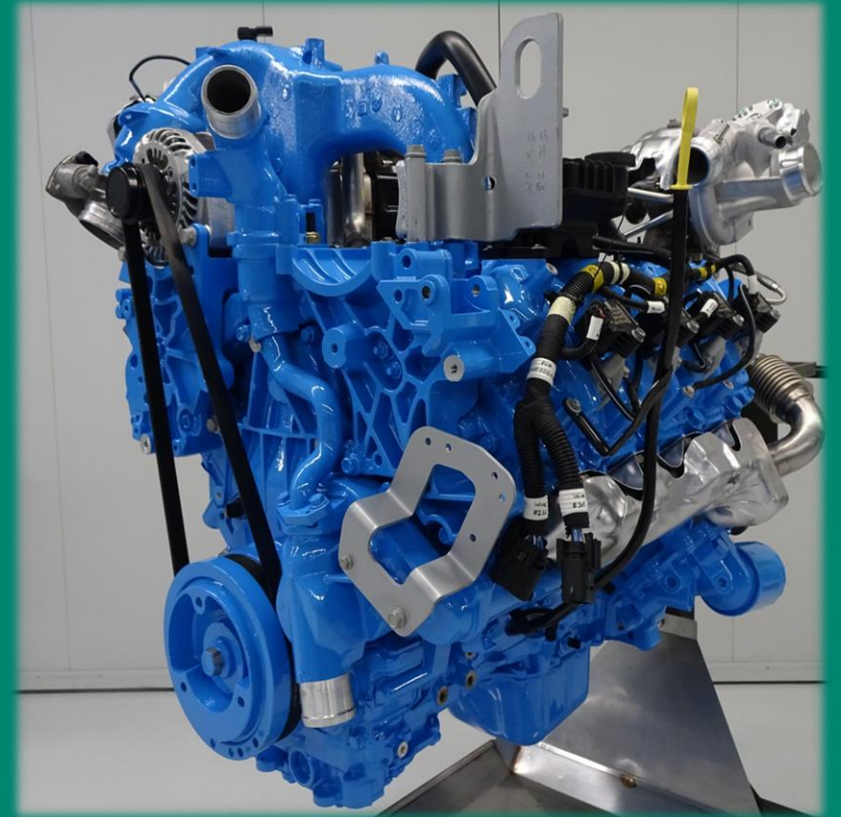
Presentation at Aachener Kolloquium
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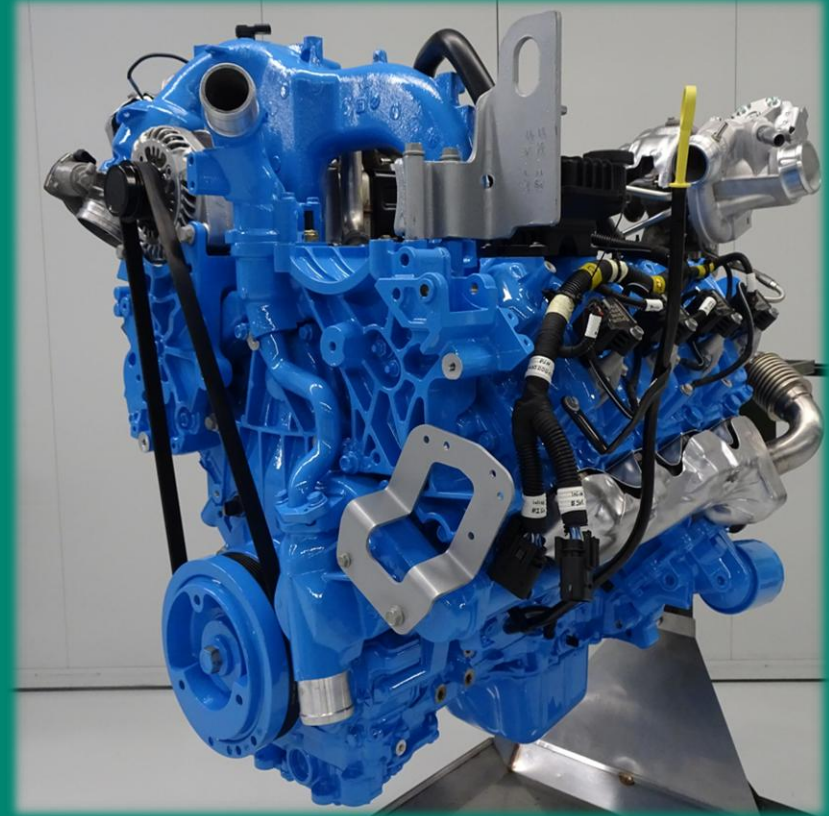
Agenda

