Advanced Petroleum-Based Fuels - Diesel Emissions Control (APBF-DEC) Program

Diesel SUV / Pick-Up Truck Program Status

Principal Investigators:

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Phillip Weber

Motor Fuels: Energy Efficiency in Transportation

October 9, 2002

Program Goals / Objectives
Light-Duty SUV / Pick-Up Truck

- Determine the Influence of Diesel Fuel Composition on the Ability of NO_X Adsorber Technology, in Conjunction With Diesel Particulate Filters To Achieve Stringent Emissions Levels

    – (i.e. LD Tier 2 Bin 5: NO_X <0.07 g/mi, PM <0.01 g/mi)

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- Can Regeneration / Desulfurization Strategies be Periodically Reoptimized to Maintain a Given Level of Tailpipe Emissions and Minimize the Fuel Economy Impact?

- How Can Engine / Catalyst Systems be More Thoroughly Optimized to Provide Optimal Temperature and Reactants for Emissions Control Systems?

Southwest Research Institute – DEC Pick-Up Truck Program

Scope:

One Pick-Up Truck + Two Emissions Control System Configurations

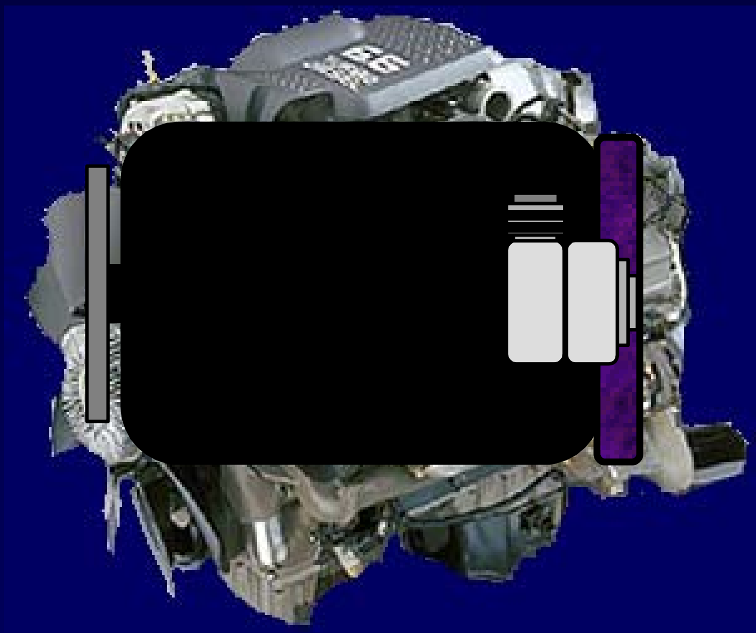
Vehicle and Engine:

2002 Chevrolet Silverado, 2500 Series

2002 Isuzu Duramax 6.6L with EGR

\+ Two Emissions Control System Configurations

SCOPE:



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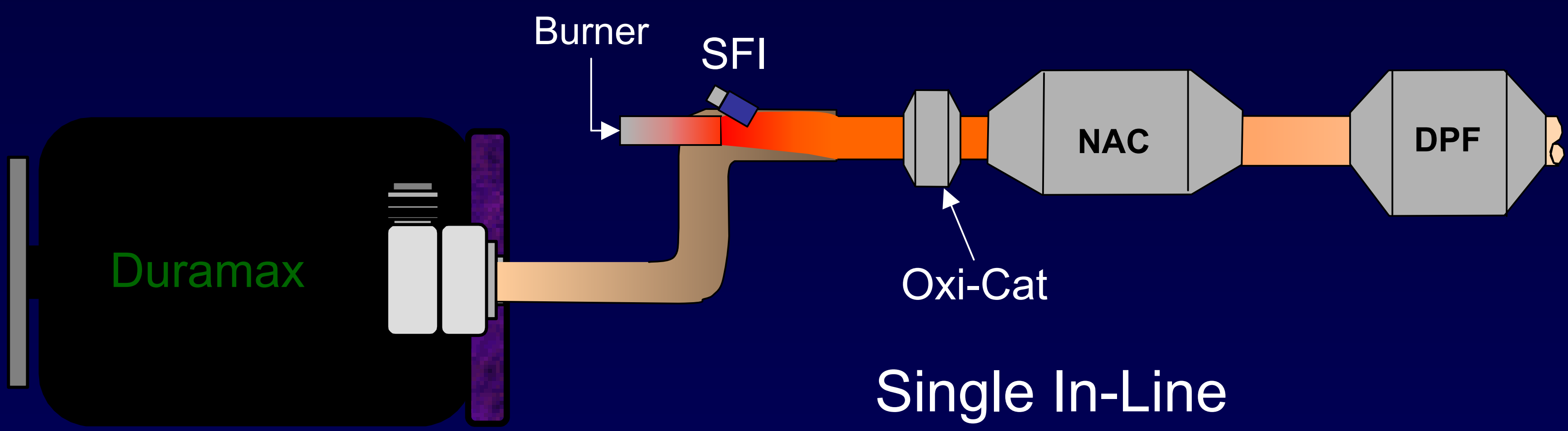
Two Emissions Control System Configurations

ECS-A and ECS-B

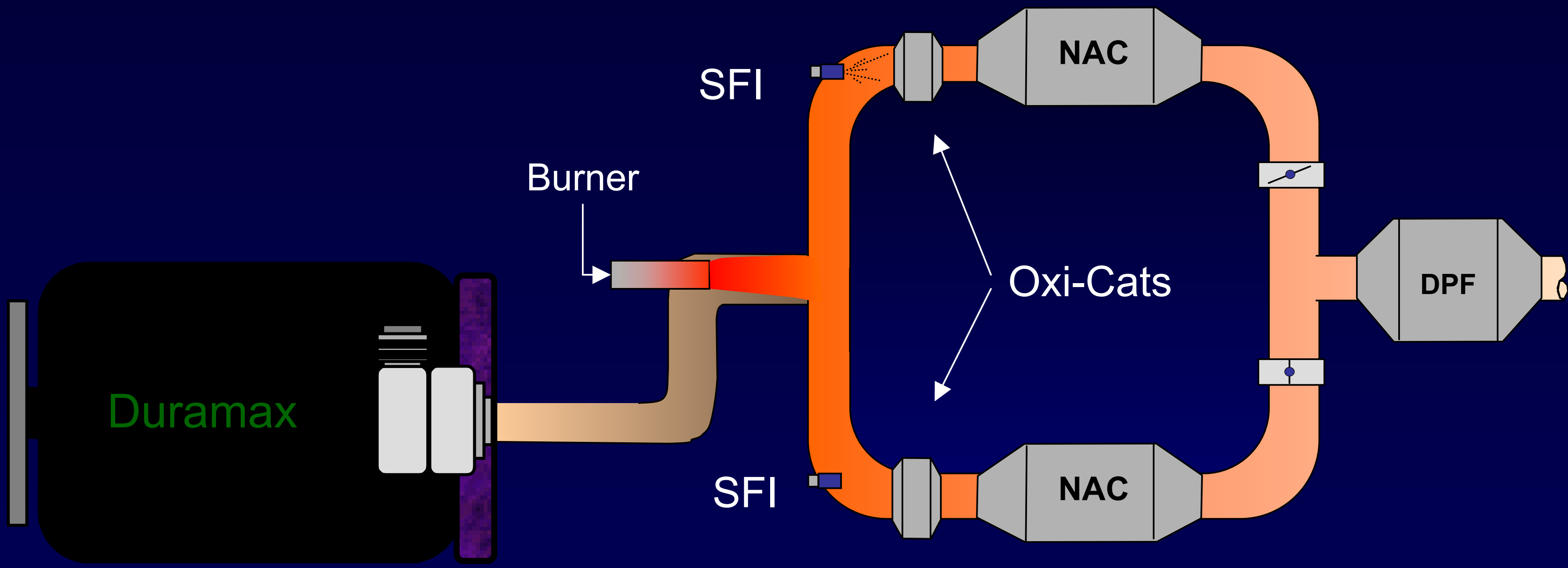
Emissions Control System A:



Single In-Line
Emissions Control System

-Smallest Physical Package / Lowest Cost
-Requires Full Flow Regeneration
-Highest Fuel Economy Penalty

