Optical Diagnostics and Modeling Tools Applied to Diesel HCCI

Upul DeSilva
Cathy Y. Choi
Caterpillar Engine Research

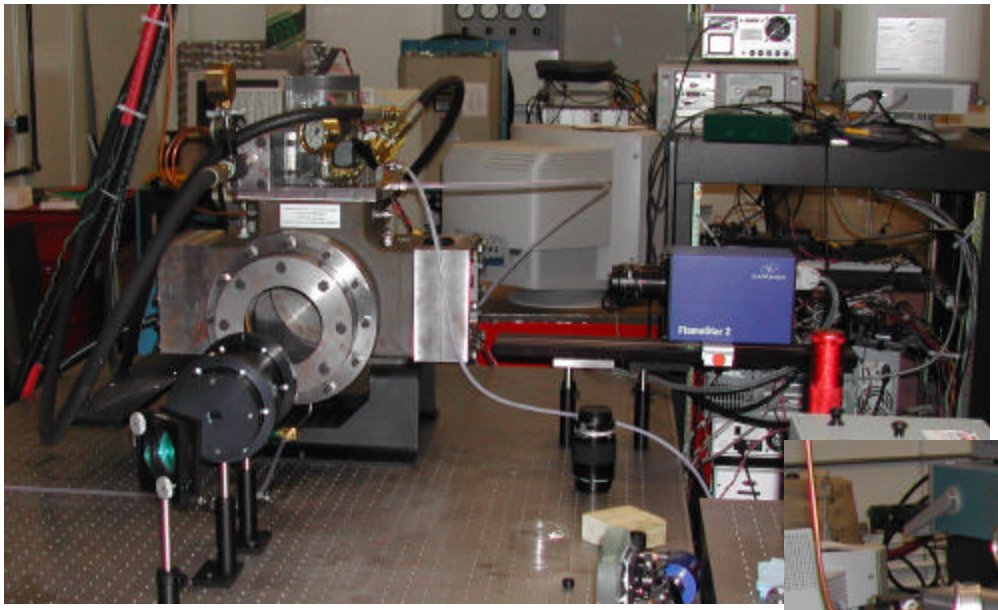
Optical Diagnostics and Combustion Modeling

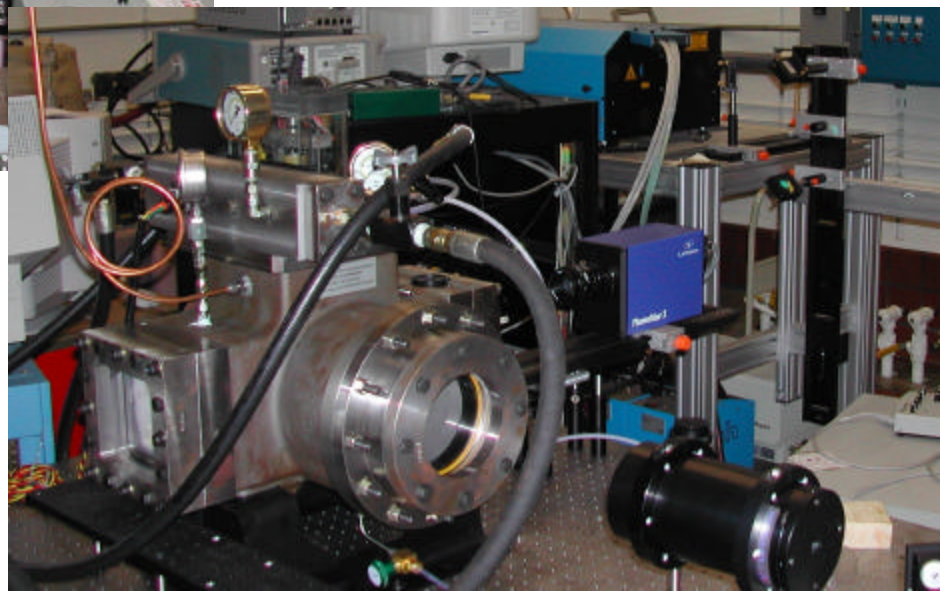
- Diesel HCCI is being pursued in order to meet Diesel 2010 emissions requirements
- Optical Diagnostics
  - Used to gain fundamental understanding of Diesel HCCI combustion
  - Provide data to the combustion modeling team
- Multidimensional Combustion Modeling
  - To gain further insight into HCCI
  - To optimize HCCI conditions to maximize performance