- Engine description & critical systems
- Test rigs and bench activities
- Solutions and conclusions



Engine Description & Critical Systems

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Engine description and key subsystems

CONVERSION MAIN FEATURES:

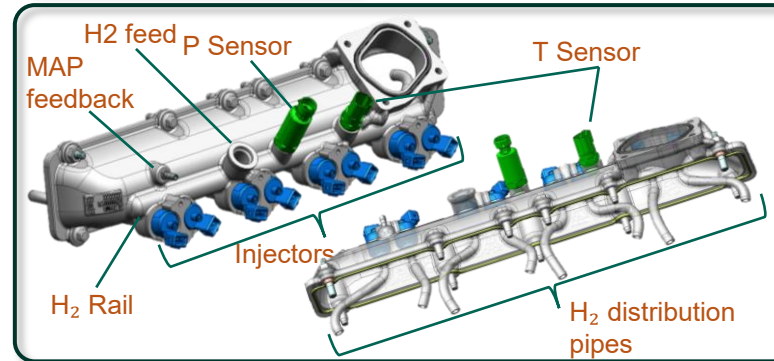
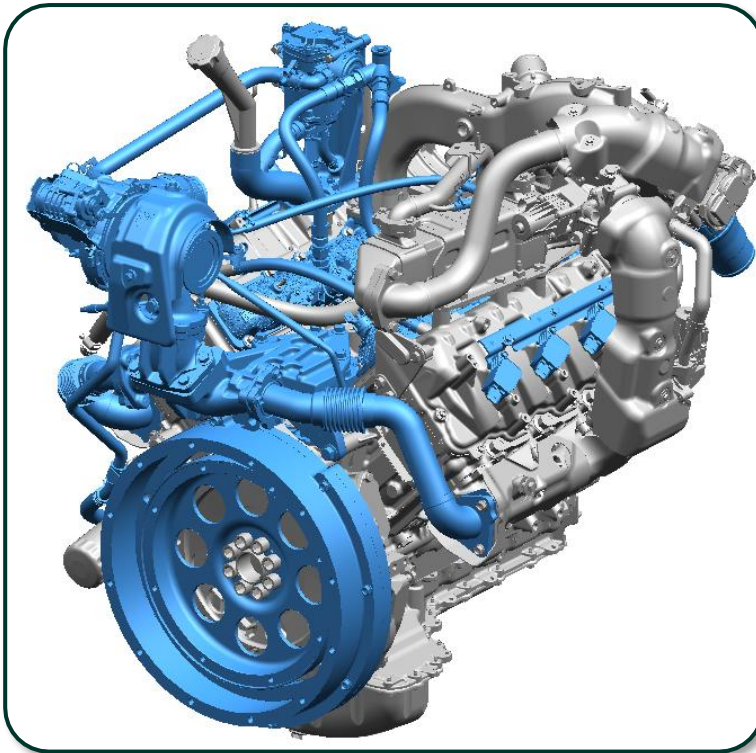
- ◆ **sequential port-fuel injection**, integrated in the intake manifold
- ◆ **ultra-cold spark plugs**, and centrally mounted **ignition coil** for each cylinder
- ◆ **low-end torque oriented VGT**
- ◆ **Positive active ventilation**

Injection system:

- ◆ Additive manufactured Intake Manifold with integrated H₂ rails
- ◆ PFI Injectors (2 injectors per cylinder)
- ◆ Mechanical H₂ Pressure regulator

Ignition System:

- ◆ Semi-Surface Discharge Spark Plug
- ◆ Inductive Ignition Coil, which includes specific feature for H₂ application



