Visualization of In-Cylinder Combustion R&D

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Overview

Timeline

- Started May 2008
- Ends Sept. 2010
- 25% Complete

Budget

- Total project funding
  - DOE share 100%
  - Contractor share 0%
- Funding received in
  - FY08 $200k
  - FY09 $550k

Barriers

- Barriers addressed
  - Mechanism to control LTC Timing
  - LTC high load and high speed operation
  - LTC control during change of speed and load

Partners

- Argonne is project lead
- Partners are
  - GM Europe and GM R&D
    - Engine maps, piston crowns and other hardware, cylinder head modifications, technical support
  - University of Illinois - Chicago
    - Graduate student performing engine simulations using Converge code
  - USAF
    - Fuels, sensors, technical support
  - FACE program
    - Fuels

Objectives of this Study

- Utilize in-cylinder combustion imaging to enable the implementation of low temperature combustion in a production automotive engine
- Focus upon gasoline-like (low cetane) fuels
  - Avoid soot/NO_x production by insuring the end of injection occurs before the start of combustion
  - Diffusion flames show up well in endoscope imaging
  - Fuel/(Air+EGR) will be premixed, but not well mixed
- Maintain relatively high power densities (~10 bar BMEP) while retaining high efficiency and low emissions
- Control combustion phasing by utilizing in-cylinder controls
  - EGR will be unevenly distributed, as well as cylinder wall temperature
  - Cylinder-to-cylinder control required
  - Use pressure transducer and other sensors for feedback control

Milestones

■ Endoscope access cylinder head installed on engine	Dec 2008
■ New postdoc arrived to support project	Feb 2009
■ Drivven controller commissioned	Feb 2009
■ Optical images acquired on diesel operation	Mar 2009
■ Validate gasoline fuel cart operation	May 2009

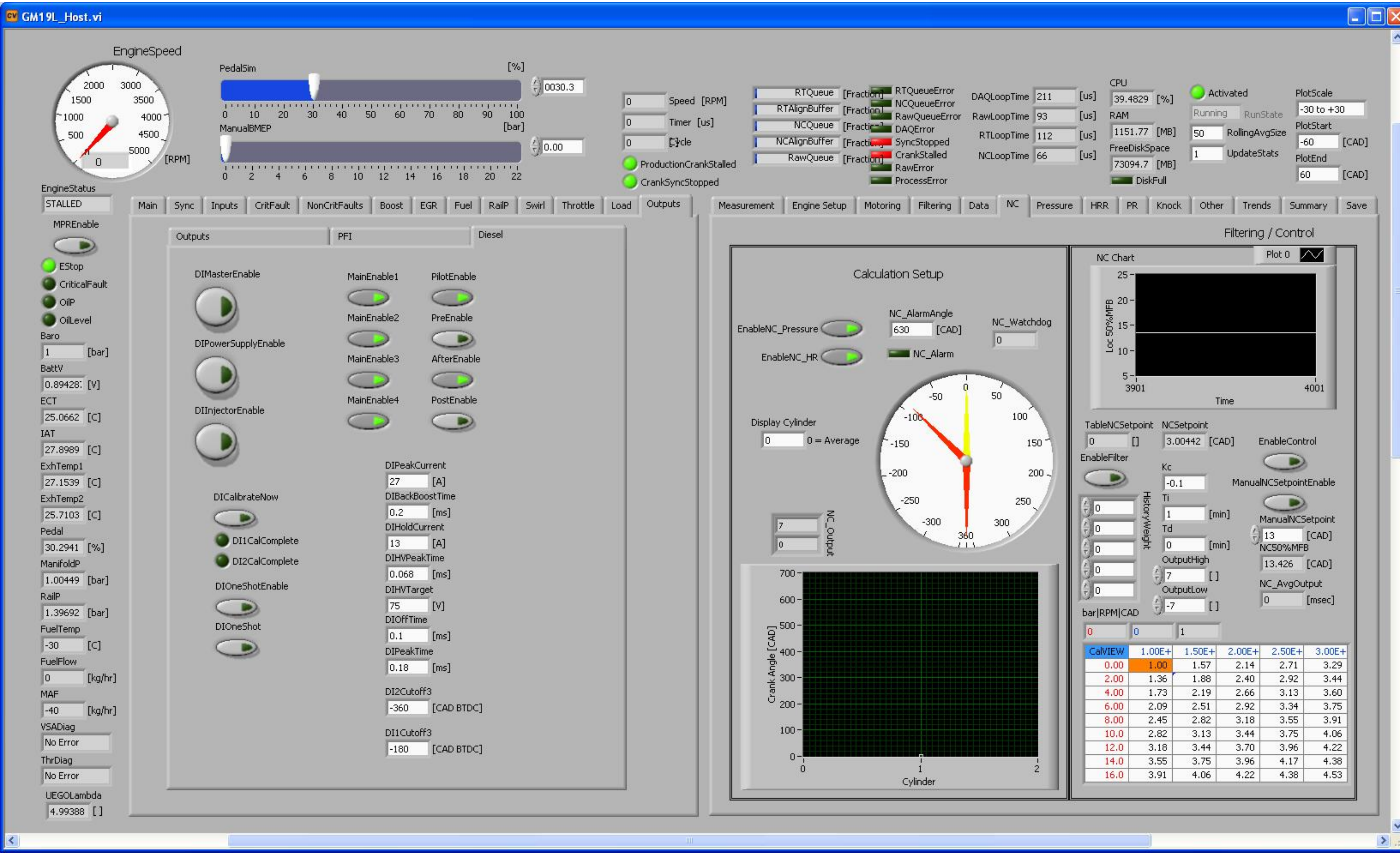
■ Future milestones	
■ Install lower compression ratio pistons	Jun 2009
■ Attempt LTC with 14:1 pistons	Jul 2009
■ Discover LTC operating envelope	Sept 2009

