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Catalytica ENERGY SYSTEMS

Transient Dynamometer Testing of a Single Leg NOx Adsorber Combined with a Fuel Processor for Enhanced NOx Control

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Presentation Outline

- **Description of the Xonon® Fuel Processor (XFP™)**
- **Overview of control strategy**
- **Simulation studies**
- **Dynamometer results**
- **Summary**

Advantages of a Diesel Fuel Processor

What the fuel processor does?

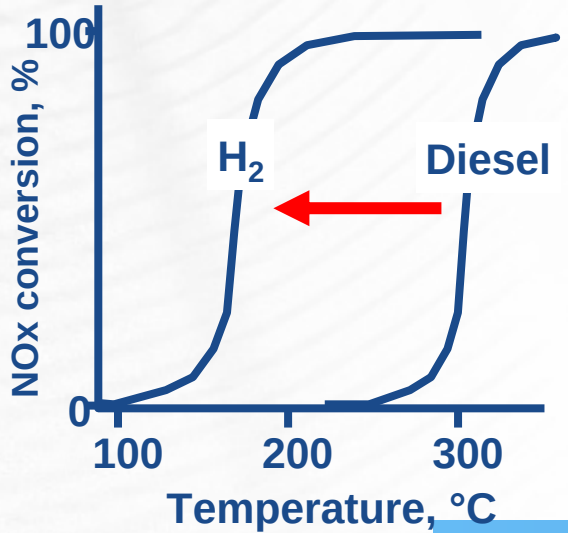
#1—Efficiently converts diesel fuel to REACTIVE REDUCTANTS

Benefits of Reactive Reductants

Regenerate the NOx trap at low temperatures
H_2 shown to regenerate NOx trap at 150°C

Reactive reductants used very efficiently by NOx trap

Complete regeneration of NOx trap capacity allowing minimum LNT volume



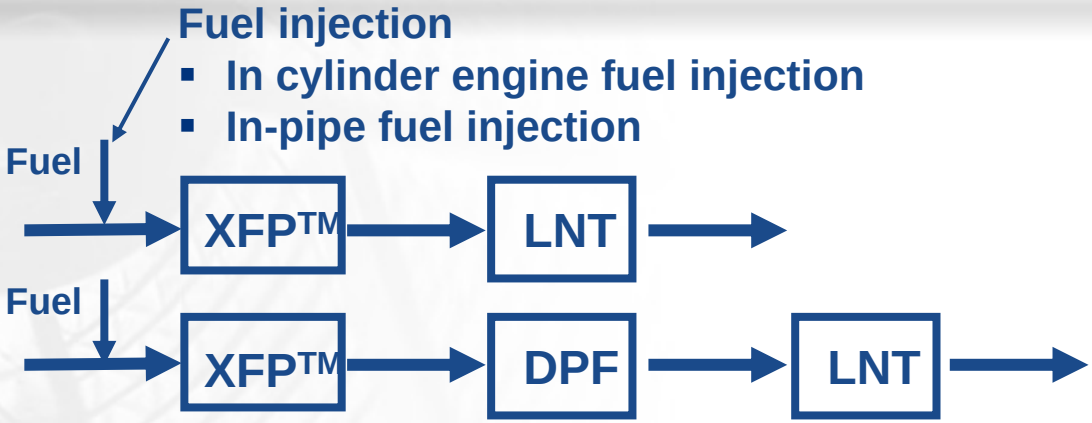
$$2NO_2 + 4H_2 \rightarrow N_2 + 4H_2O$$

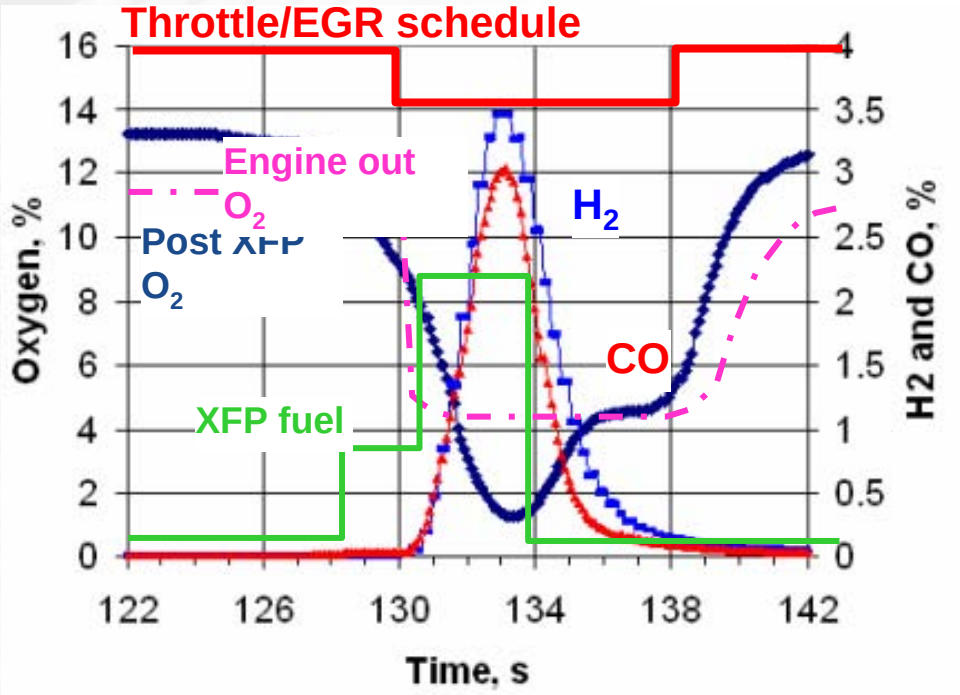
Theoretical Reductant Requirements

$$\frac{H_2 \text{ or } CO}{NOx} = 2$$

Large NOx trap capacity over wide temperature range

Application Configuration





Xonon® Fuel Processor (XFP) Functions:

- Regenerate LNT
- LNT heat up and desulfation

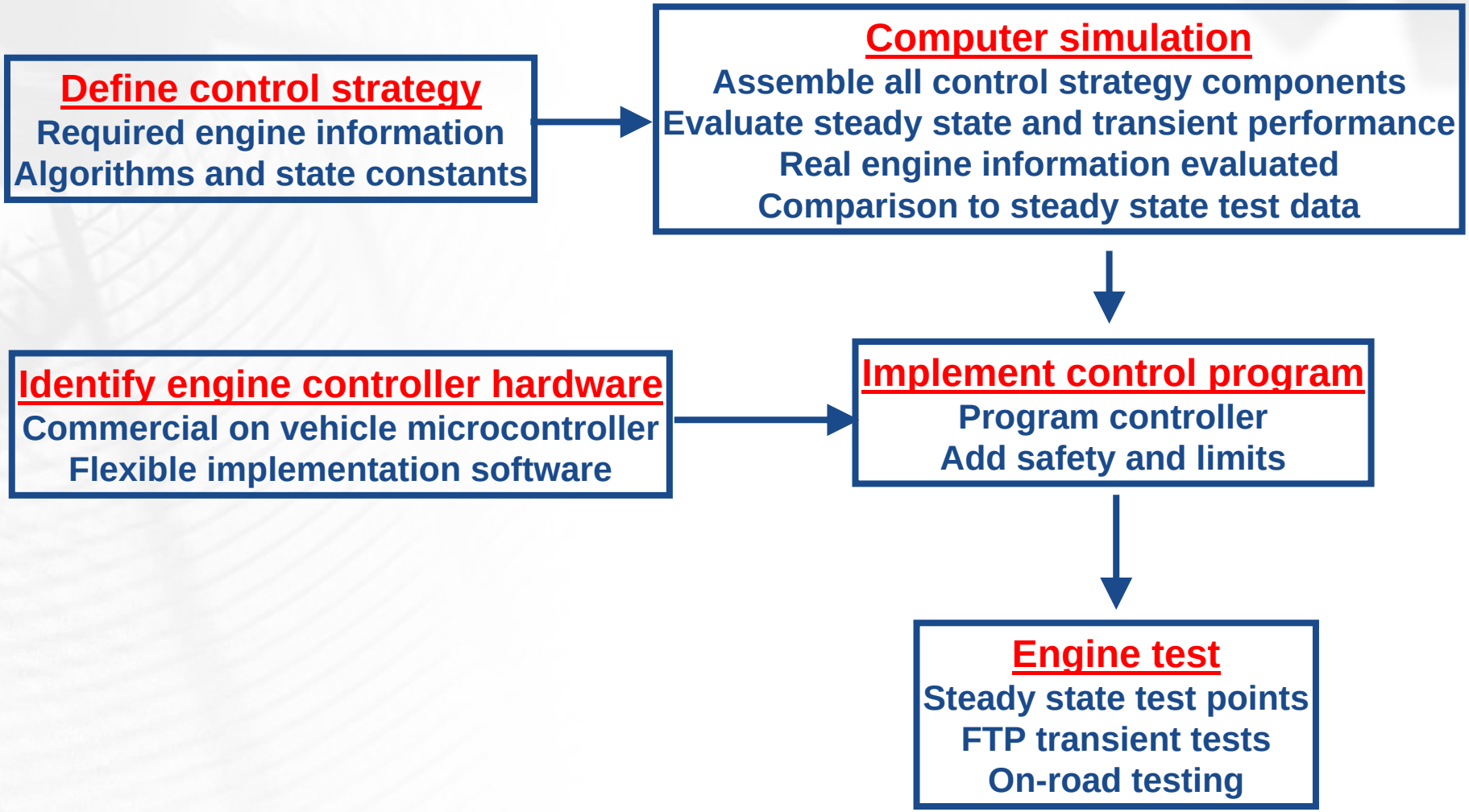
Also

- Thermal management during PM filter regeneration

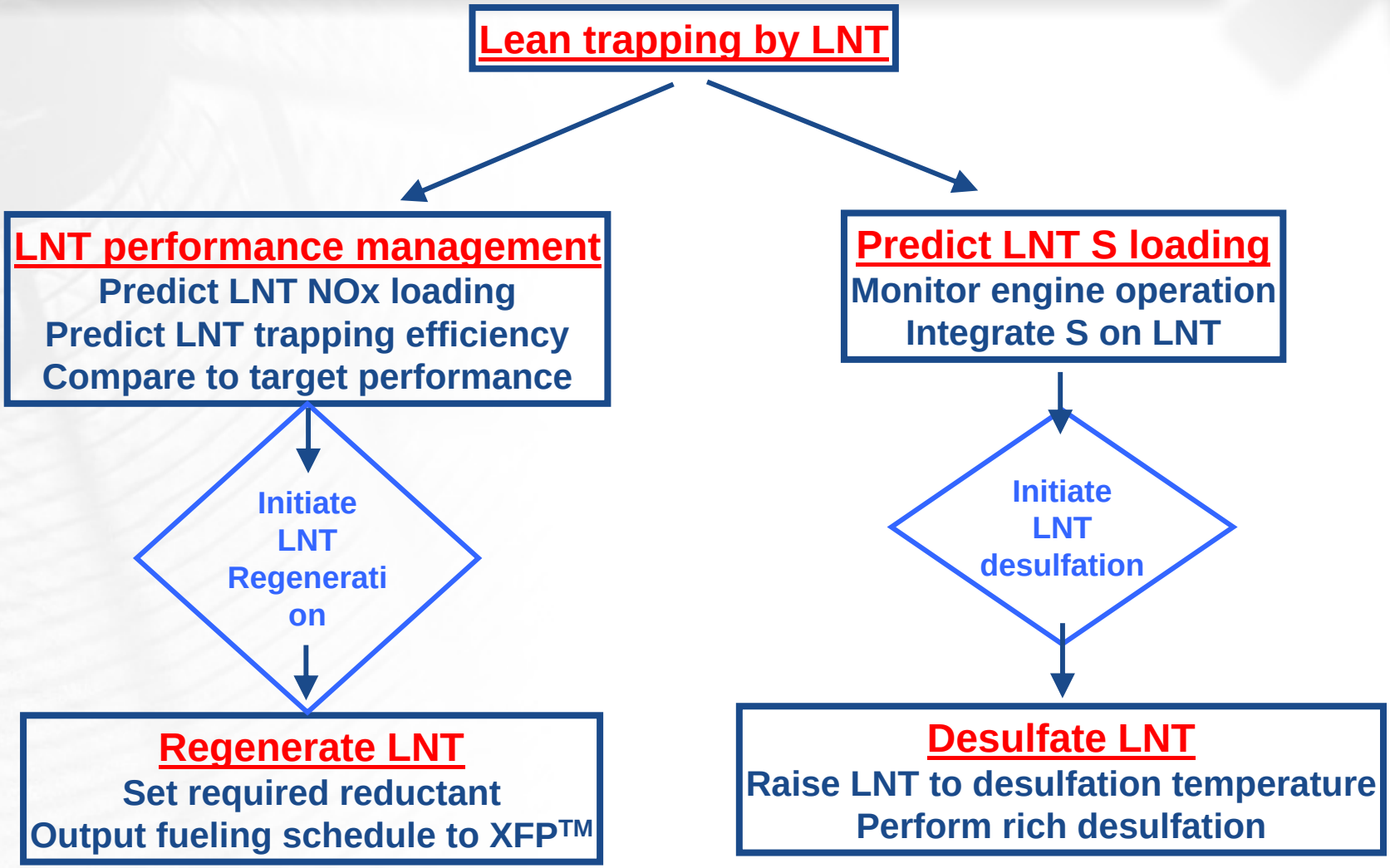
Unique XFP aspects

- Processes full exhaust stream
- Operates with high exhaust O_2 levels
- LNT regeneration cycle can be very short, 4 to 8 seconds