Caterpillar Optical Diagnostic Capabilities

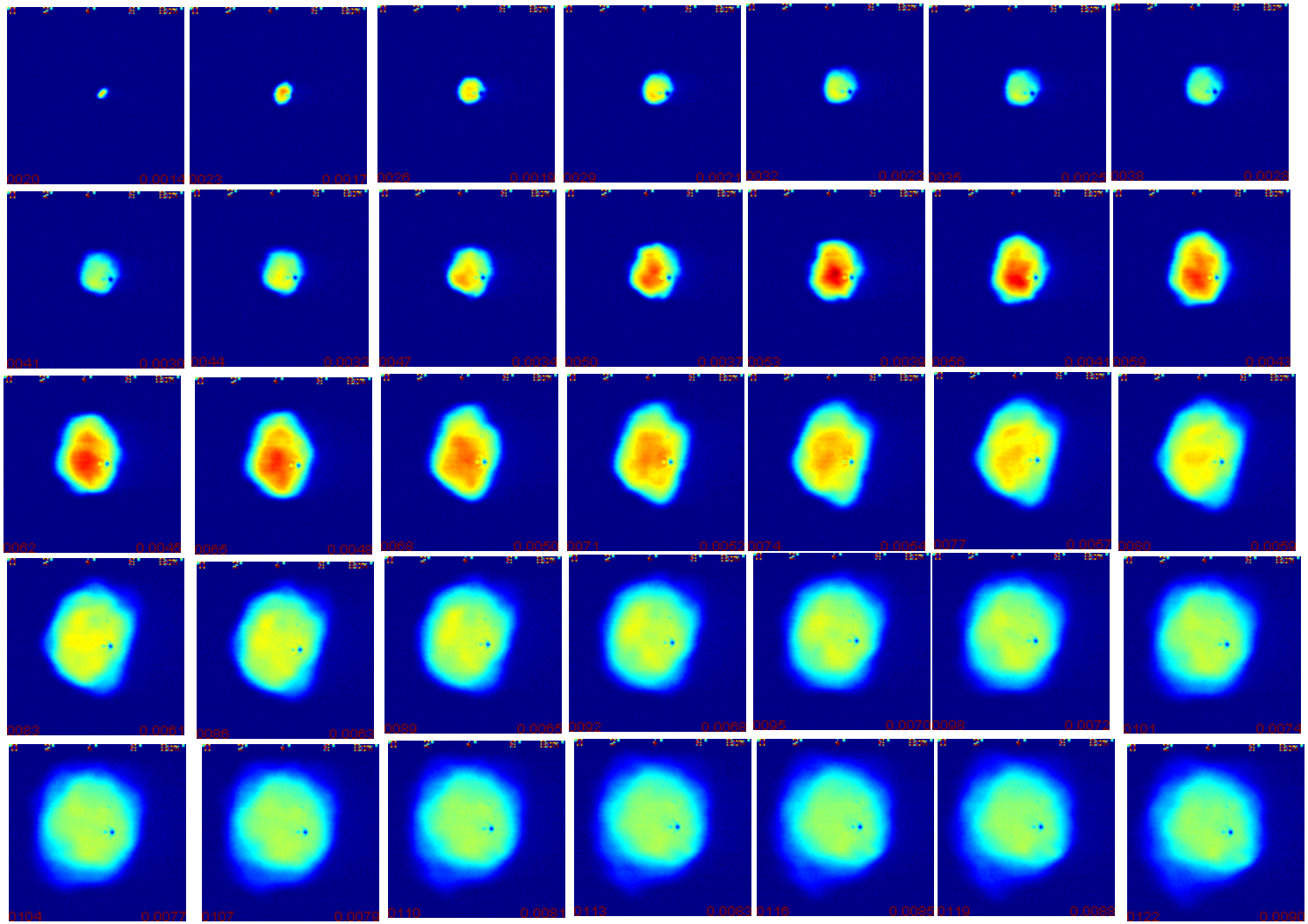
- **Non-vaporizing spray chambers**
  - 300 and 400 psi chamber pressure capabilities
  - Liquid spray penetration and geometry
  - Droplet SMD
- **Optically accessible reciprocating engine**
  - Providing access for combustion laser diagnostics
  - Chemiluminescence studies (combustion species)
  - PLIF (NO and OH)