H2 Cold start: targets and technical challenges



CRANKING PERFORMANCE

1 Startability
down to -20 °C

2 Natural gas
like crank time

3 Efficient
combustion

IDLE COMBUSTION STABILITY

1 Negligible
misfire events

2 CoVIMEP < 5%
(≈15 kPa)

3 Idle speed
stability
(± 25 rpm)



INJECTION

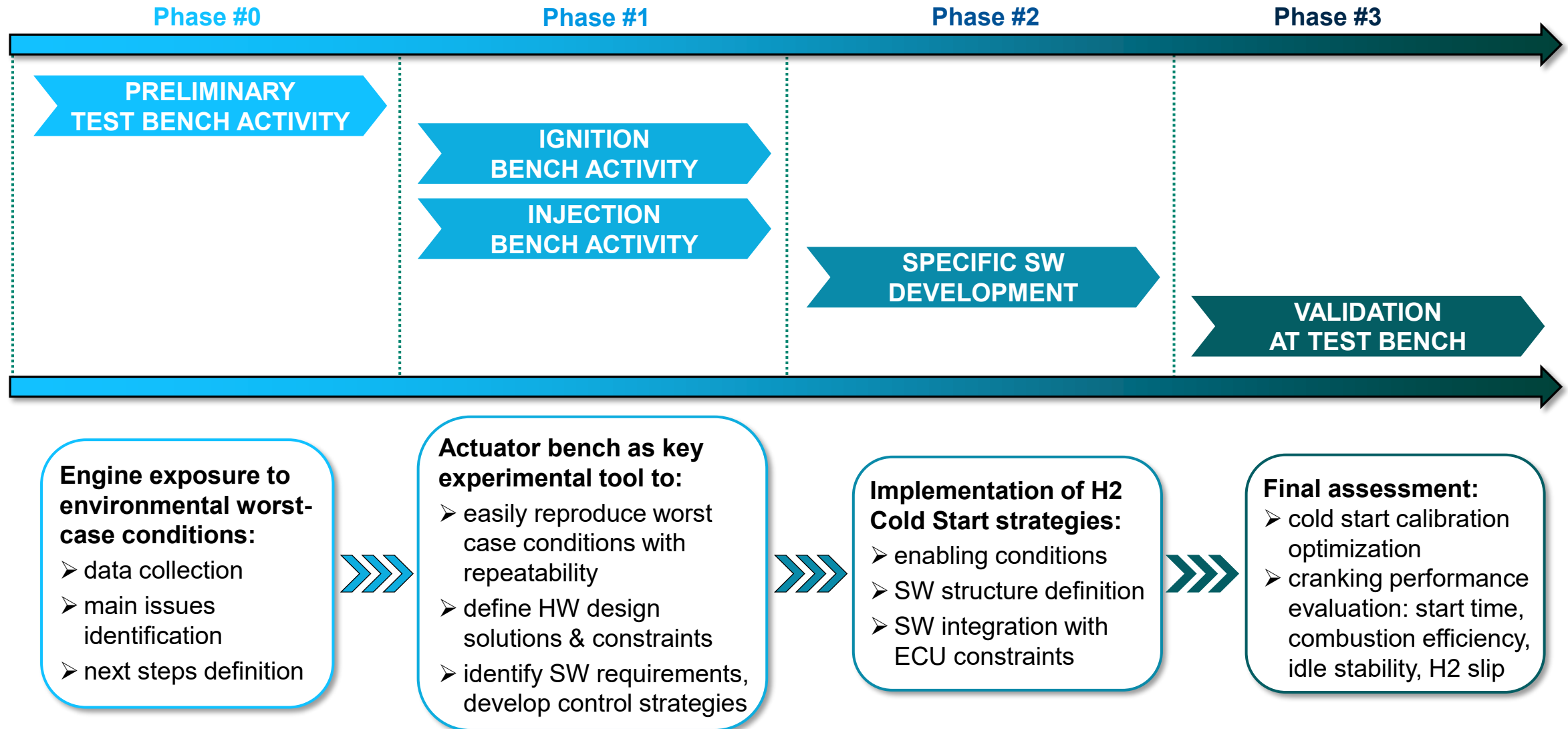
- × **Delivery derate (partial-sticking)** due to elastomer material properties change
- × **Injector sticking** due to rubber seal icing (mistroke events)
- × **Shot-to-shot variation**



IGNITION

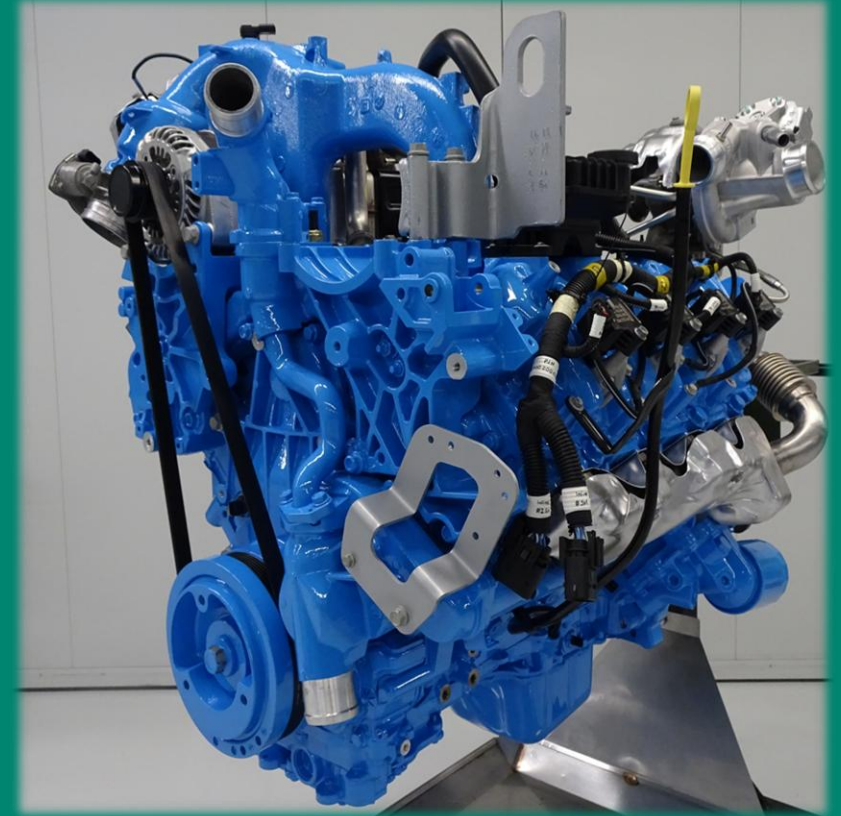
- × **Misfire** due to cold environmental conditions
- × **Water-bridge on spark-plug electrode** due to combustion water condensation
- × **Water icing** on spark-plug electrode