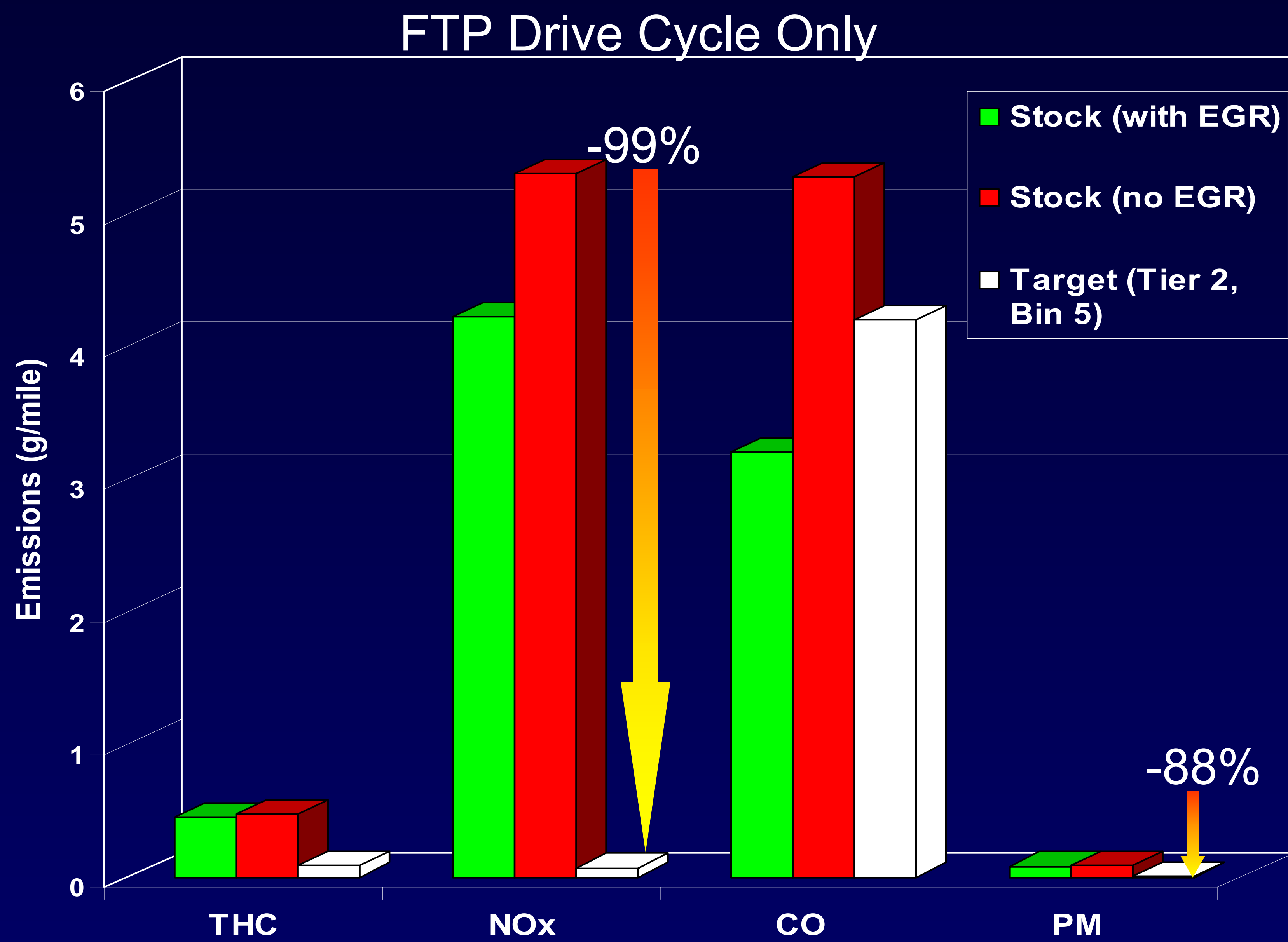
Emissions Control System B:



Dual-Branch
Emissions Control System

-Partial Flow Regeneration
-Higher Efficiency
-Higher Cost / Larger Physical Package

Engine-Out Emissions vs. Tailpipe Goals



ECS Control Requirements:

- Temperature: Activity Window

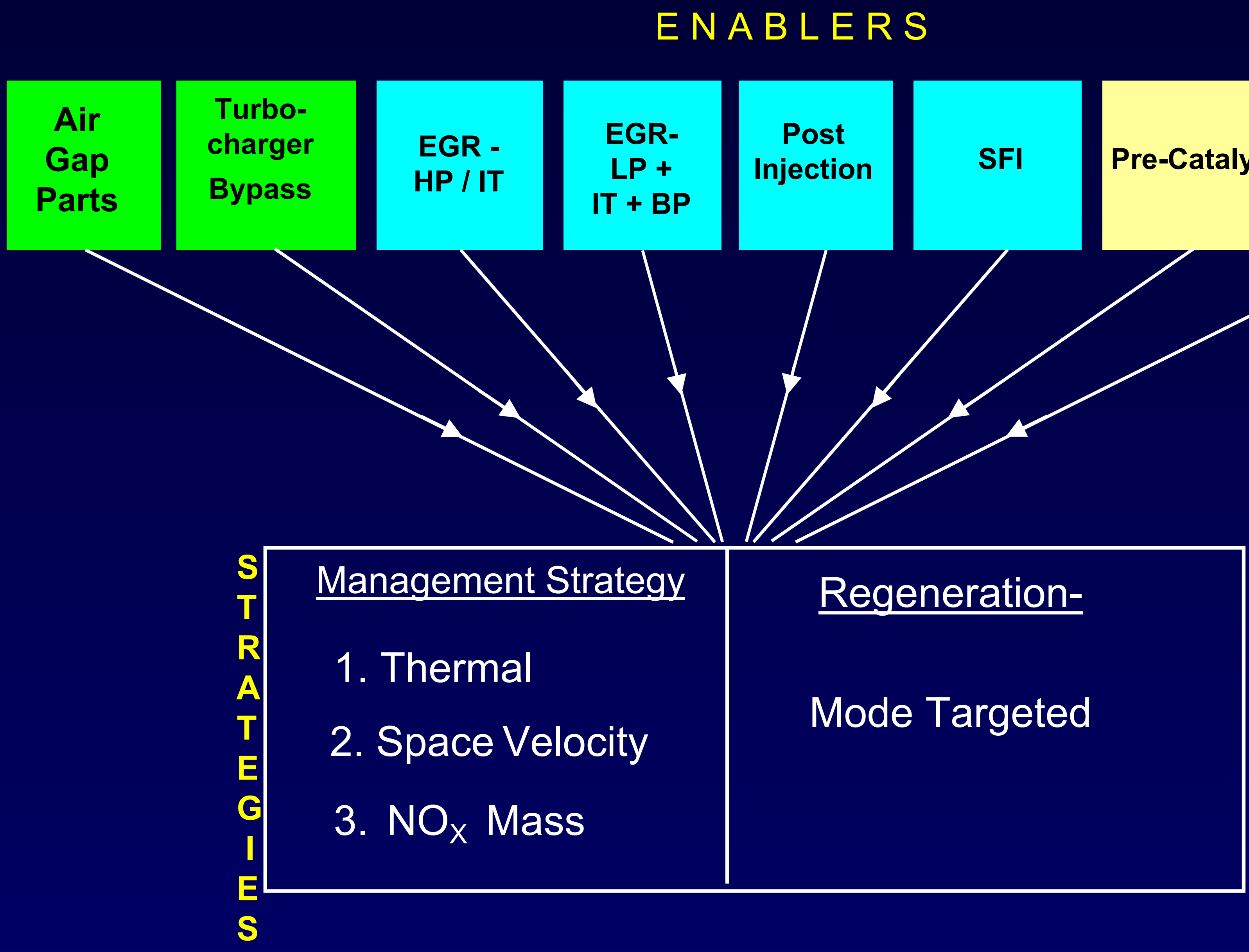
- Inlet Concentration: Capacity and Breakthrough

- Regeneration: Periodic Rich Excursion to Clean Trap

Enabling Systems

Tools developed to allow modification of the exhaust gas character (concentration, mass, temperature) to help achieve the aftertreatment requirements for high system efficiency.