Approach

- This project will use low cetane/high volatility fuel
  - Increase ignition delay
  - Limit/eliminate wall and piston fuel wetting
  - Ignition to occur AFTER the end of injection to avoid mixing controlled combustion
- Low compression ratio pistons from GM-E (14:1, 15:1 and 16:1)
- Gasoline-like fuels with low cetane/high volatility
- Lubricity additive to insure operation of diesel injection equipment
- Use fluid mechanics to control combustion phasing and engine load
- Use combustion imaging to guide optimal engine parameters and evaluate different fuel combustion characteristics
- Support experimental work with engine simulations from UIC using “Converge” code
- Leverage our APS injector work to better understand diesel injector performance using gasoline-like fuels

Technical Accomplishments

- Full authority control of engine parameters
  - EGR
  - Boost
  - Intake Swirl
  - Injection Rail Pressure,
  - Injection Timing
  - Multiple Injection - up to 5 independent injections/cycle
- Lambda closed loop control
- Next Cycle control
- Engine can operate on the stock Bosch engine map or modified in any way the operator chooses.
- Cylinder by cylinder independent control capability is functional.



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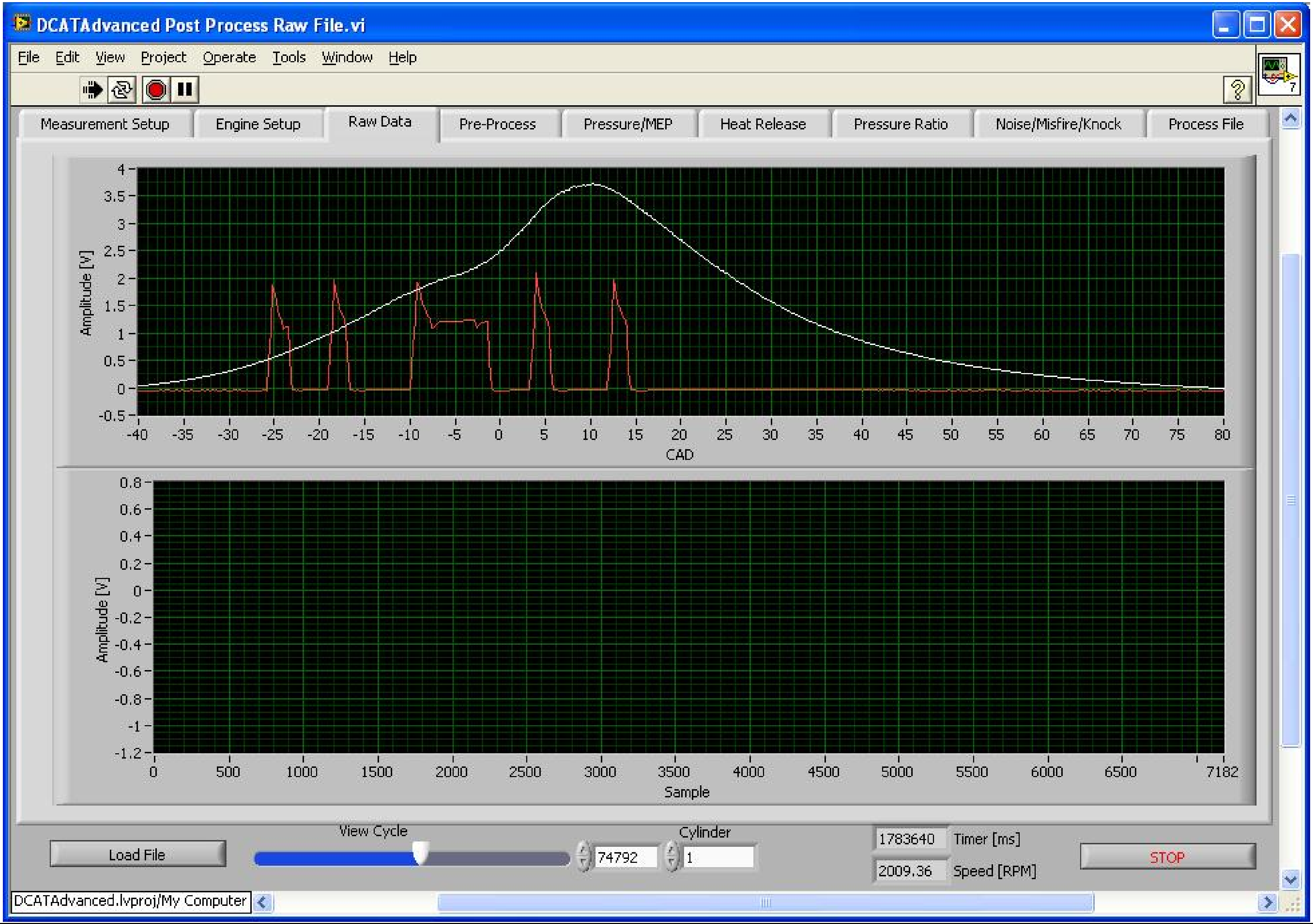
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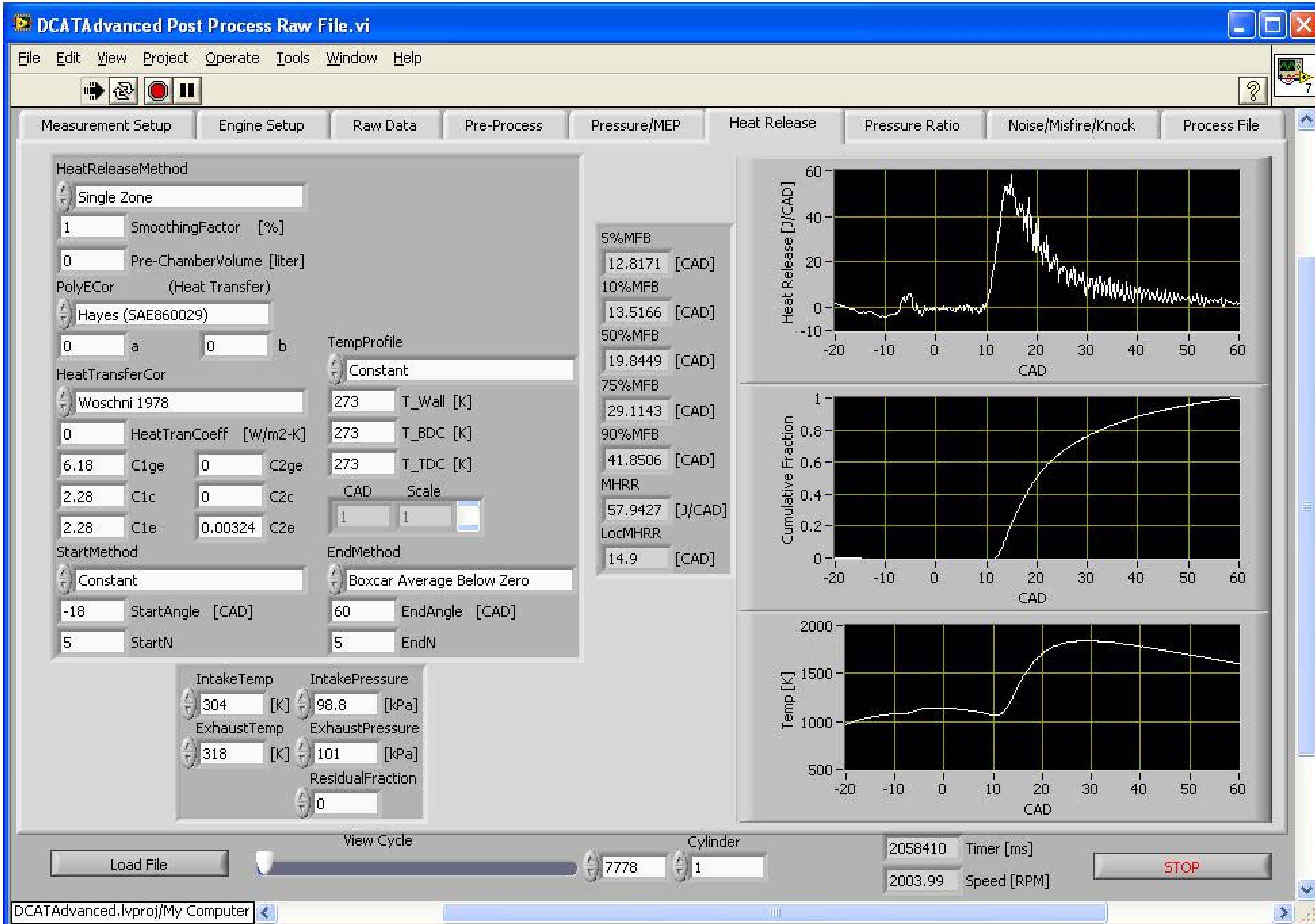