H2 Cold start: strategies development process



Test rigs and bench activities

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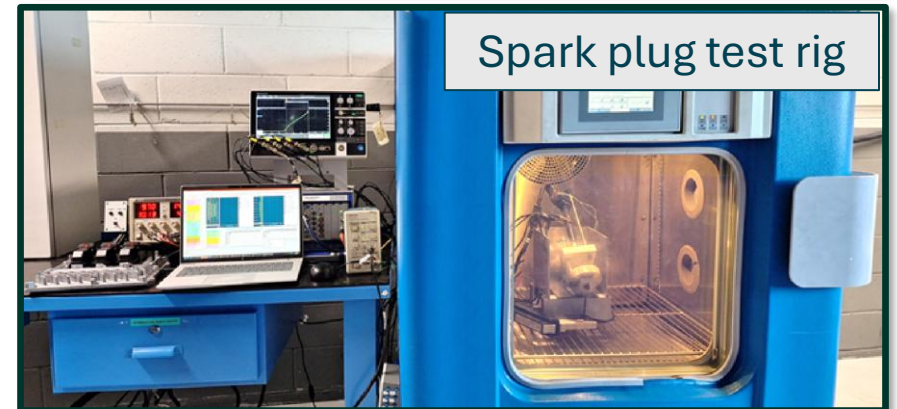
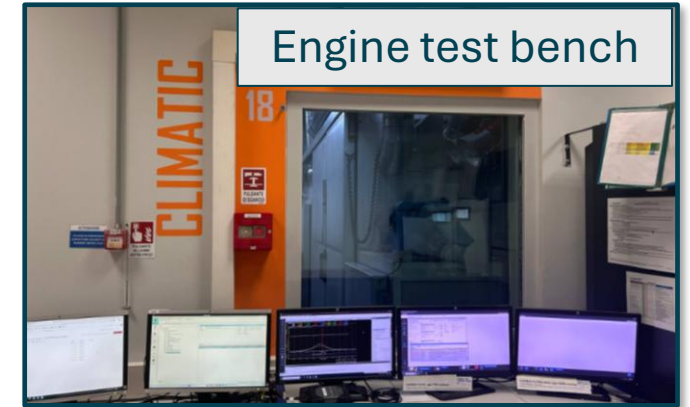
Climatic Capabilities

► Climatic test bench

- ✓ Full environmental simulation for engine validation: climatic testing from -30°C to +40 °C and altitude simulation down to 850 mbar
- ✓ High-power multi-fuel test capability, supporting diesel and hydrogen applications up to 2,680 Nm / 499 kW
- ✓ Complete test cell integration, including thermal conditioning, emissions measurement and automated test control platforms