Controls Development Path



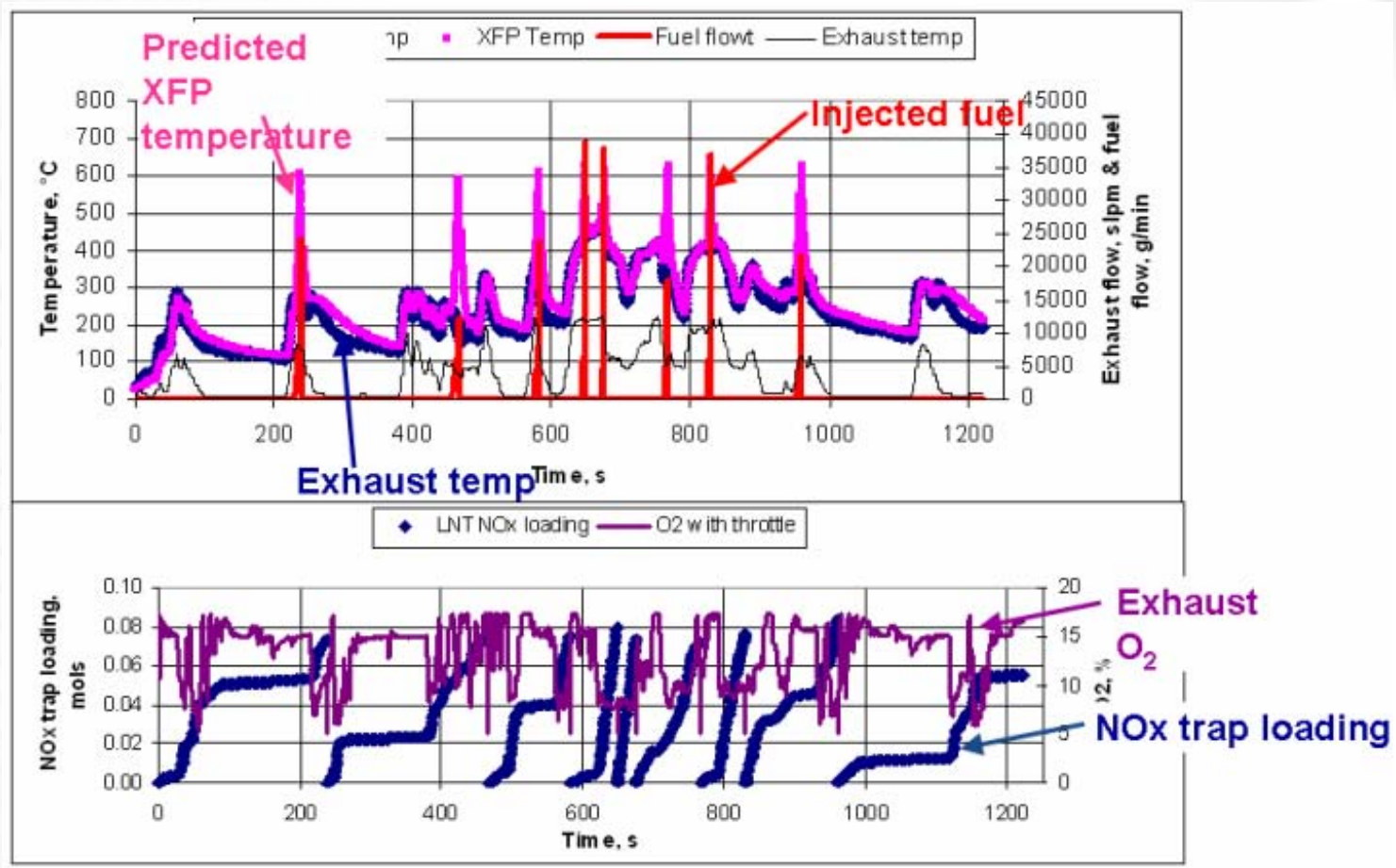
Control Strategy Overview



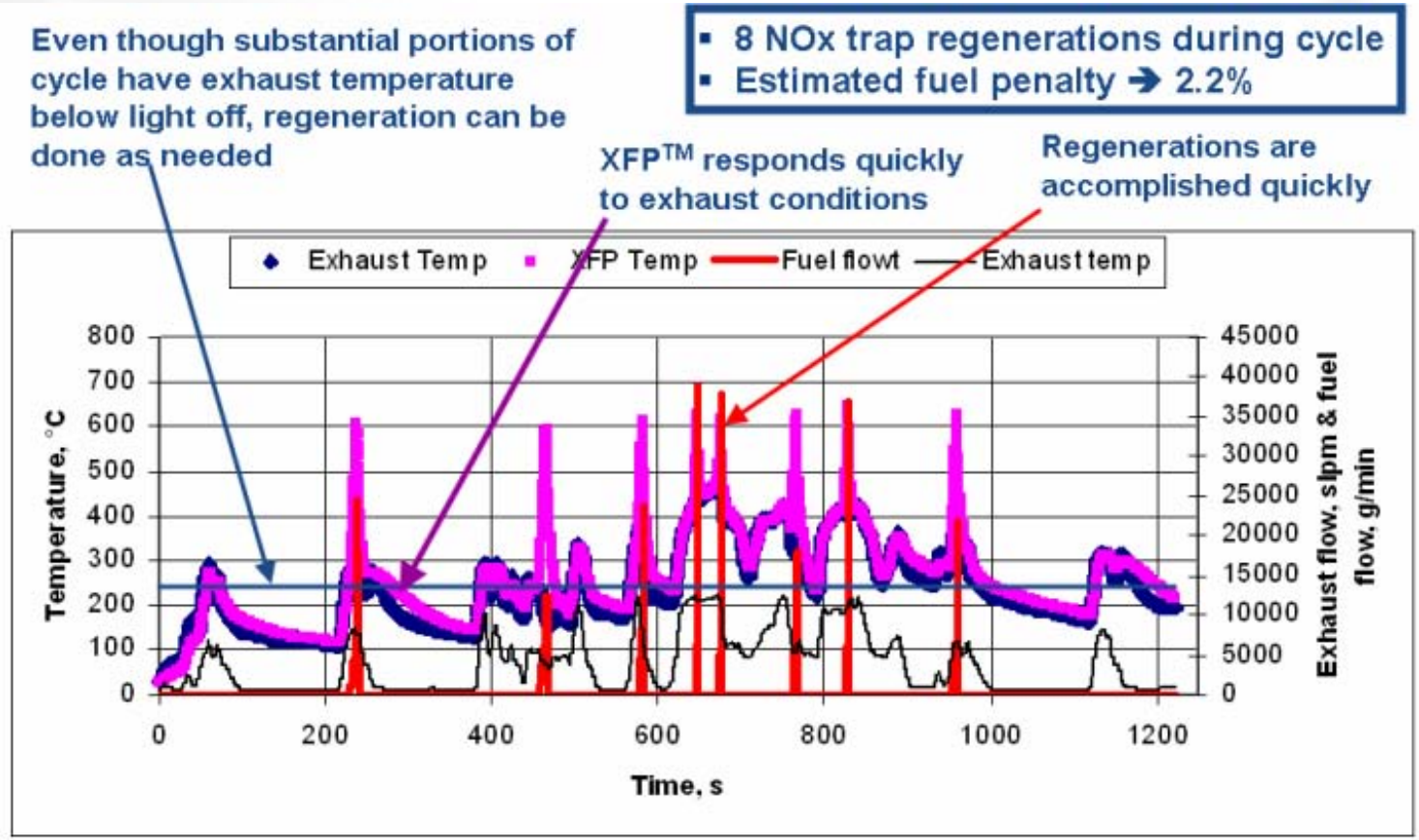
Simulation Parameters

- **System description**
  - 6 liter engine with ~ 7 liter NOx trap
  - Engine data from FTP cold cycle
- **Simulation input parameters—typical:**
  - XFP™ light off temperature: 240°C
  - Engine throttled to reduce exhaust O_2 to 5% during rich XFP™ cycle
  - NOx trap capacity: 0.07 mols NOx (0.5 g NO_2/liter for a 7 liter trap)
  - Reductant to NOx ratio during the regeneration: 3