NAC: Management Strategy



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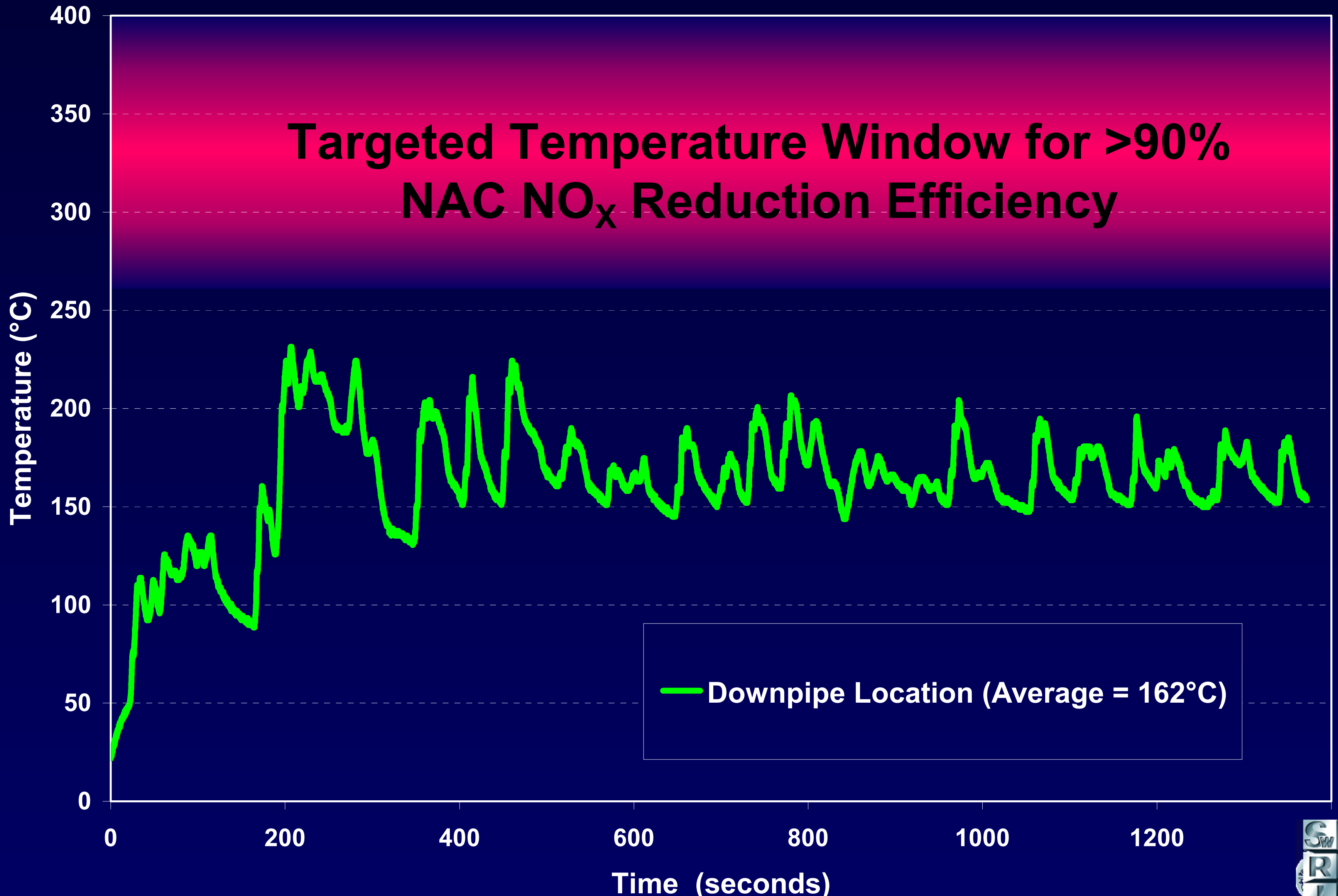
Measured Exhaust Temperature - On-Vehicle



Enabling Systems-
Thermal Management

- Air Gap Exhaust Components
- Turbocharger Bypass

CONSERVATION

- Exhaust Gas Recirculation (EGR)
- Post Injection (In-Cylinder)
- Intake Throttling
- Increased Idle Speed

ENGINE-BASED

- Pre-Catalyst
- Burner

SUPPLEMENTAL

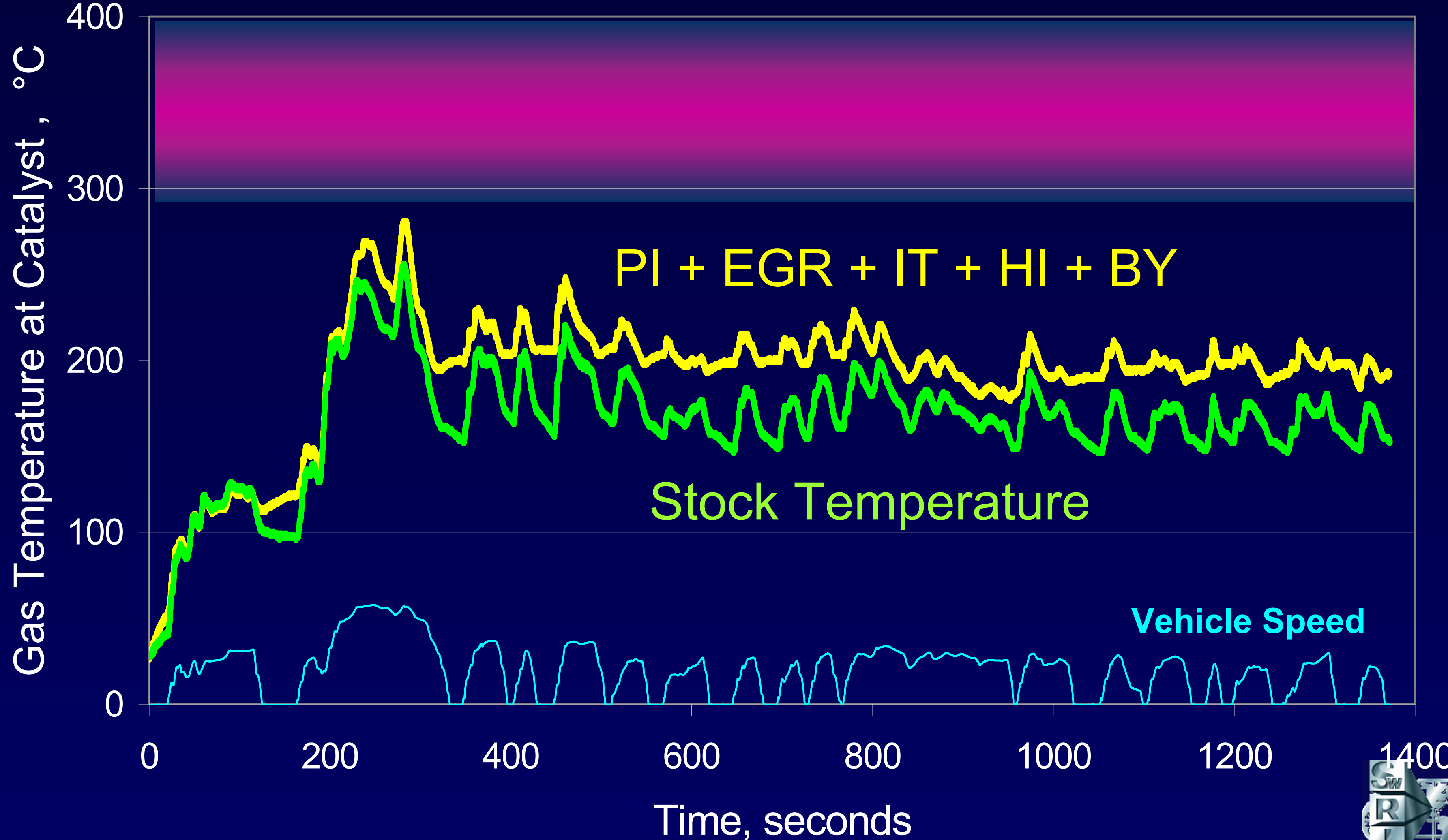
Approaches in Thermal Management

Goal: Exhaust Gas Temperature 300°C - 400°C

	Approach1:	Approach2:
Heat Generation:	Engine-Based	Supplemental
Conservation:	Insulation and Loss Minimization	Insulation and Loss Minimization