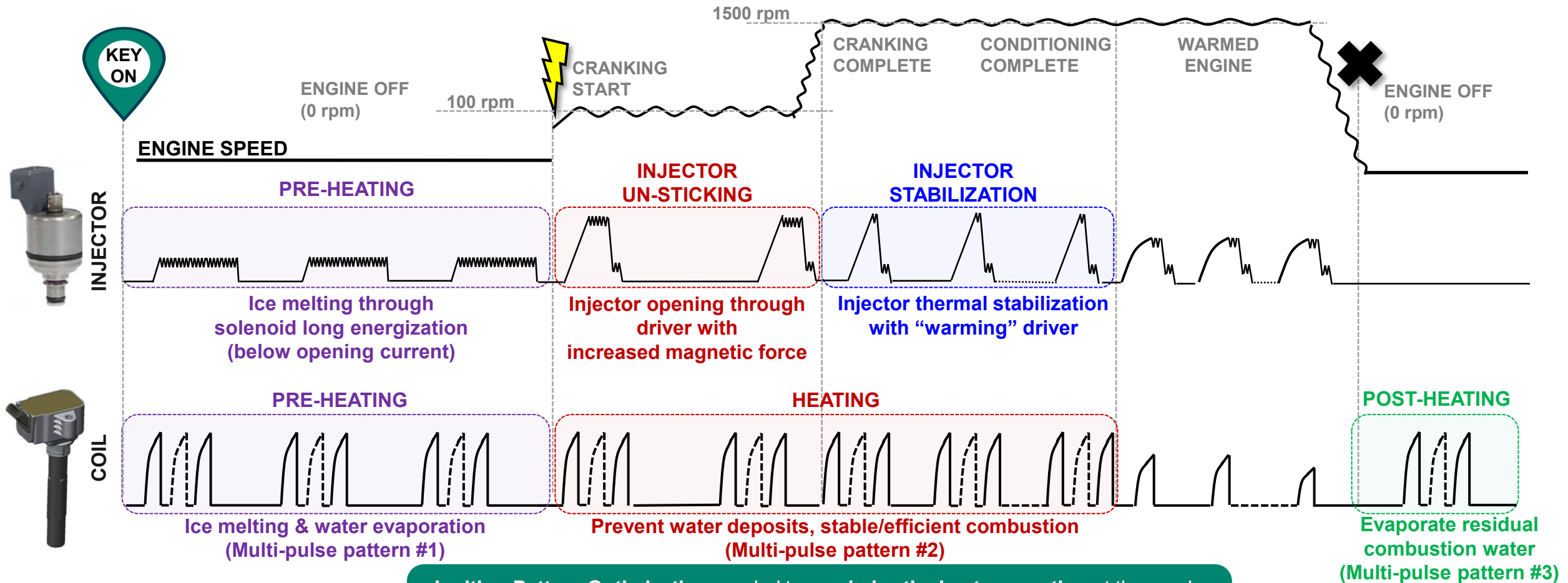
► Injector and Ignition systems test rig

- ✓ Repeatable, flexible and cost-effective test environment
Efficient and reliable system evaluation: easy test set-up with lower complexity respect to engine dyno
- ✓ Ambient temperature and humidity control
Spark-plug and injectors testing in extreme conditions (water condensation/icing).
- ✓ Full components characterization capability (electrical and performance)