Advanced Laser Spray Visualization Facility

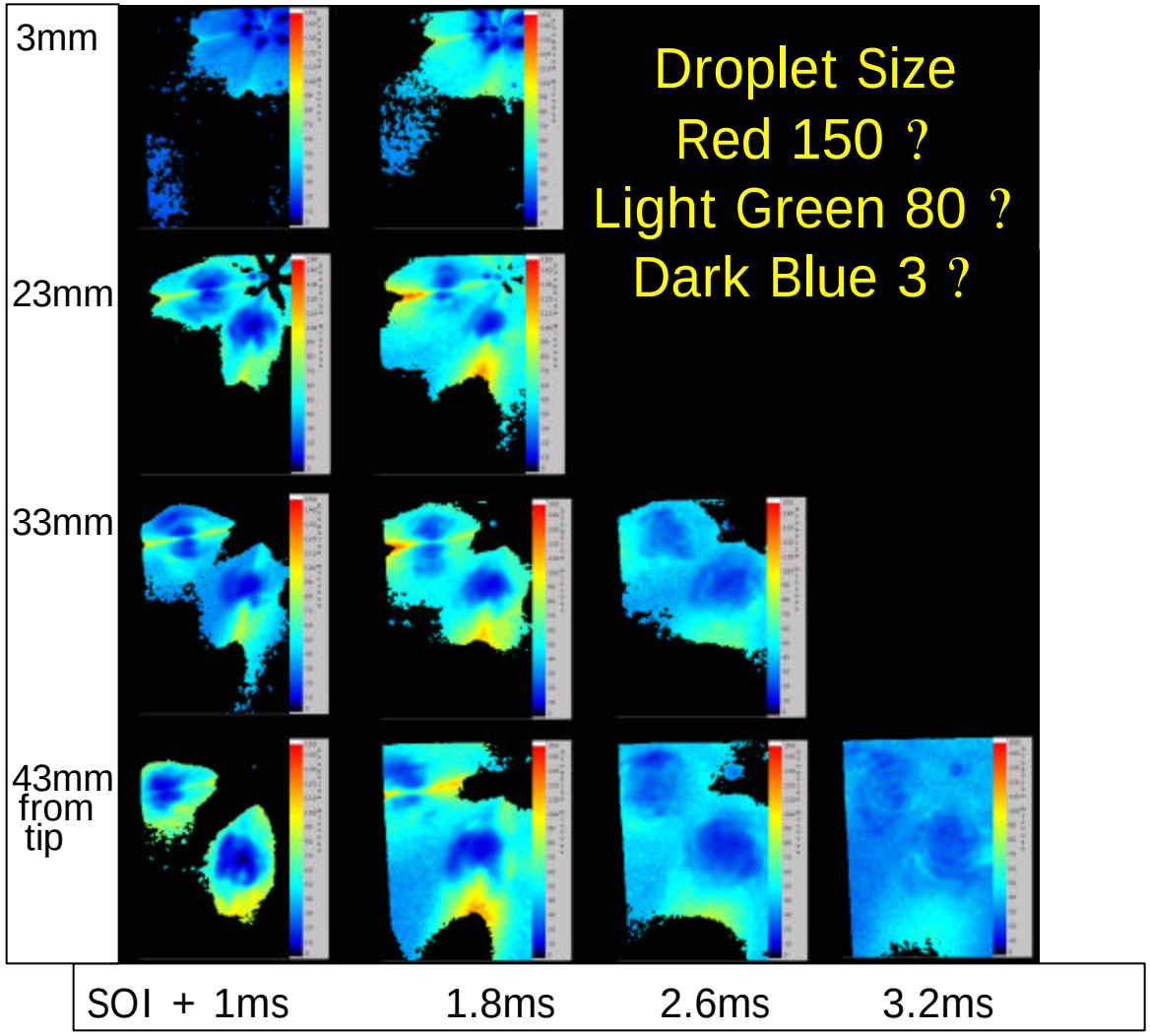




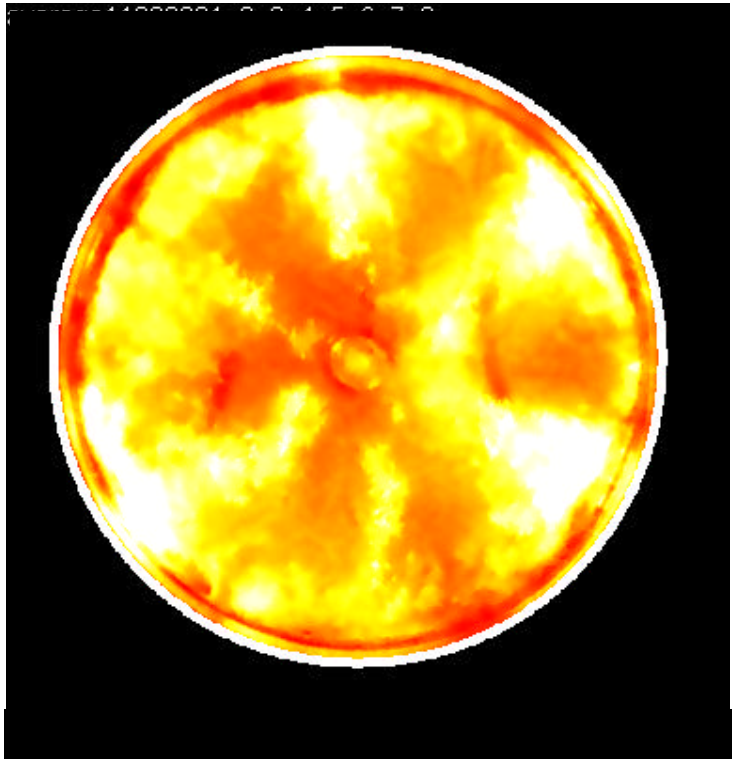
Spray From a HCCI tip



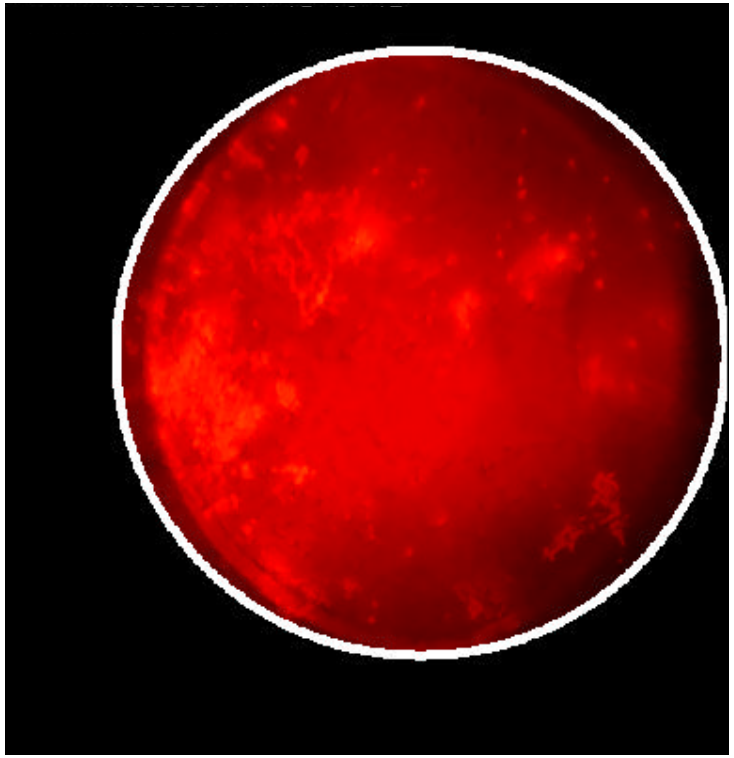
Droplet Sizing



Comparison of Conventional and HCCI Combustion



Conventional



Diesel HCCI

Reactive CFD Modeling for Diesel HCCI Combustion

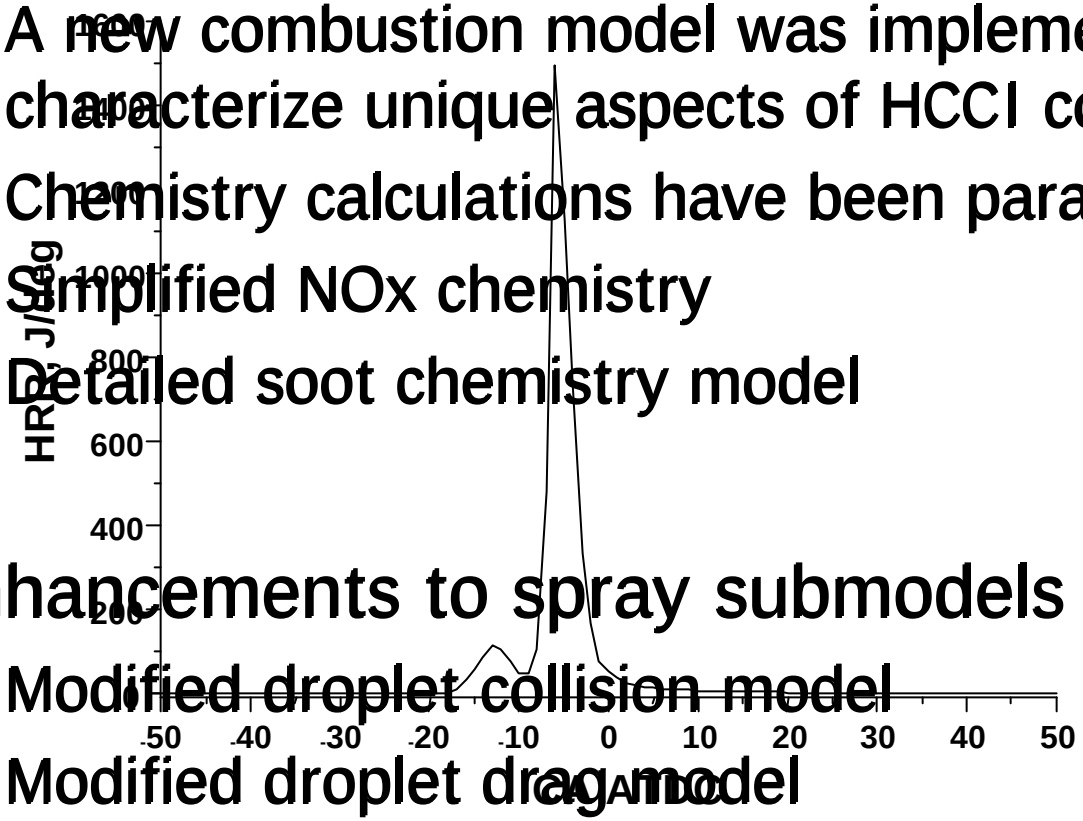
- Objective: Optimize HCCI combustion for engine emissions and performance.
- Proprietary multi-dimensional reactive CFD code
- LINUX based code
- Portions parallelized to increase computational speed

Computational Facilities

- CAT Engine Research LINUX cluster
  - ~40 nodes 1.2-1.66 Ghz AMD Athlon single and dual processors
  - Cluster currently operates at 256 GigaFlops
  - Ranked 55 out of top 500 supercomputers in the world
  - Applications include both CFD codes and metal stress analyses codes.