  - Reductant concentration out of XFP™: 6% (H_2+CO)
- **Simulation output results:**
  - Plot showing performance of the system during operation and regeneration cycles
  - NOx trap loading at each regeneration
  - After treatment system fuel penalty based on fuel used in XFP™ compared to engine fuel

FTP Cold Start Simulation



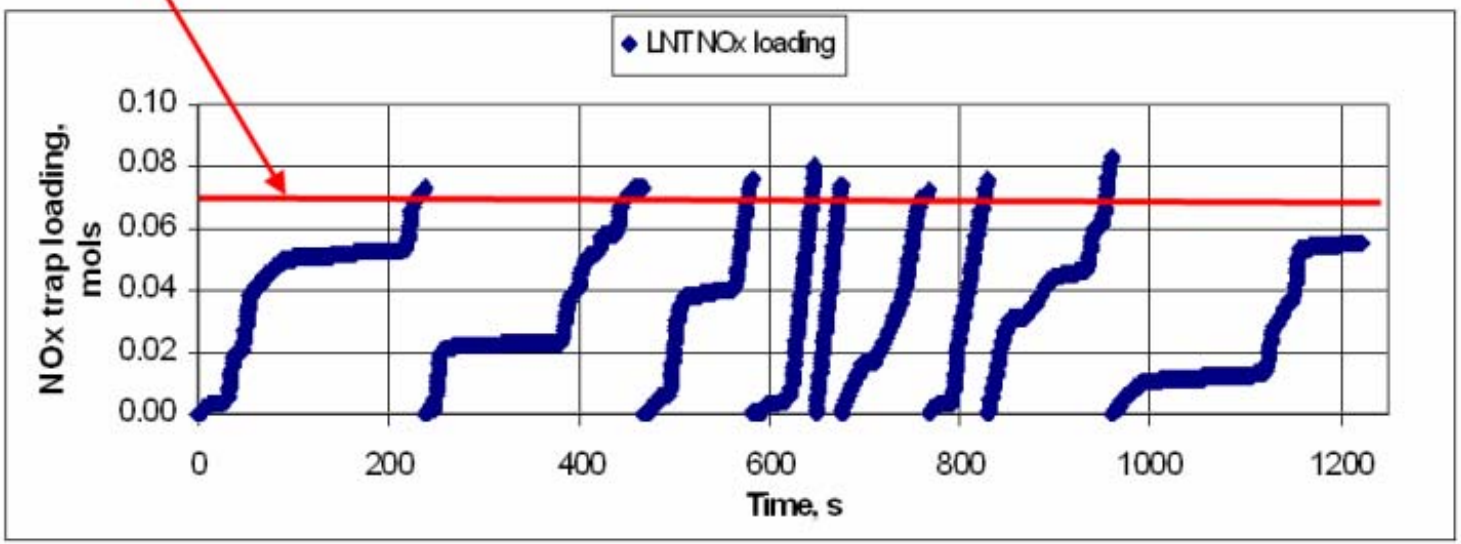
Observations from Simulation



Observations from Simulation

NOx trap capacity set at 0.07 mols (0.5 g/L) and regeneration occurs close to this loading throughout the cycle