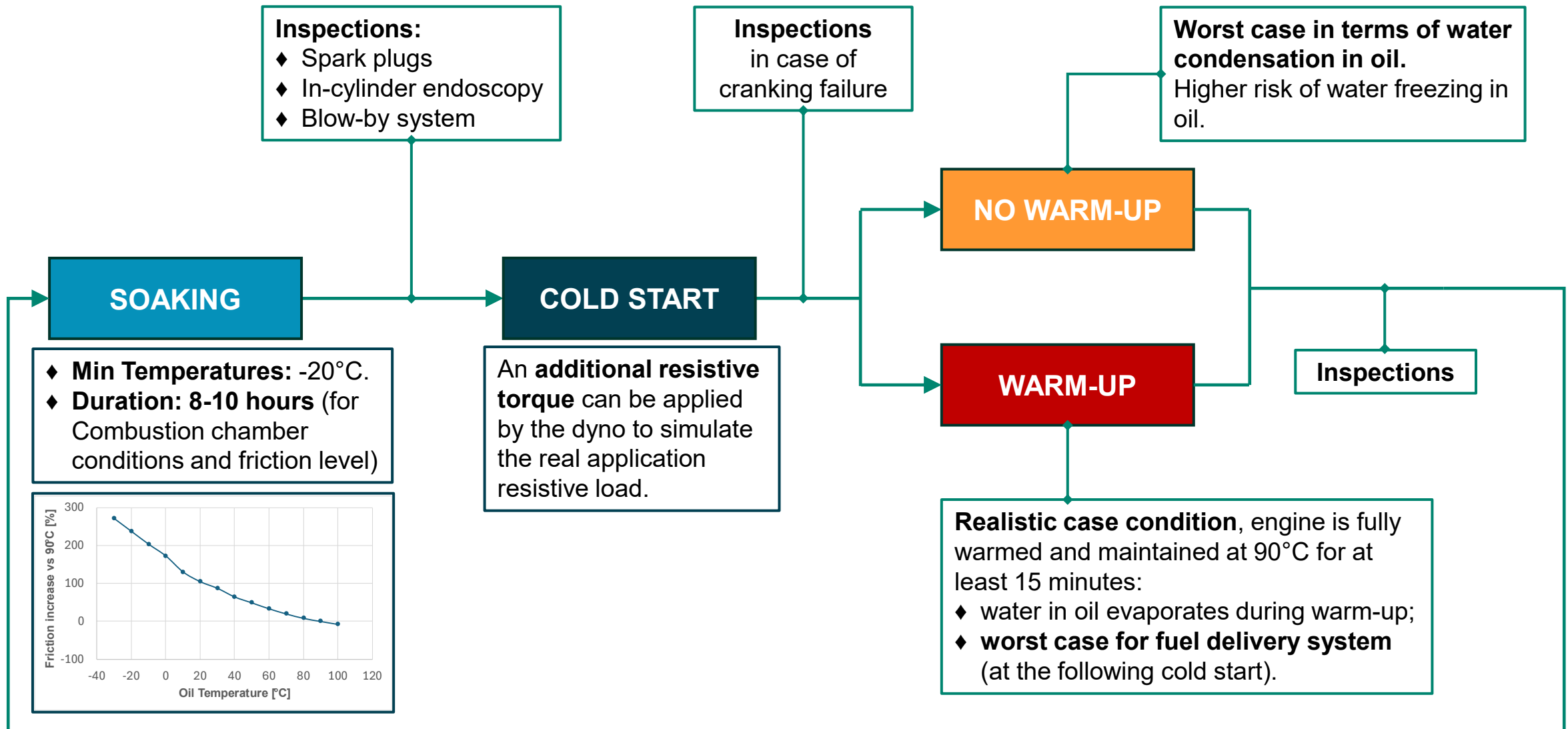
Injection and ignition strategies

Besides standard combustion calibration (spark advance angle and lambda optimization) the key **enabler for robust startability** was the definition of a specific strategy for controlling injection and ignition systems.



Ignition Pattern Optimization needed to maximize the heat generation at the spark-plug electrodes **respecting HW constraints** (coil restrictions, angular limits,...).

Test procedure at engine bench

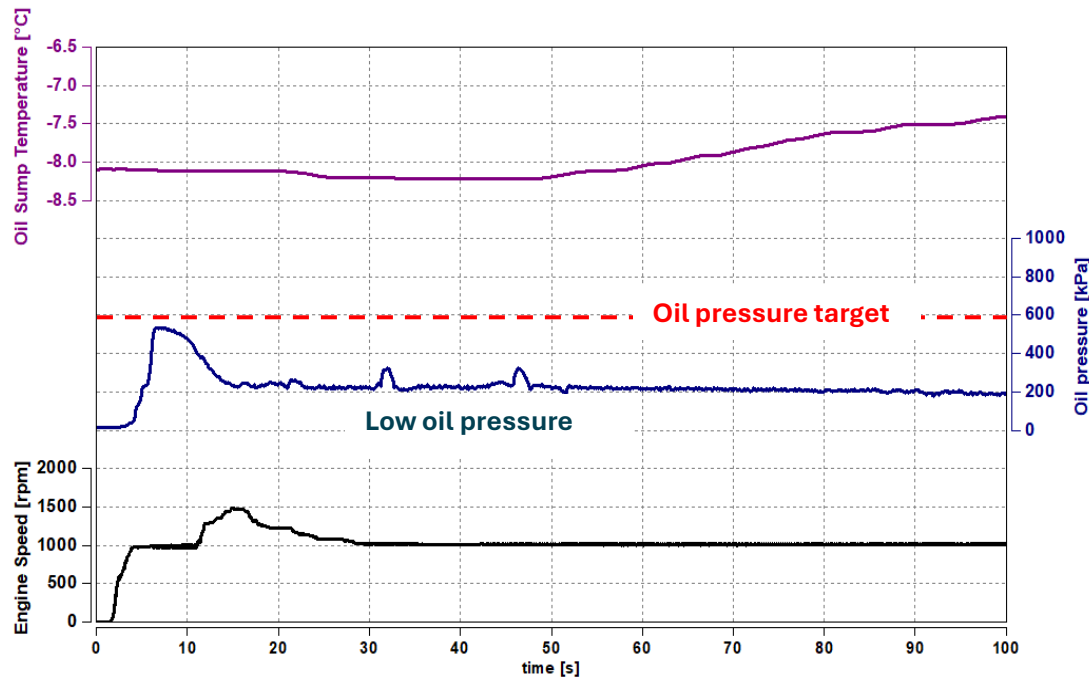


Oil contamination



In H₂-ICE engines, water generated by hydrogen combustion can accumulate in the lubricant through blow-by and condensation, leading to reliability issues, such as oil pressure instability.

This phenomenon showed in graph, is more evident especially during cold start, low-load operation, and short-duty cycles.