HCCI Modeling Issues

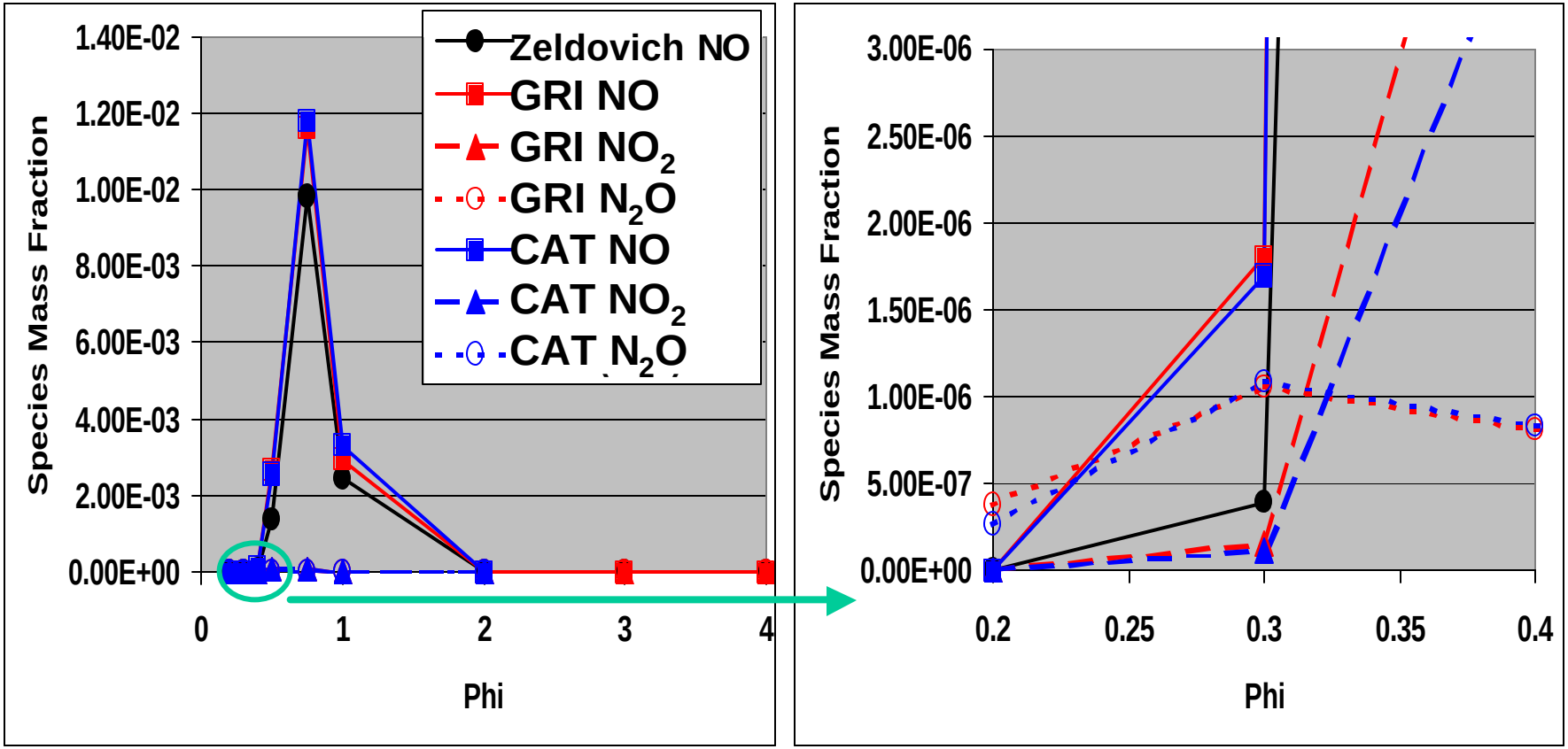
- HCCI needs detailed chemistry model
  - A new combustion model was implemented to characterize unique aspects of HCCI combustion
  - Chemistry calculations have been parallelized
  - Simplified NOx chemistry
  - Detailed soot chemistry model
- Enhancements to spray submodels
  - Modified droplet collision model
  - Modified droplet drag model



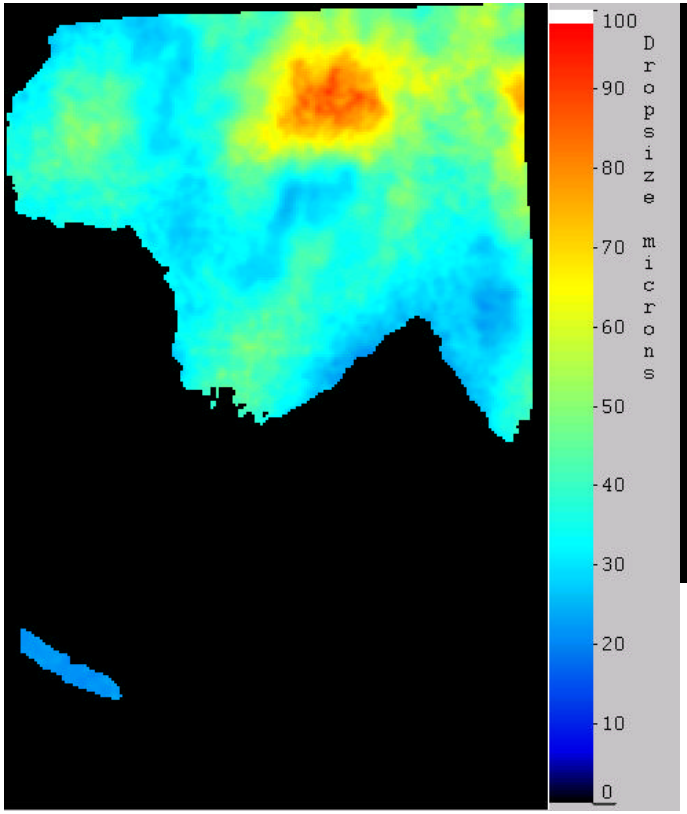
NO_x Chemistry

	Ext. Zeldovich	CAT developed	GRI Mech
	Simple 3 reactions	Simple reaction scheme ? 10 reactions	Above 2000 reactions
	Predict NO	Predict NO Predict N_2O Predict NO_2	Predict NO Predict N_2O Predict NO_2 Predict other species
	Least computational time	Moderate computational time	Very high computational time