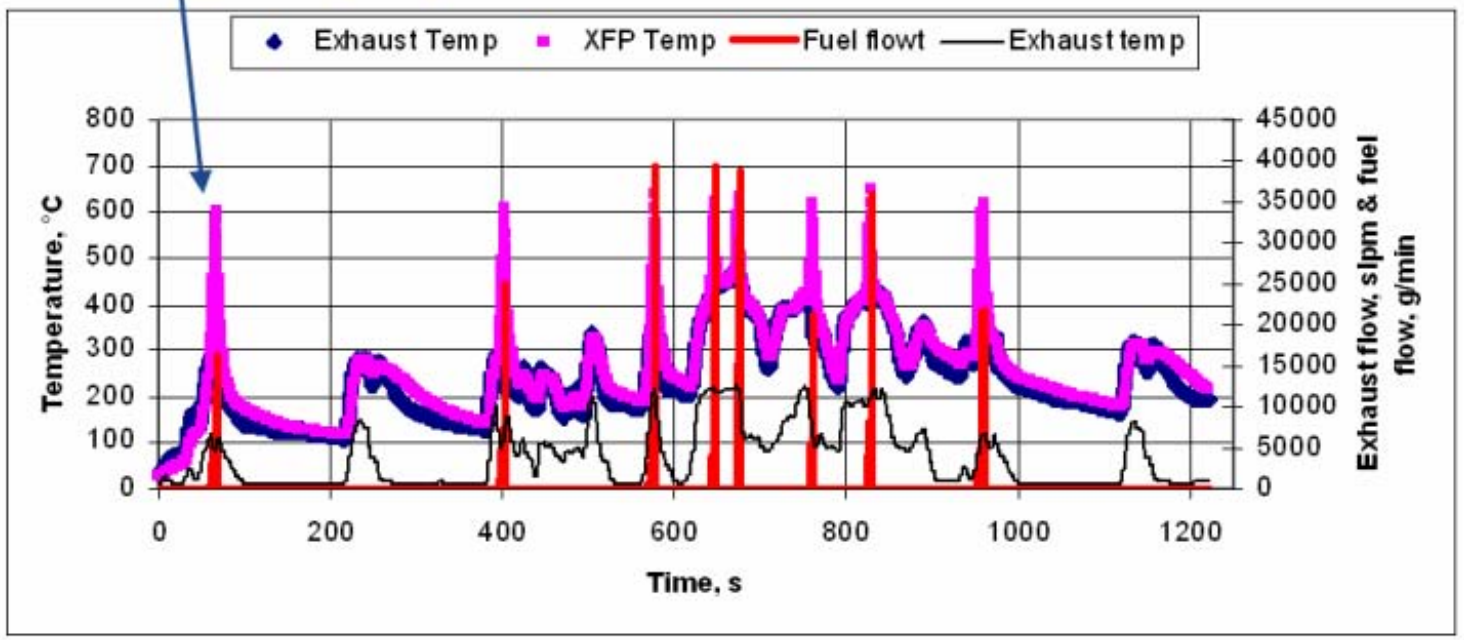
- Higher NOx trap capacity would decrease frequency of regeneration
- Good NOx trapping model is essential to optimize high NOx conversion and fuel penalty



Cold Start Simulation with Loaded Trap

- Cycle started with NOx trap 50% loaded (0.035 mols NOx)

Regeneration occurs at the first acceleration in the cycle since NOx trap is at capacity at this time



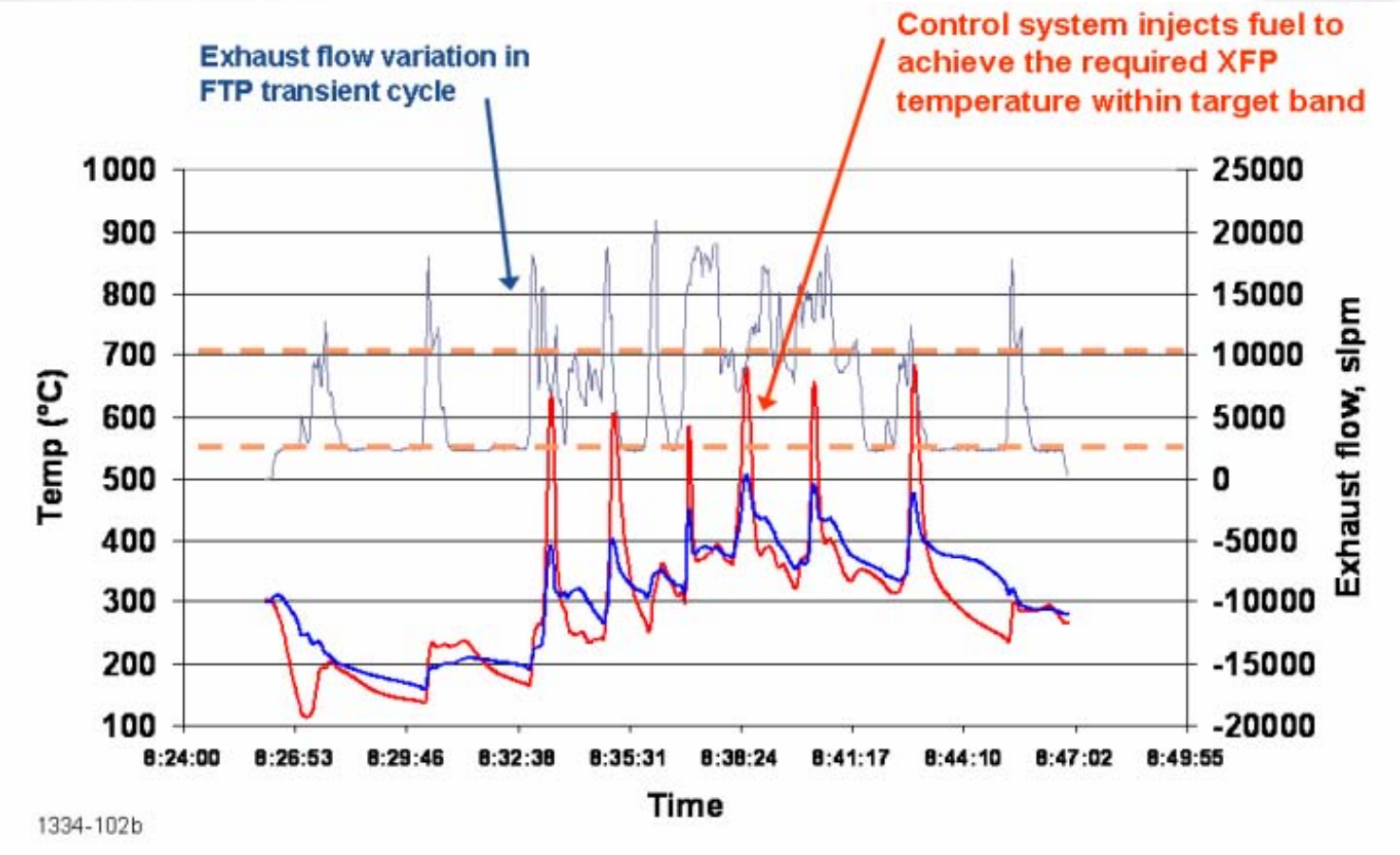
Comments on Simulation Results

- **Simulation suggests that the XFP™ will operate well in the FTP cycle for this engine**
- **Fuel penalty estimates show about 2.2% fuel requirement for this cycle**
  - **Comparison of steady state simulations to engine test data show similar fuel penalty numbers, 10 to 30% higher**
    - **As simulation is improved to include heat loses, etc., agreement will improve**
- **These simulations assume an exhaust O_2 level of 5% during the XFP rich cycle**
  - **Fuel processor operation with higher O_2 levels is possible**
  - **In use, O_2 sensor will provide actual exhaust level during fuel processor operation**