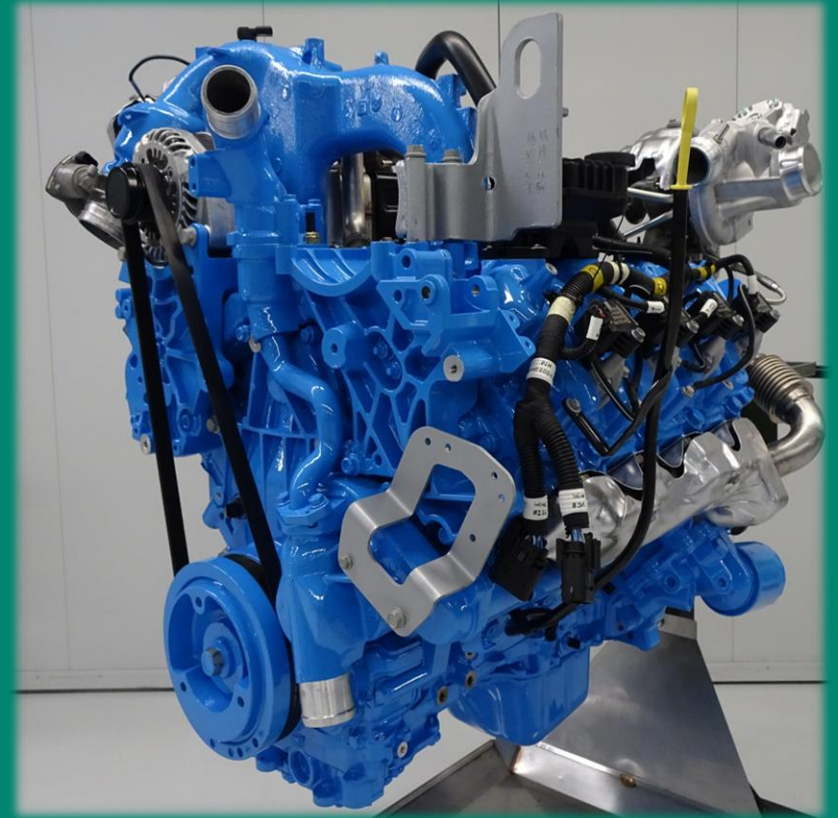


Required countermeasures:

- ✓ **Specific oil formulation:** H₂-ICE engine generate a higher amount of water with respect to conventional engine, need to manage and retain the amount of water to avoid reliability issue
- ✓ **Positive crankcase ventilation:** by diluting the blowby with fresh air the dew temperature decrease → **Reduced risk of water condensation**
- ✓ **Thermal management strategies:** at extreme low temperature ice formation must be considered and properly managed to avoid engine damage → engine full warm up demonstrated to be an effective strategy even in extreme cold conditions

Solutions and conclusions

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Conclusions: Problems & Solutions

► H2 ICE SUB-ZERO STARTABILITY CHALLENGES:

H2 engine faces distinctive startability issues: water condensation and icing which induce:

- injectors sticking → fuel delivery derate or total mistroke;
- water-bridge on spark-plug electrodes → missing spark events.

► DUMAREY COLD START STRATEGY:

An experimental assessment has been performed on the Dumarey H2 ICE V8 6.6l GSET, defining guidelines for cold engine effective and robust startability:

- design solutions:

semi-surface discharge spark-plugs (water-bridge risk minimization).

- control methodology:

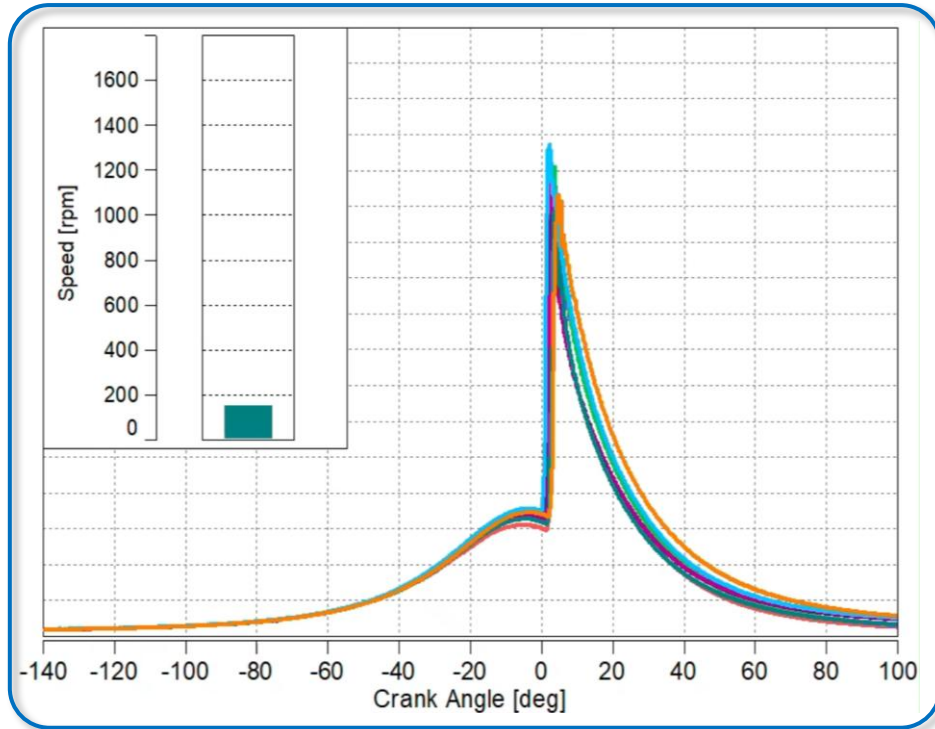
injectors → pre-heating, elevated first-opening current level;