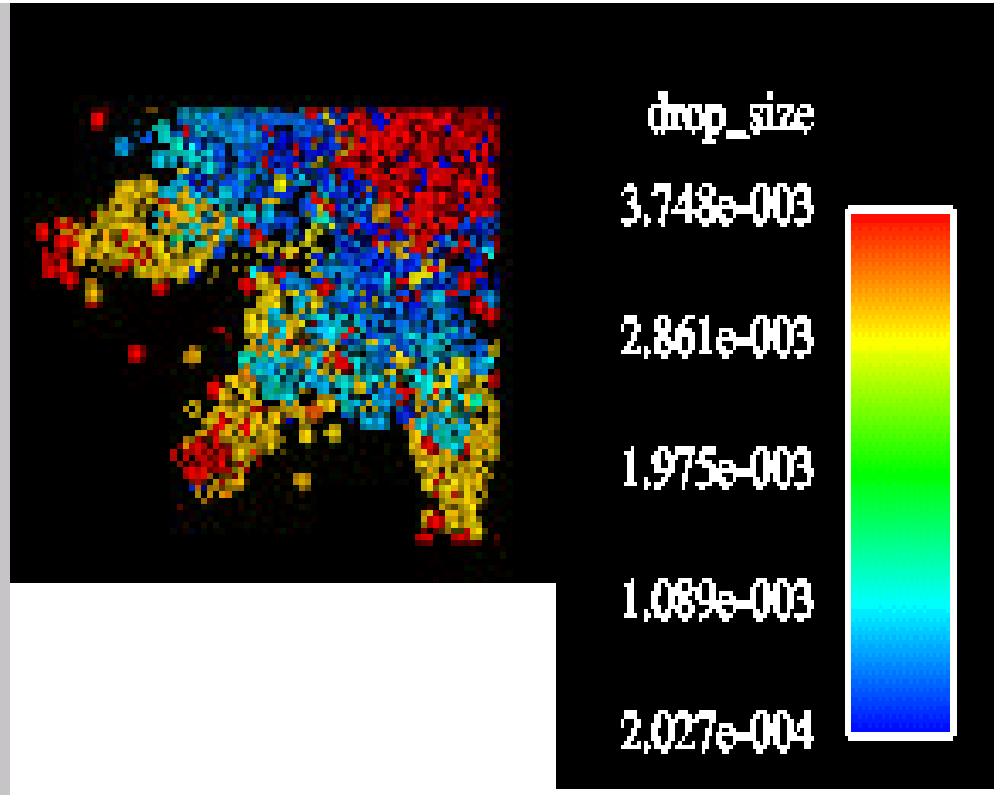
Comparison of NOx Models for a Premixed n-Heptane Flame