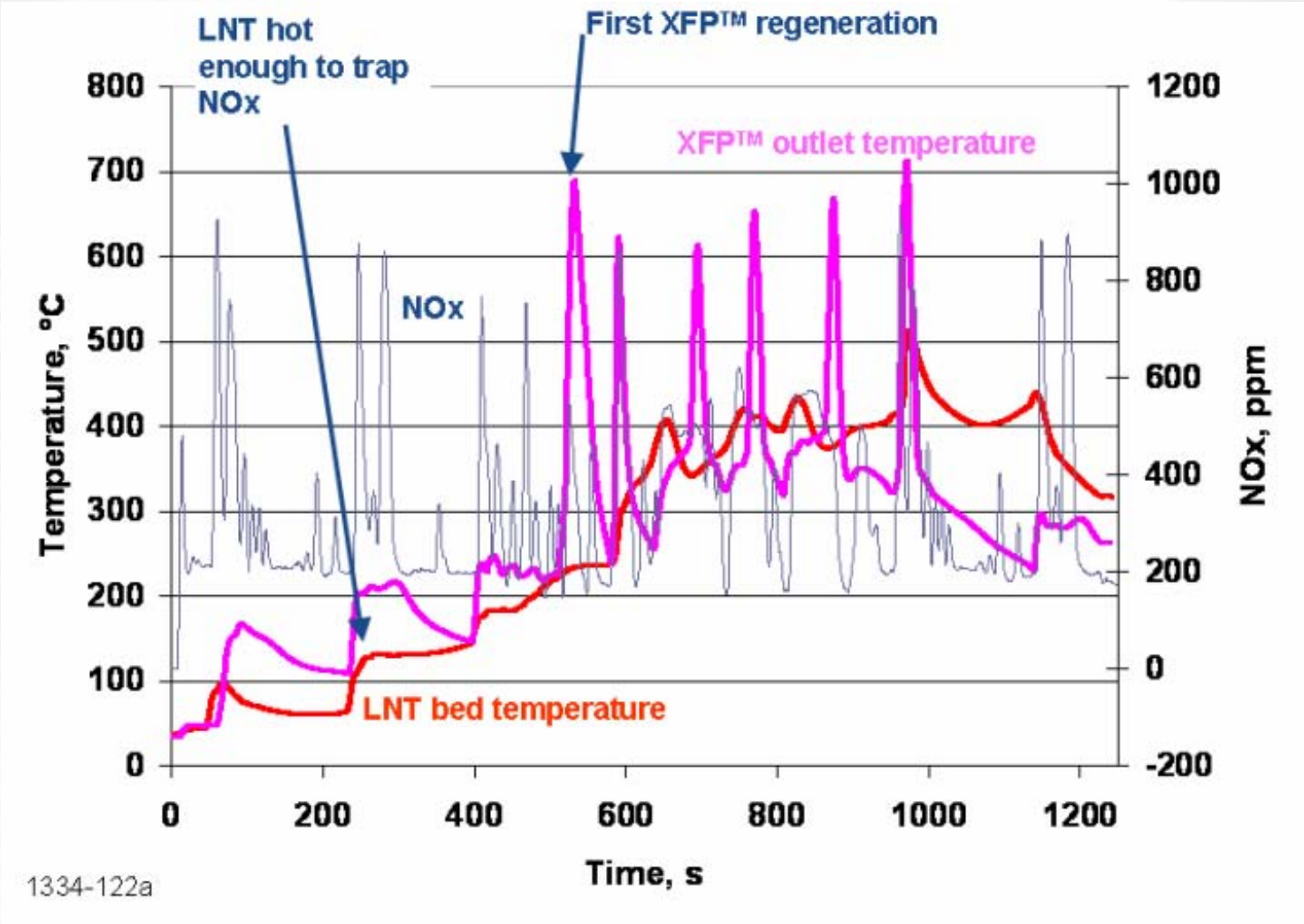
Engine Dynamometer Testing

- **DT466 engine used for development of XononD™ XFP™ retrofit system (Poster on Wednesday evening)**
  - **4.5 g NOx/hp-hr emissions level**
  - **~12 feet (3.6 meters) exhaust length from engine outlet to after treatment system**
  - **Transient testing with HD FTP cycle (cold and hot)**
  - **Commercial vendor supplied NOx trap**
- **No modification of engine control**
  - **High exhaust O_2**
- **Control system**
  - **Implemented on third party controller designed for vehicle use**
  - **Interfaced to engine for speed and air flow information**
  - **Exhaust NOx estimated from simple engine map**

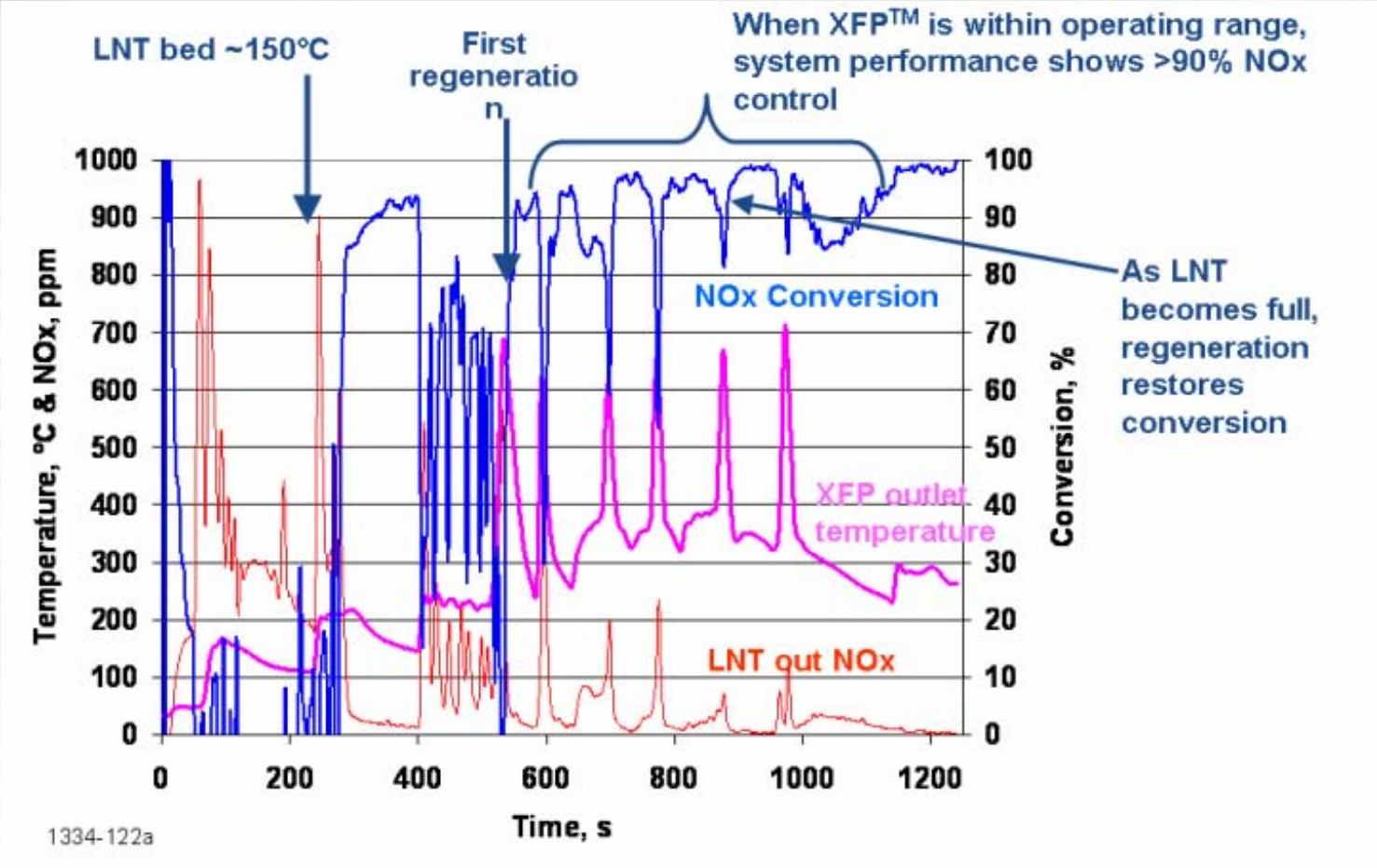
FTP Transient Test—Fuel processor control