Approach 1: EO modification

UDDS Interpretation on Engine



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Approach 2: Burner modification

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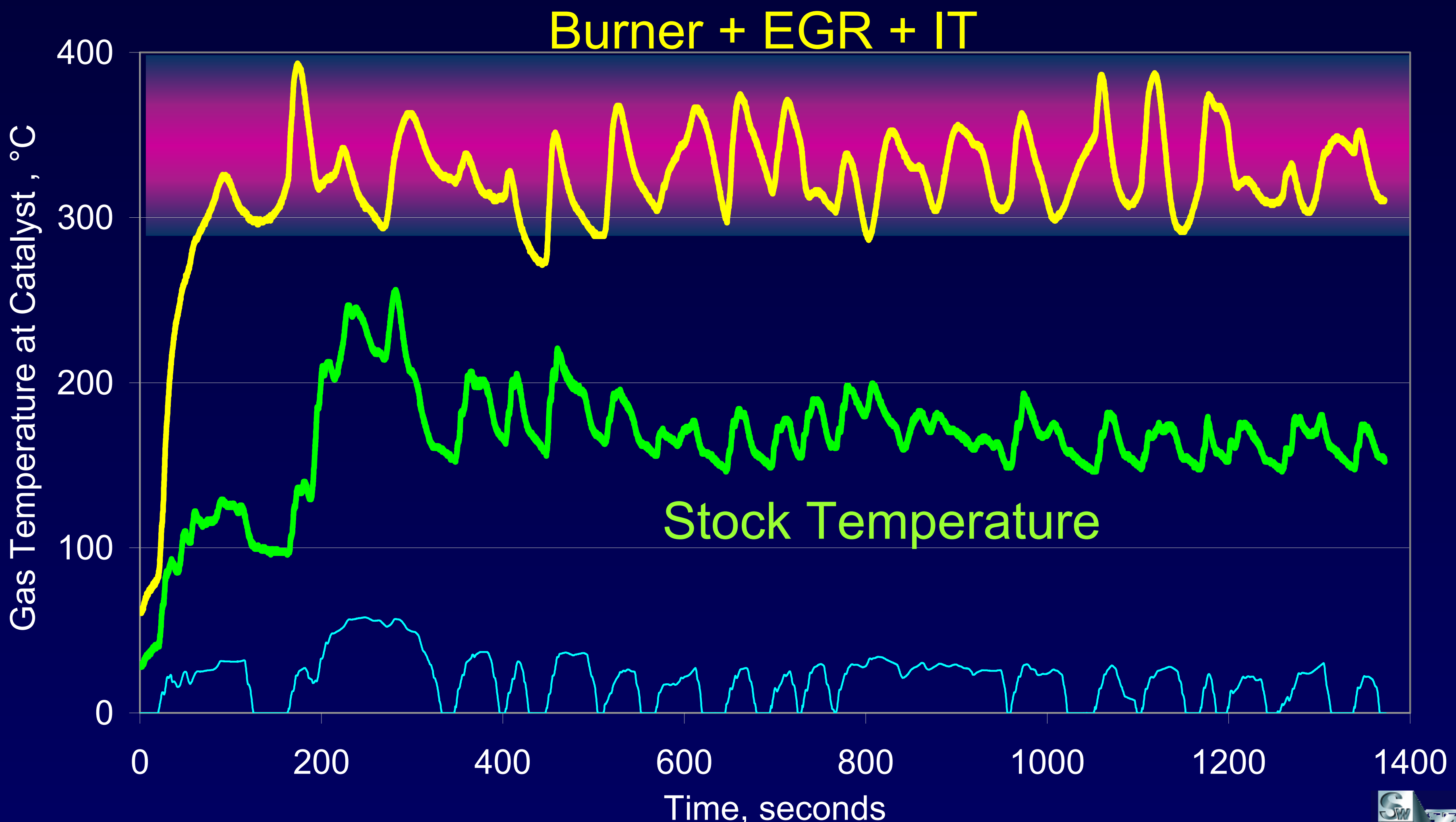
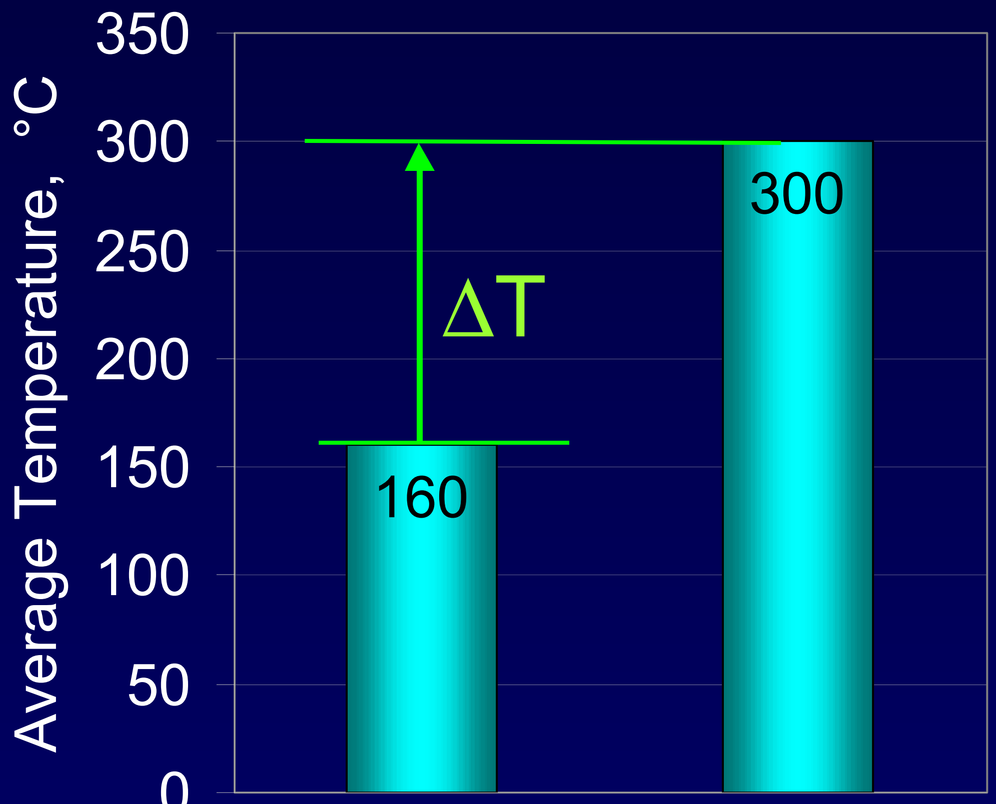


Cost of Thermal Management

$\dot{m} \times c_p \times \Delta T$ = Theoretical Energy Req.