Comparison between Experiments and Simulations

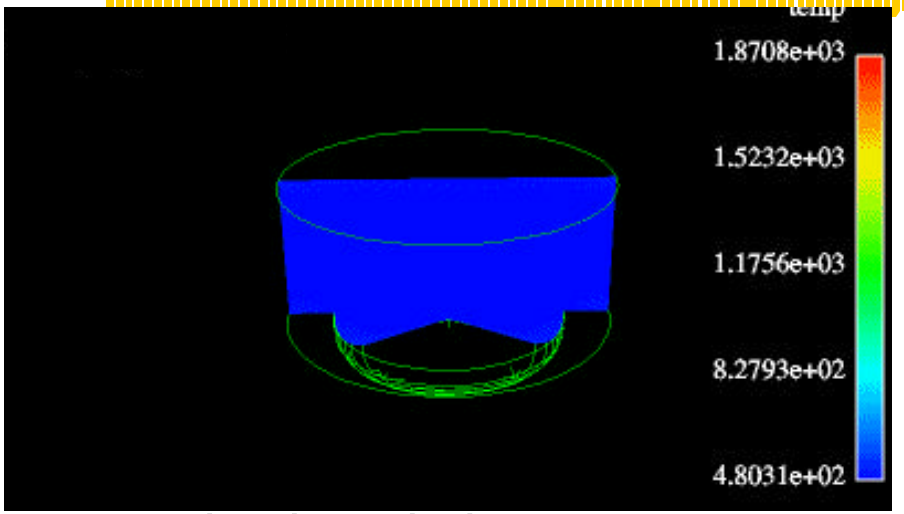


Spray Rig

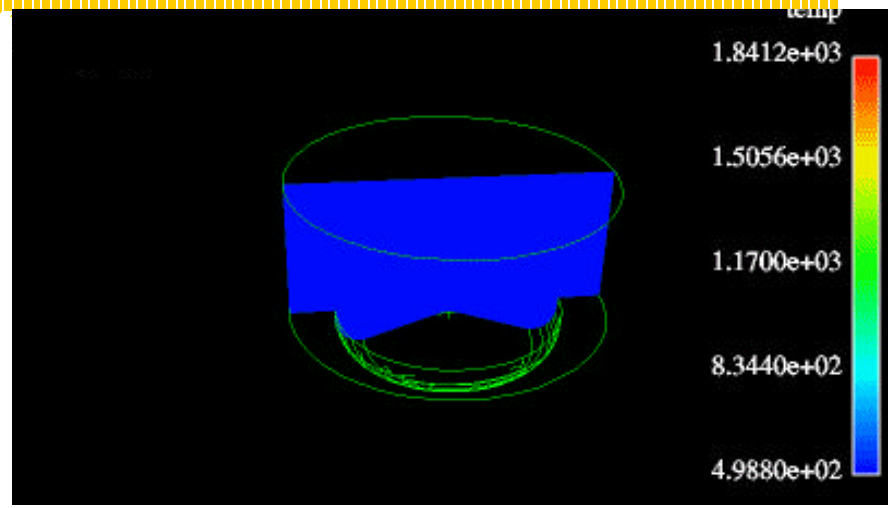


Spray Simulation

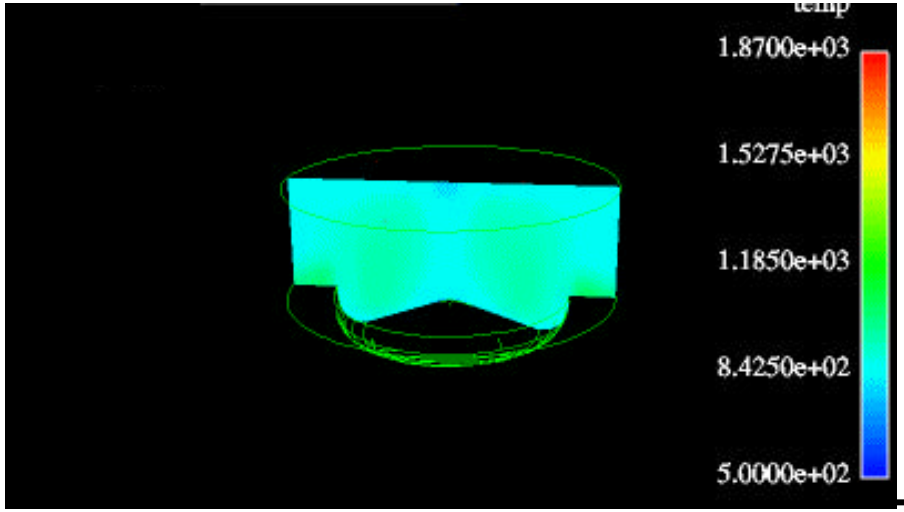
Comparison of Convention Diesel to HCCI Combustion