spark-plugs → pre/post heating, multi-spark

Conclusions: Problems & Solutions

RESULTS/ACHIEVEMENTS:

- ✓ Injectors successfully open at the first engine cycle
- ✓ Good combustion efficiency since the first engine cycles
- ✓ Robust engine startability down to -20°C with cranking time in the range 3-10s



Thanks for your attention!

Gianmarco Stirpe

Senior Development Validation Calibration Engineer

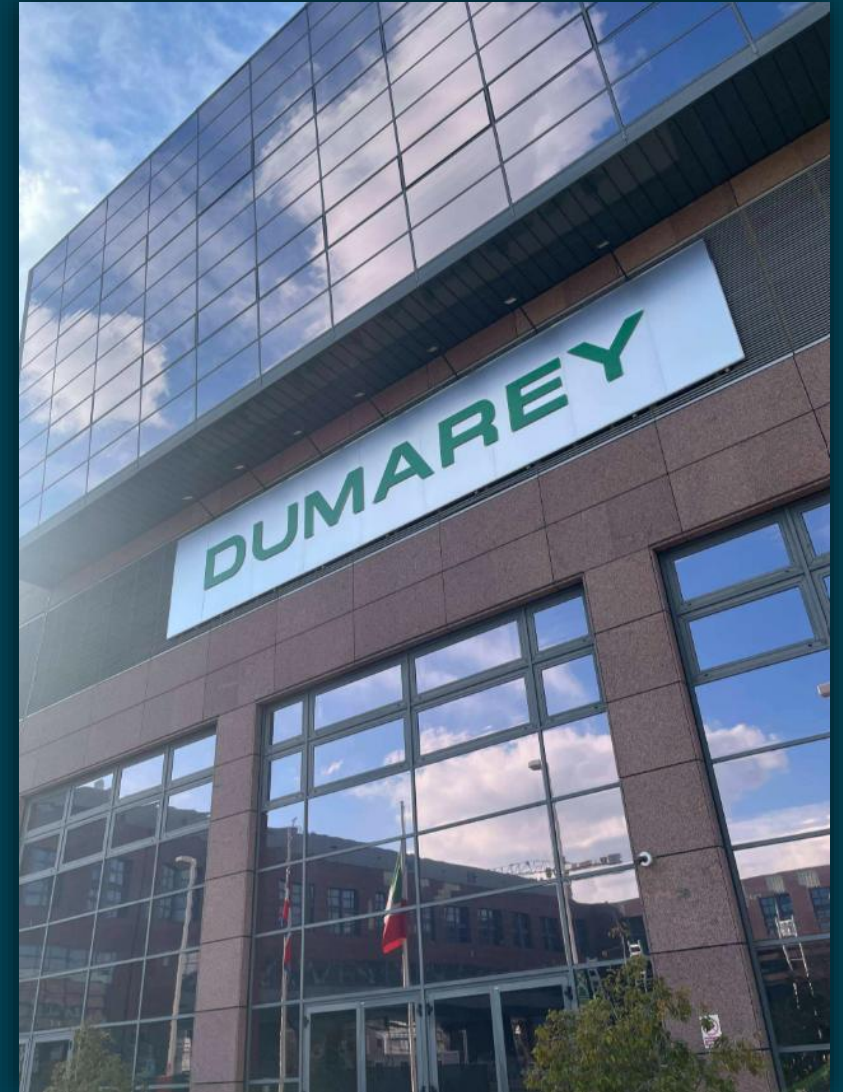
Hardware Engineering

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