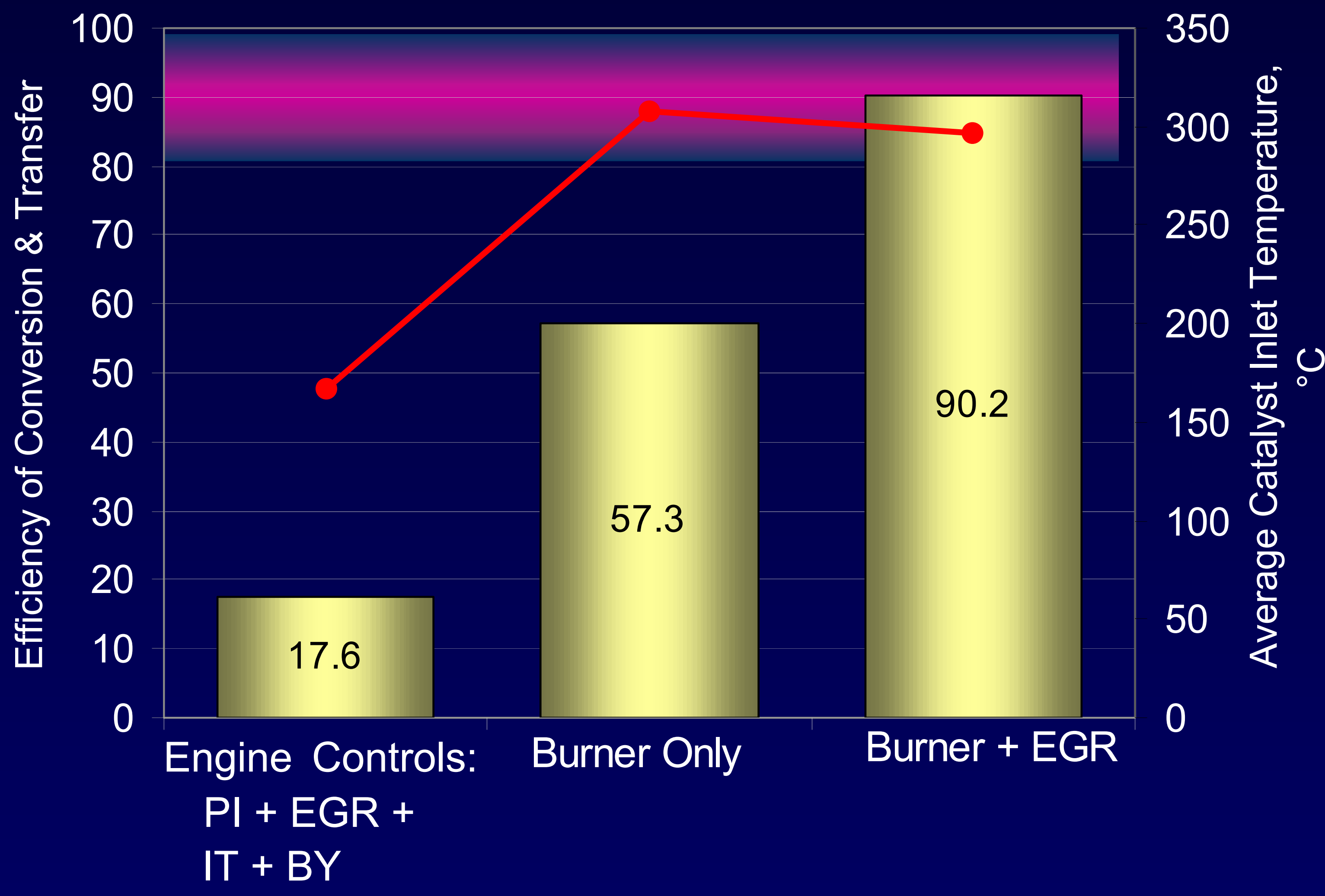
$\dot{m} \times c_p \times \Delta T \times \eta$ = Actual Energy Req.



Efficiency in Conversion and Transfer Matters!!!

Reduced Exhaust Mass Also Important!! (i.e. HP EGR)

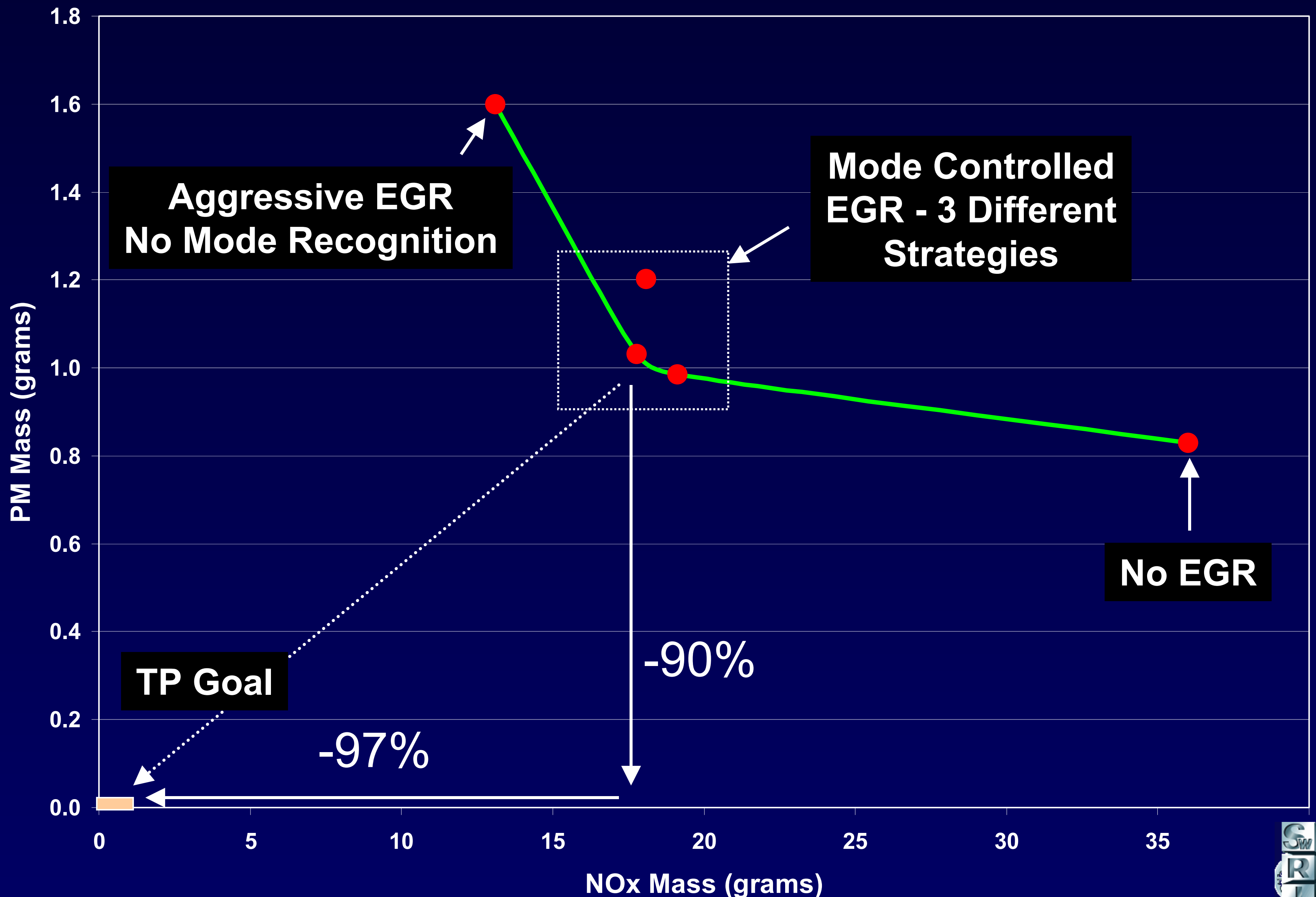
Efficiency of Converting Fuel Energy to Exhaust Gas Heat



ECS Requirements for High Reduction Efficiencies:

- Temperature Requirements
- Inlet Mass / Concentration - NO_X, PM
  - Volume Considerations
  - Opportunities for Reducing Engine-Out Levels

PM / NO_X Tradeoff - Test Cell Runs



ECS Requirements for High Reduction Efficiencies:

- Temperature
- Inlet Conditions
- NAC Regeneration Requirements
  - NO_X Regeneration - Requires Reductant to Inlet of NAC
  - Desulfurization - Requires Elevated Temperatures and Preferably a Reducing Environment