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Future Work

- Validate engine operation on lower compression ratio pistons with gasoline fuel
  - Lubricity additive
  - FACE fuel (~30 cetane), USAF fuel (20-25 cetane) and low octane (20-25 cetane) gasoline
- Characterize entire engine operating range of speeds/loads for each fuel to see what range of BMEP is possible.
- When LTC operation is determined, use combustion imaging to obtain detailed fluid mechanics and chemistry information
  - Spectroscopic measurements
  - Any possible soot radiation
- Fine-tune combustion phasing control by use of multiple injections, EGR and boost.
- Correlate results with APS spray data and with SNL's fundamental combustion work
  - We are all using identical hardware (Bosch Gen II)
  - Make data available to Engine Combustion Network (managed by SNL; Lyle Pickett)

Summary

- Power density needs to be addressed in LTC operation
- Fluid mechanics is a more robust control parameter than fuel chemistry
- Project will focus upon decreasing the fuel sensitivity for LTC by utilizing injection parameters for combustion phasing
- Insuring that ignition occurs after end of injection provides premixed (but not well mixed) fuel/air charge = opportunity for higher power densities than HCCI
- Cylinder to cylinder control should be helpful due to lack of even EGR distribution
- Combustion imaging is a very familiar and well-validated tool to help us understand the characteristics of LTC
  - Will be simultaneously with pressure transducers, current clamps, emissions bench, fast FID and fast NO_x analyzers
- Working with GM (and USAF) allows for a rapid path for Technology Transfer
  - Monthly GM teleconferences and scheduled visits