Injection Timing: TDC

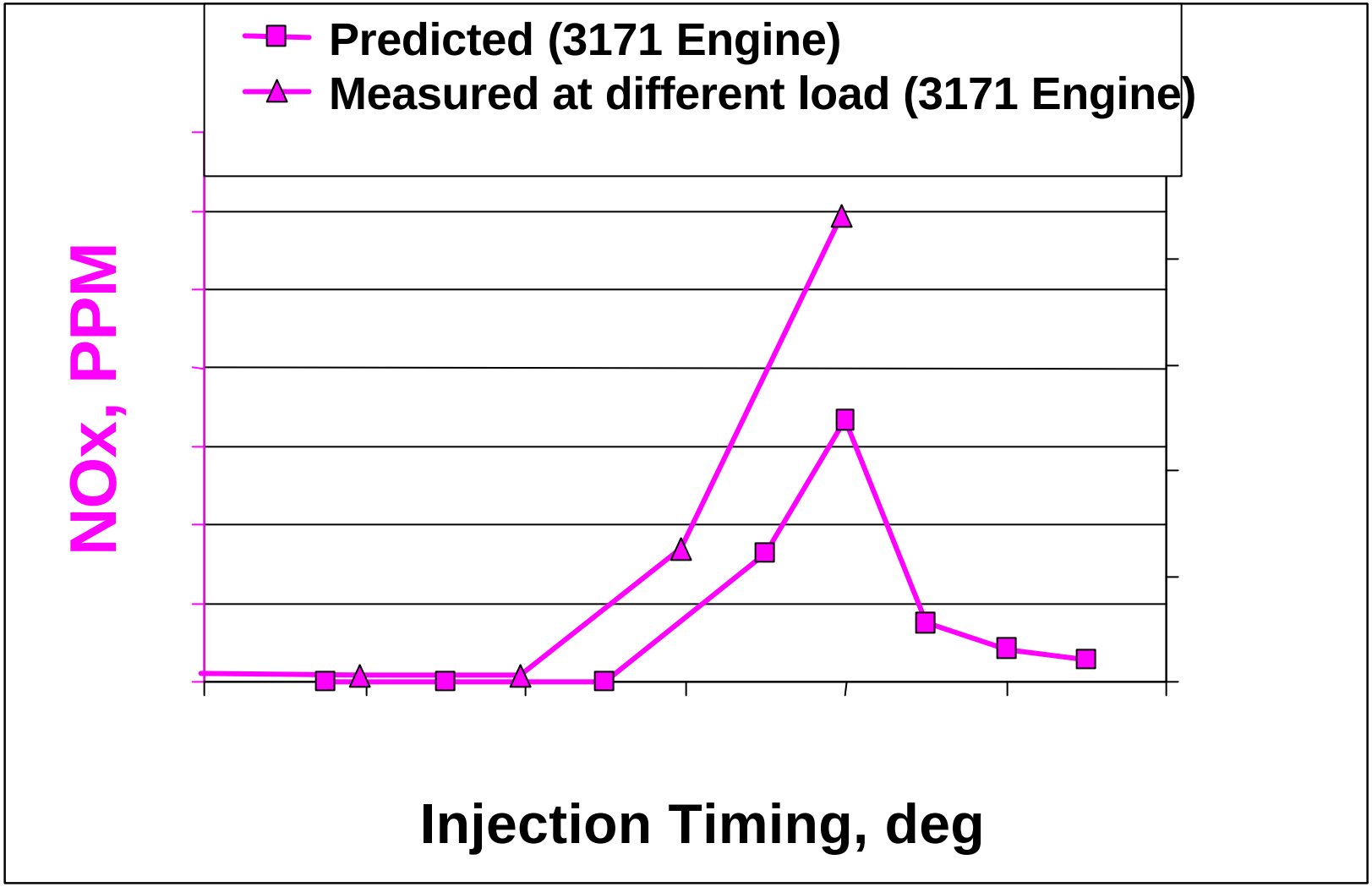


Injection Timing: -20 CA ATDC

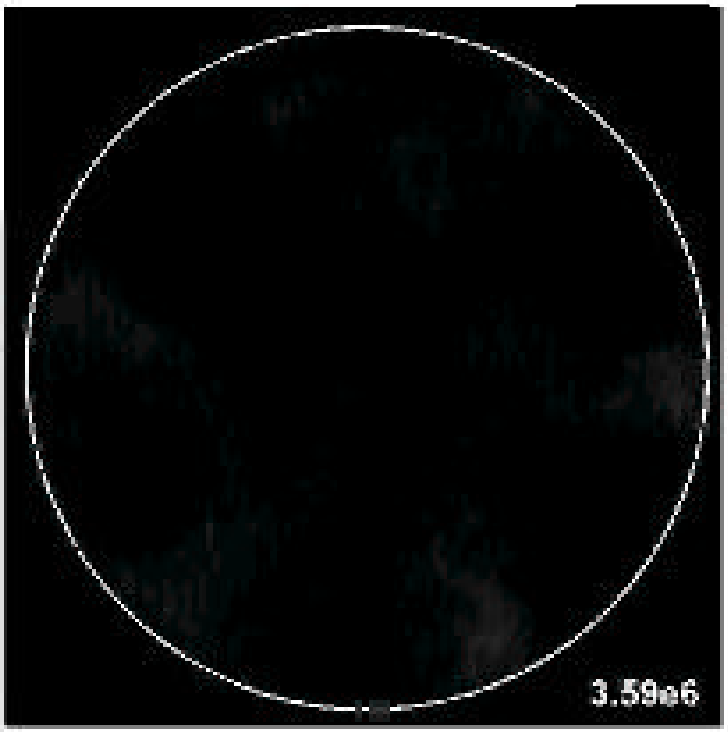


Early Injection Timing for HCCI

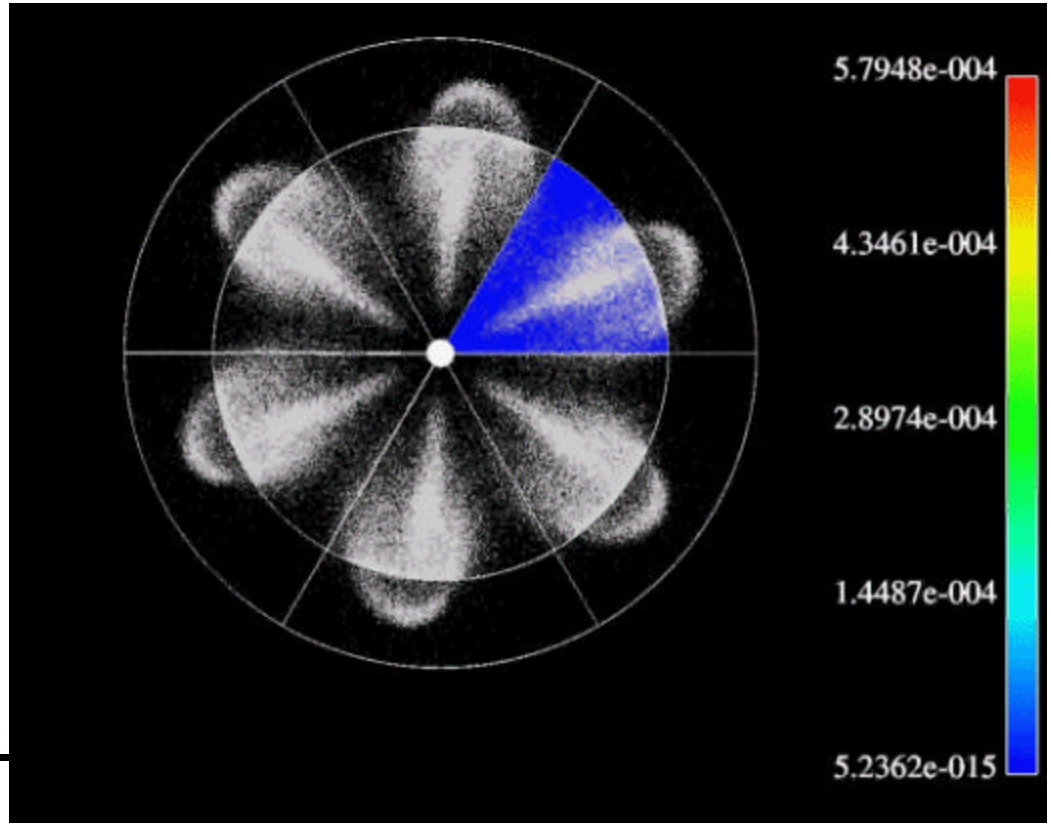
NO_x Emissions Trends



Prediction Comparison between CFD and Sandia Optical Engine Data



Sandia Optical Engine



Combustion CFD Results

Summary

- HCCI combustion technology is being pursued in order to meet Diesel emissions requirements for upcoming 2010 regulations.
- Optical diagnostic and computational tools are being used to gain understanding of HCCI
- Continuing collaborations with National Labs and Universities