Progress in NAC Management

Steady-State Development of Regeneration Strategies for High Conversion

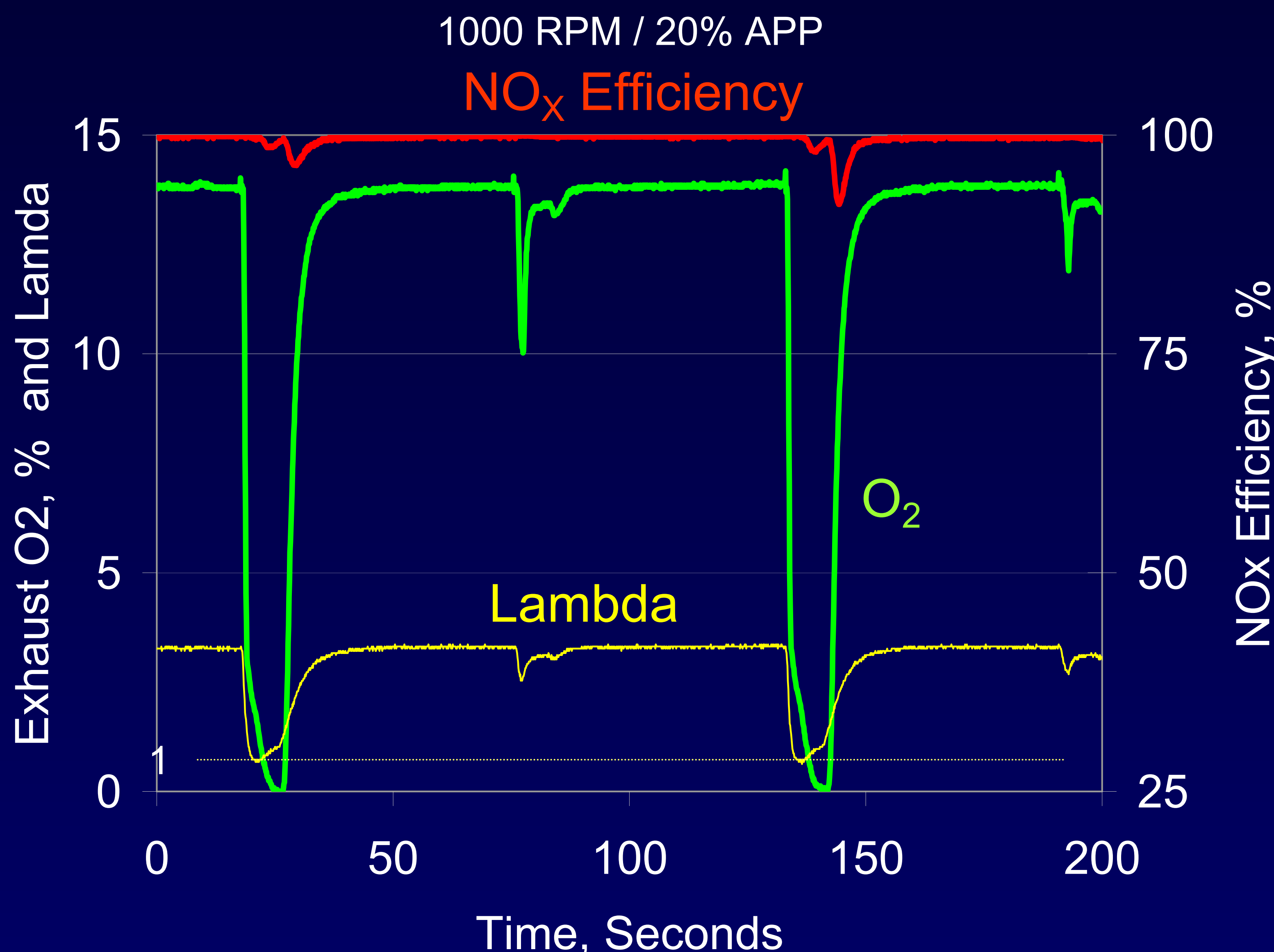
Progress in NAC Management

Regeneration Goals:

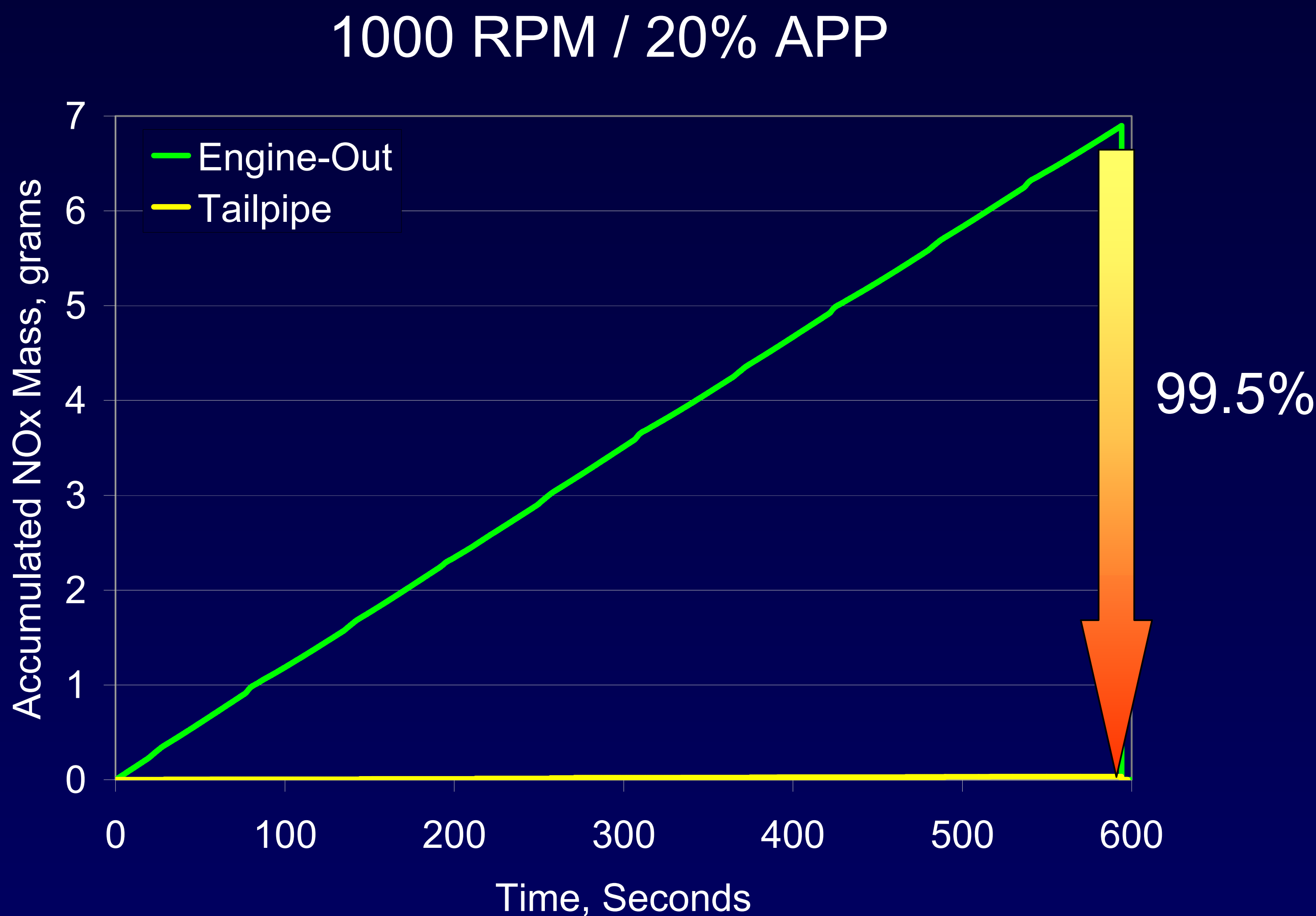
- $\lambda<1$
- Reductant Into NAC
- Reduced O_2 into NAC
- Manageable Exotherm within Catalysts

Regeneration Control: SFI + Burner + Flow Control

NAC: Progress in Regeneration Management



Progress in NAC Management



Next Steps in NAC Management

Steady-State Development of Regeneration Strategies for High Conversion

↓

Fully Automated Control of ECS

↓

Mapping of Overall Efficiency and Penalty

↓

Transient Testing

↓

Calibration Refinement

Participating Companies/Organizations

Automobile:

Ford
GM
DaimlerChrysler
Toyota

Engines:

EMA
Caterpillar
Detroit Diesel
Cummins
John Deere
Mack Trucks
International Truck & Engine

Technology:

Battelle

Emission Control:

MECA
Johnson Matthey
Delphi
DeGussa
3M
Engelhard
Siemens
Benteler

Government:

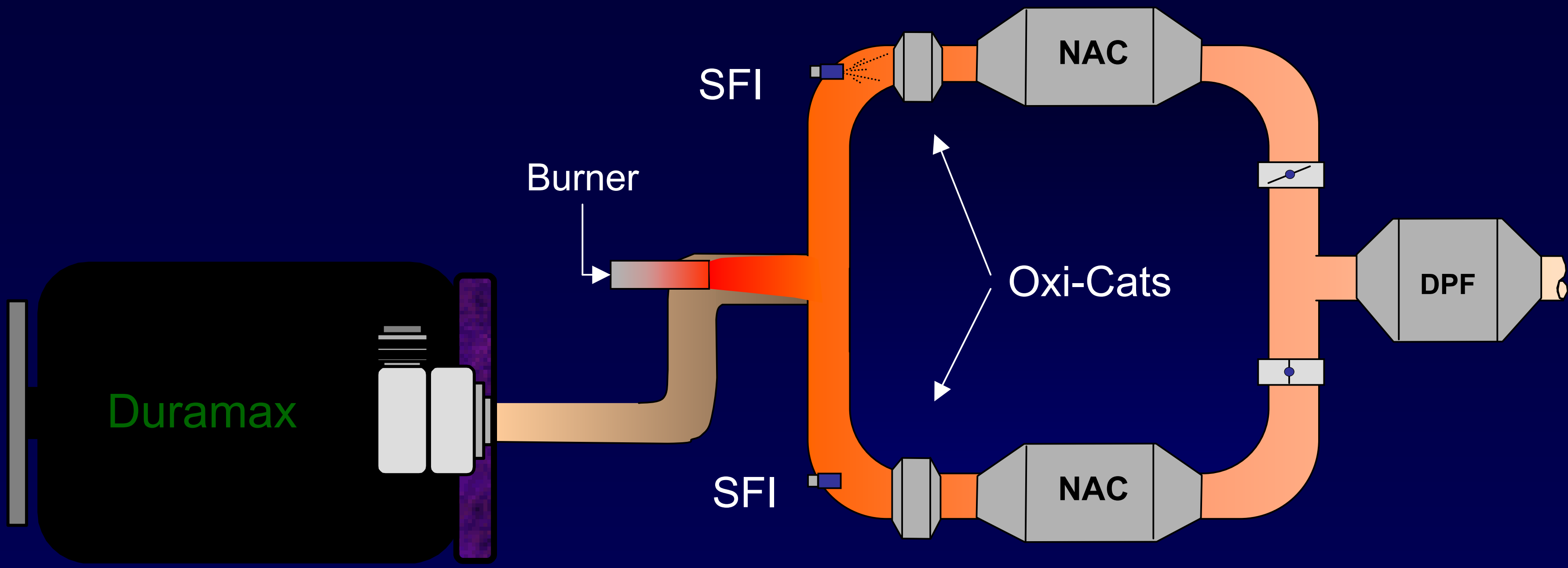
DOE
NREL
ORNL
EPA
CARB/SCAQMD

Energy/Additives:

API
American Chemistry Council
NPRA
BP
Ethyl
ExxonMobil
Marathon Ashland
Pennzoil-Quaker State
Lubrizol
Equilon
Texaco
Chevron Oronite
Ciba
Chevron Products
Ergon
Valvoline
Motiva
Infineum
Castrol

SwRI™

ECS Requirements for High Reduction Efficiencies:



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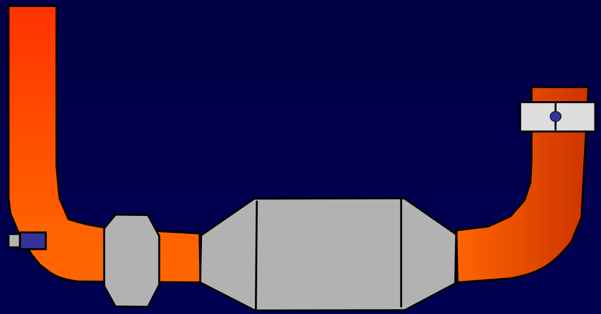

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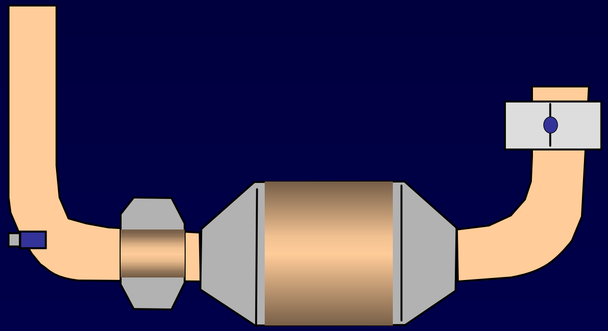

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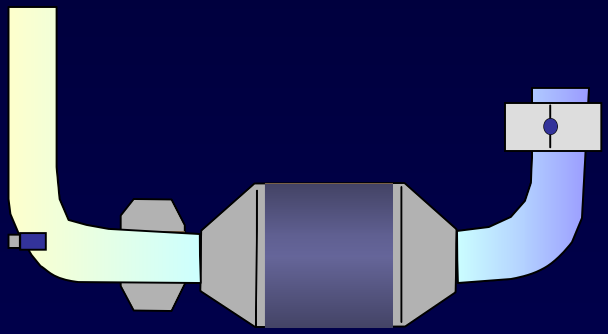


- <u>Temperature Requirements</u>

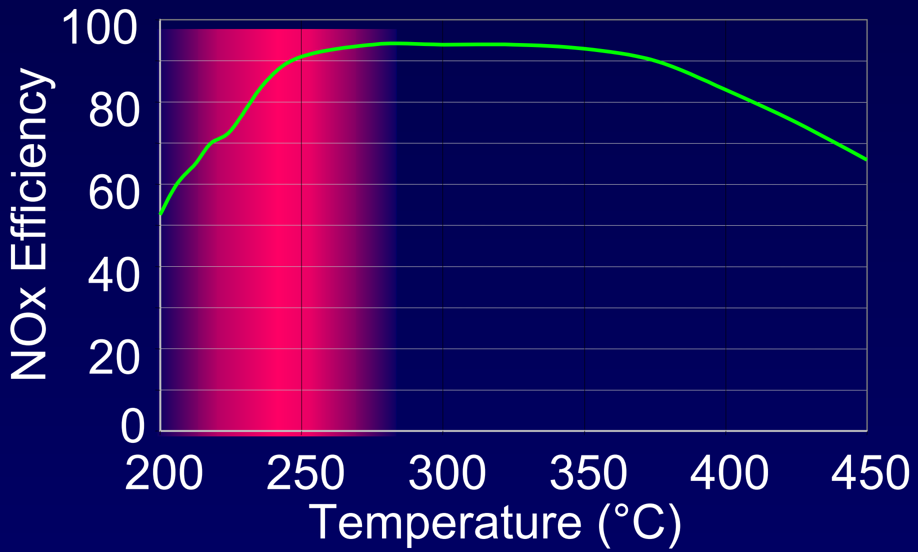
  NAC Operating Window

  - $NO + {}^{1}/_{2}O_2 => NO_2$

    (NO to NO_2 Conversion)

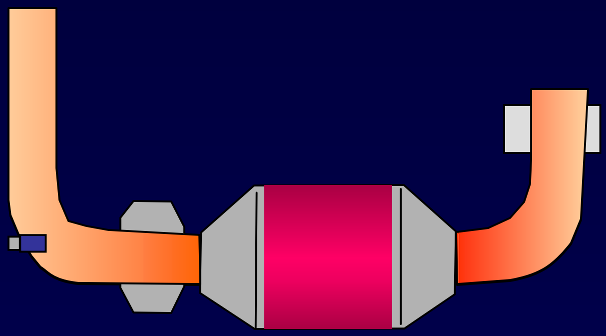
  - $NO_2 + MO^X => MNO_3$

    (NO_2 Trapping)



Too Low:
Catalytic Activity Low

ECS Requirements for High Reduction Efficiencies:



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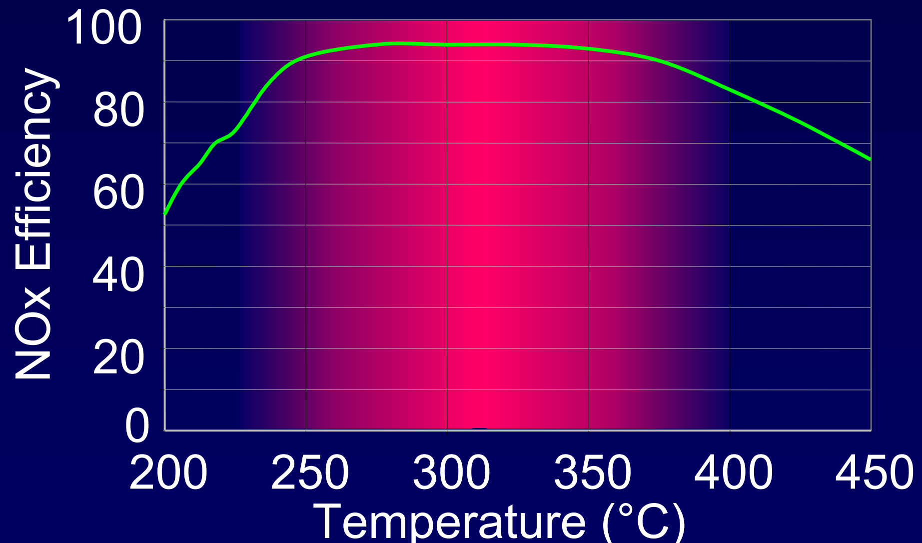
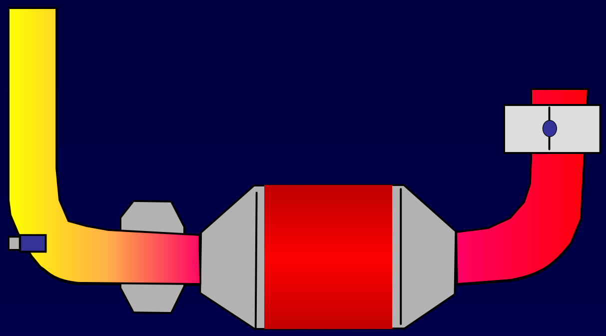