HD FTP Cycle—Effect of long exhaust pipe between engine and XFP™ and LNT



HD FTP Cycle—LNT regeneration

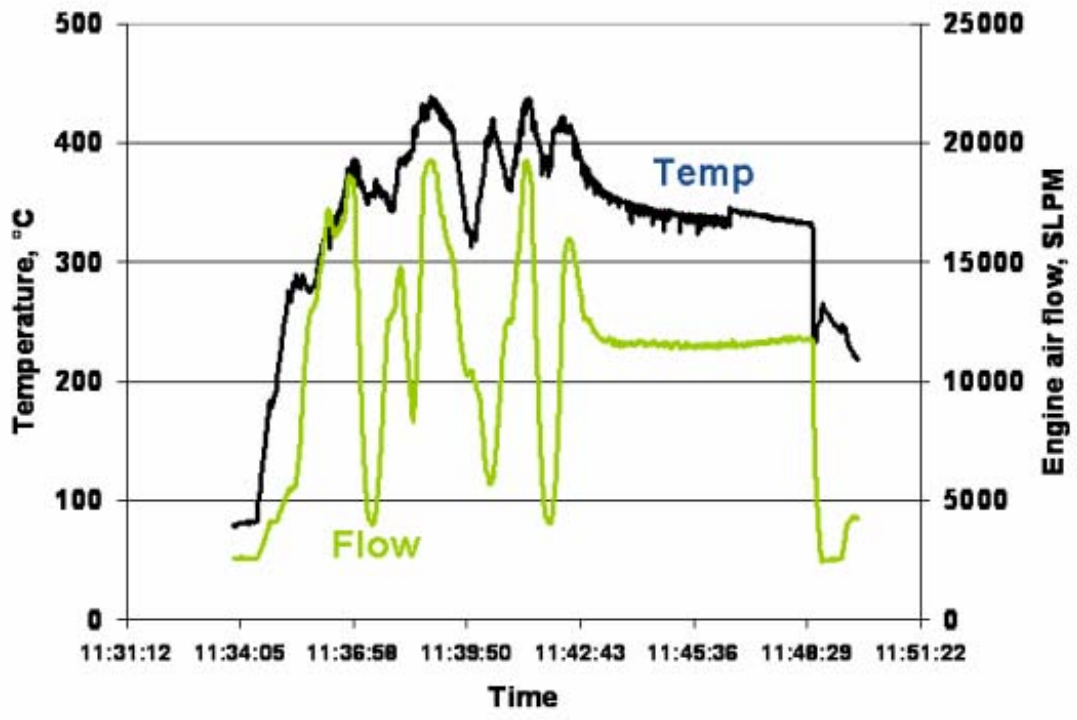


Desulfation Using XFP™

- **Use XFP™ in lean mode to heat LNT to desulfation temperature**
  - **Uniform hot exhaust to heat LNT with good control**
- **Rich operation to produce H_2+CO reductants for desulfation of the LNT**
  - **Must hold desulfation temperature during engine transients**
  - **Generate reductants during engine transients**
- **Test done using a transient cycle composed of programmed steps between AVL8 points**

Transient Cycle

- **For initial testing used a simple transient consisting of steps across AVL8 test points**
  - **Large changes in exhaust temperature and flow**



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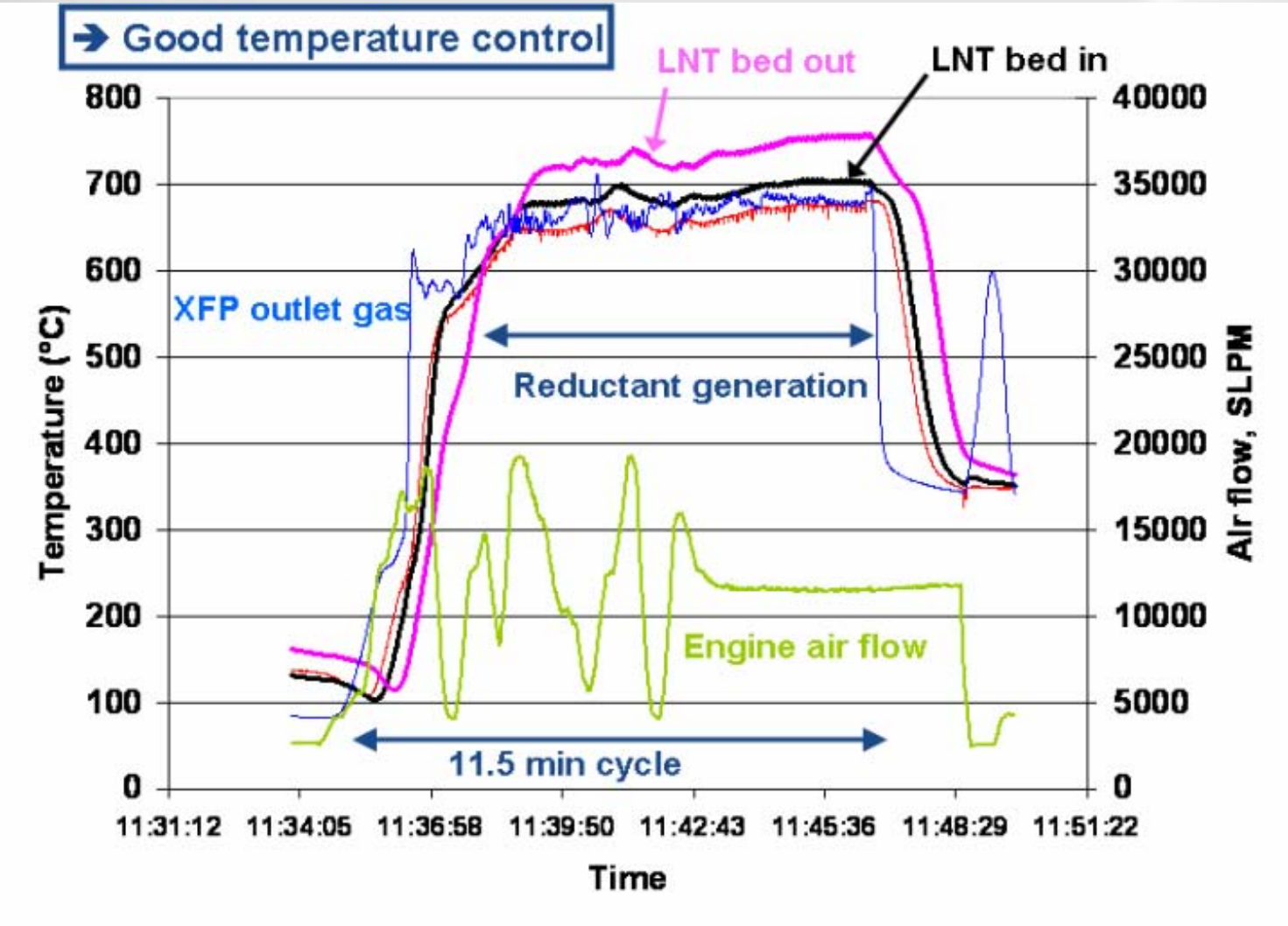
Desulfation Under Transient Conditions