In Range:
High Conversion and Trapping

ECS Requirements for High Reduction Efficiencies:



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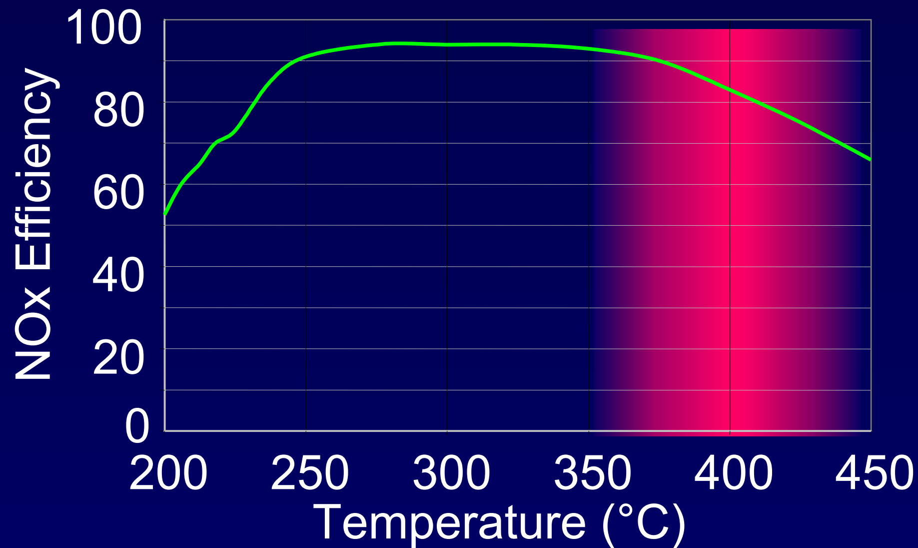
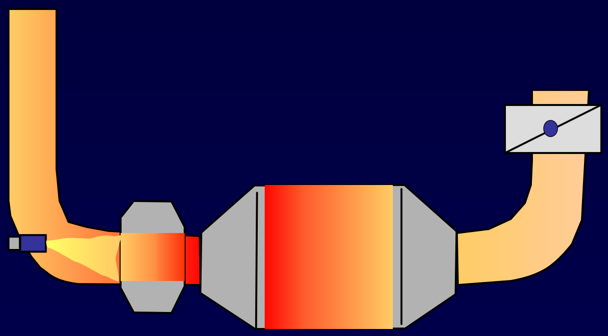


Too High:
Thermal Desorption

ECS Requirements for High Reduction Efficiencies:



- Temperature Requirements

  NAC Operating Window

  - $NO + {}^{1}/_{2}O_2 => NO_2$

    (NO to NO_2 Conversion)

  - $NO_2 + MO^X => MNO_3$

    (NO_2 Trapping)

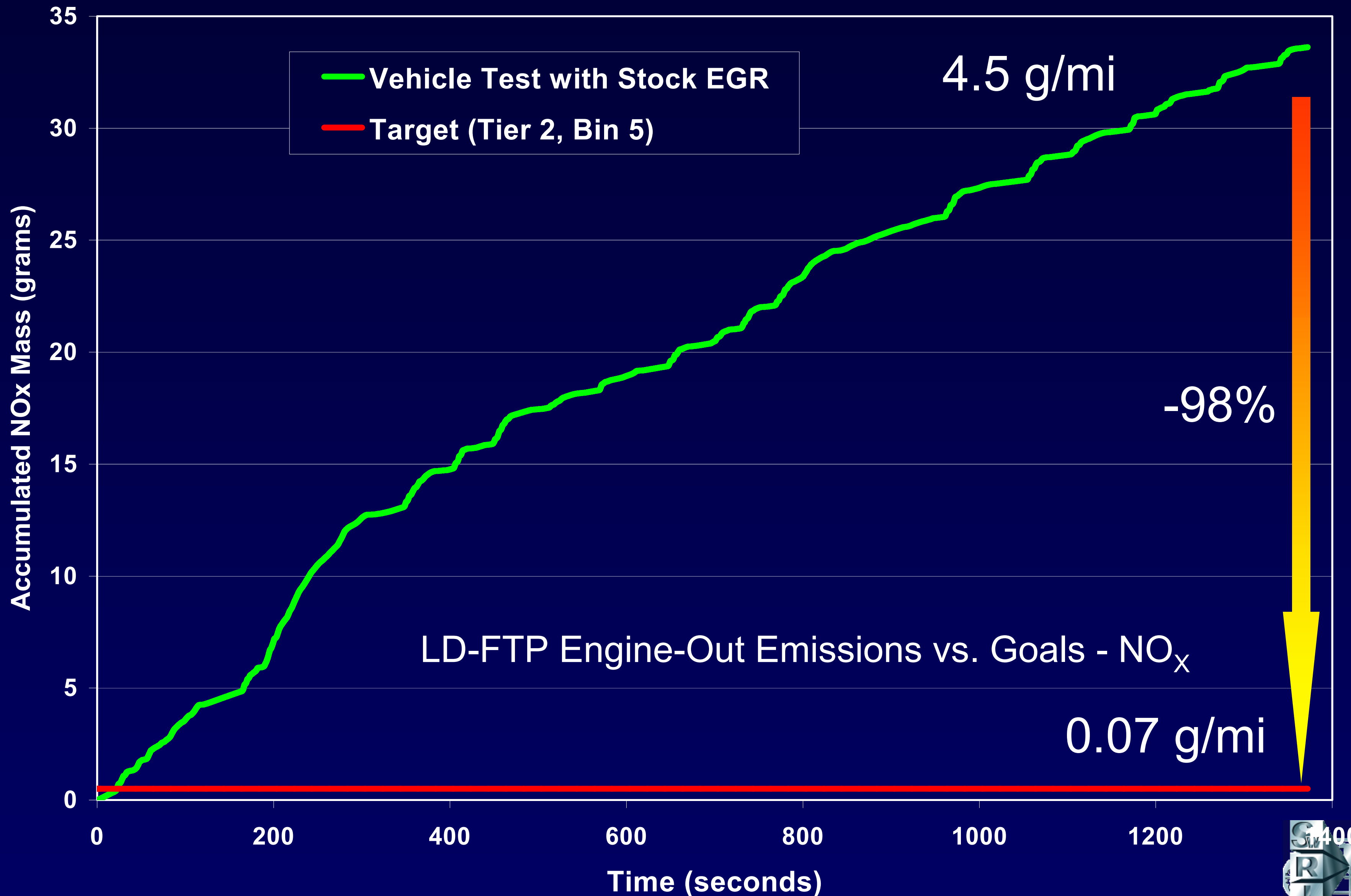
  - $NO_3^- + Red. => N_2 + H_2O$

    (Nitrate Reduction)

ECS Requirements for High Reduction Efficiencies:

- Temperature Requirements
  - NAC Operating Window (3 Distinct Functions)
    - $NO + {}^{1}/_{2}O_2 \Rightarrow NO_2$ - (NO to NO_2 Conversion)
    - $NO_2 + MO^X \Rightarrow MNO_3$ - (NO_2 Trapping)
    - $NO_3^- + Red. \Rightarrow N_2 + H_2O$ - (Nitrate Reduction)

NAC: Inlet Mass Needs



Progress in NO_X Management