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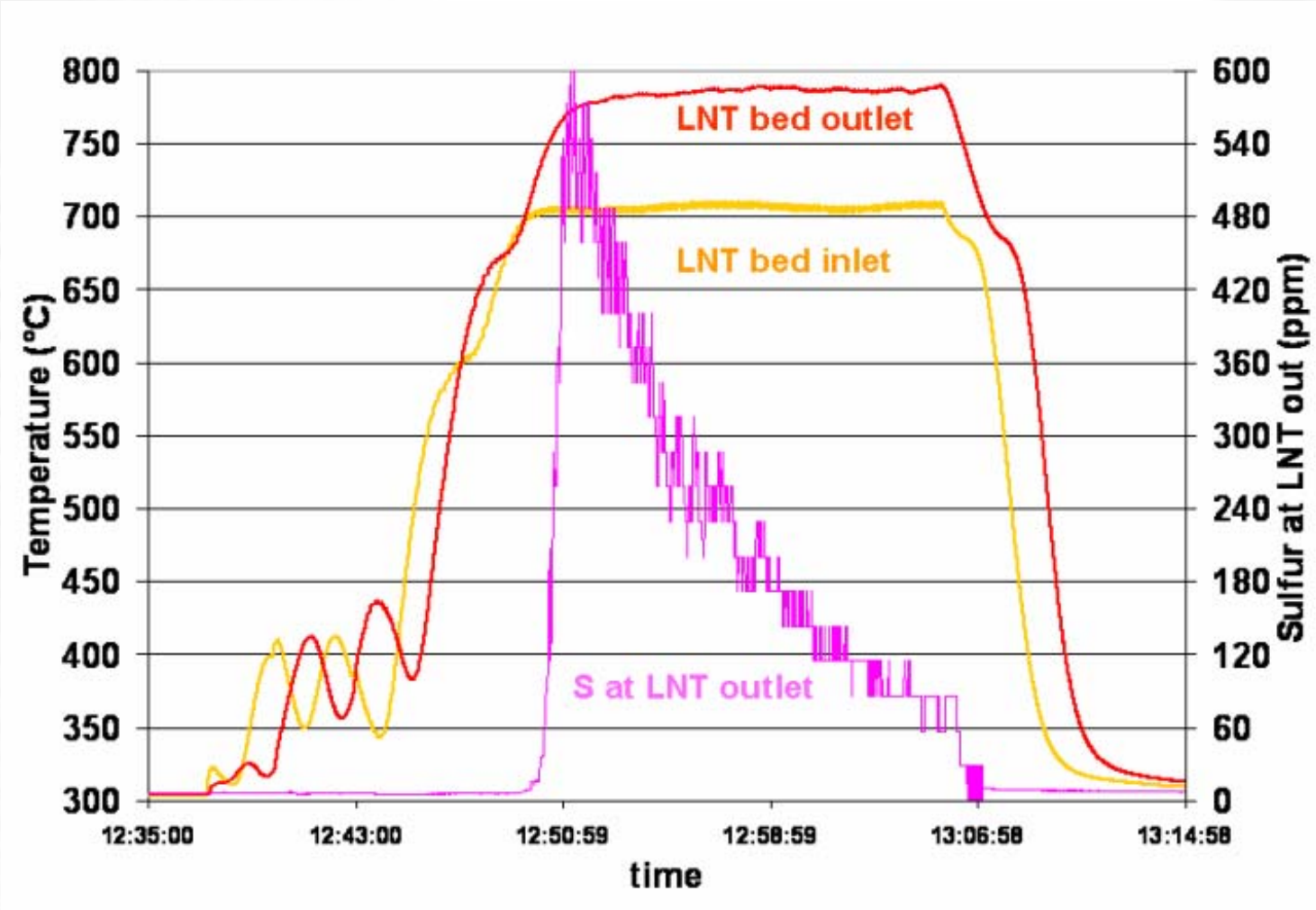
Desulfation—AVL 8.6



Vehicle Testing

- **One CESI vehicle currently in field test with retrofit system**
  - **Extensive testing of the transient control strategy**
- **Two vehicles now operating in a field test in Texas**
  - **Texas Commission for Environmental Quality is providing funding and vehicles provided by City of Denton, Texas**

Summary

- **Control strategy and algorithms developed to operate XFP™ fuel processor in steady state and transient engine cycles**
  - **Manages NOx trap regeneration**
  - **Operates fuel processor components for rapid heat up and rich operation**
  - **Provides thermal management for desulfation of NOx trap**
- **Dynamometer and vehicle testing**
  - **Control strategy implemented on a controller designed for vehicle use**
  - **Fuel processor control and NOx trap operation demonstrated in steady stated and transient operation**
- **Next steps**
  - **Implementation on engines with 2007 level emissions**
  - **Demonstration of 2010 emissions targets**

Thank you

Contracts

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