SAND2012-3586P

Thinking into the Box: Solving Engineering Problems Using Lasers and Cameras in Optical Engines

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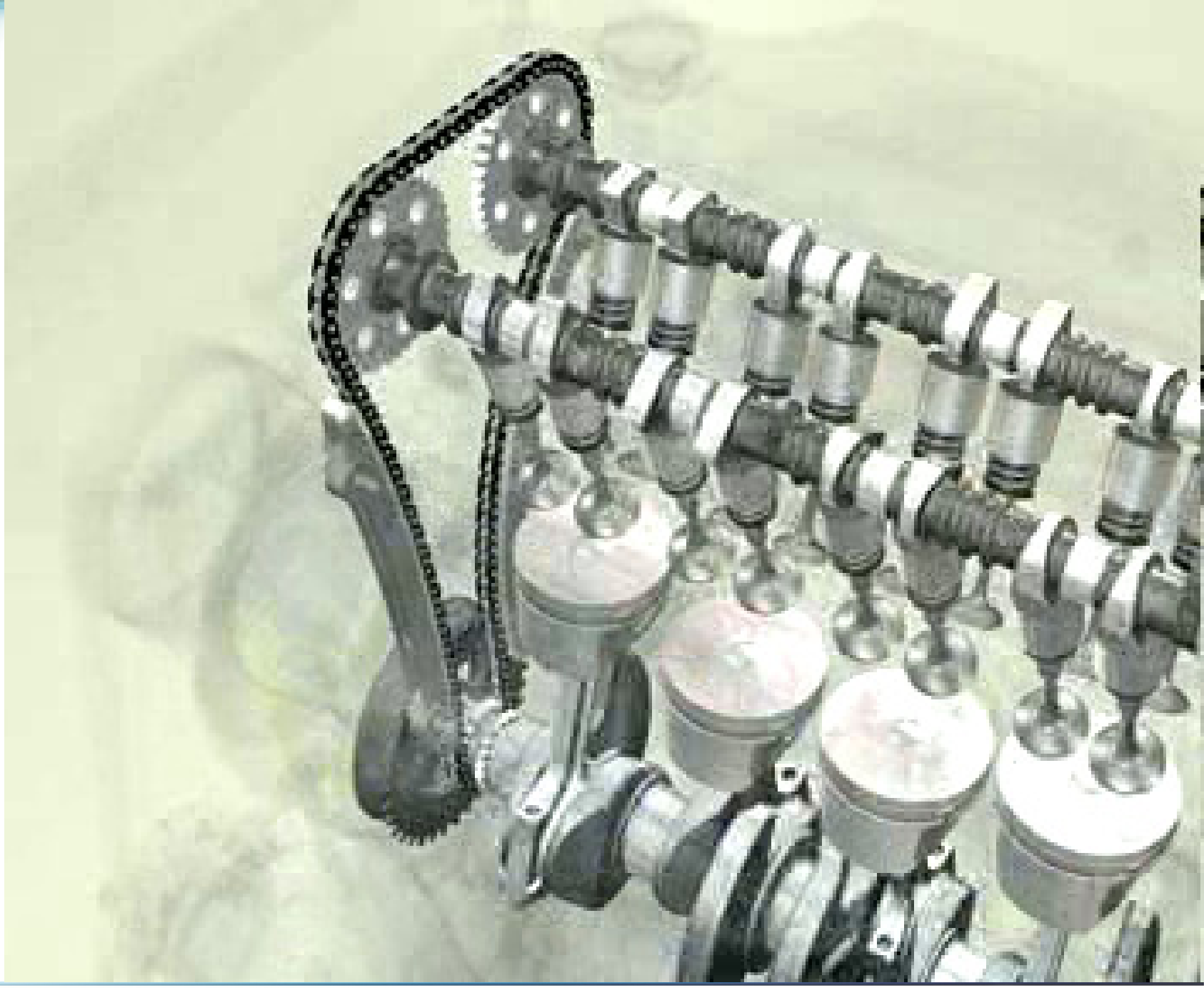
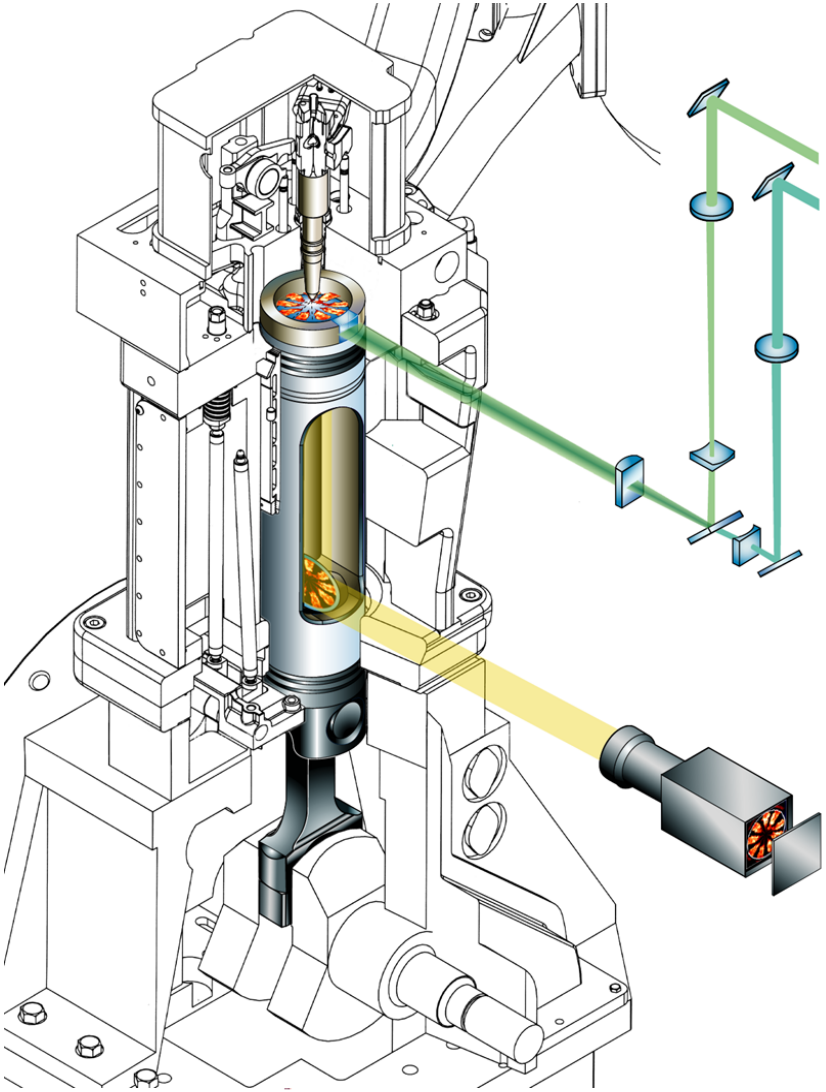
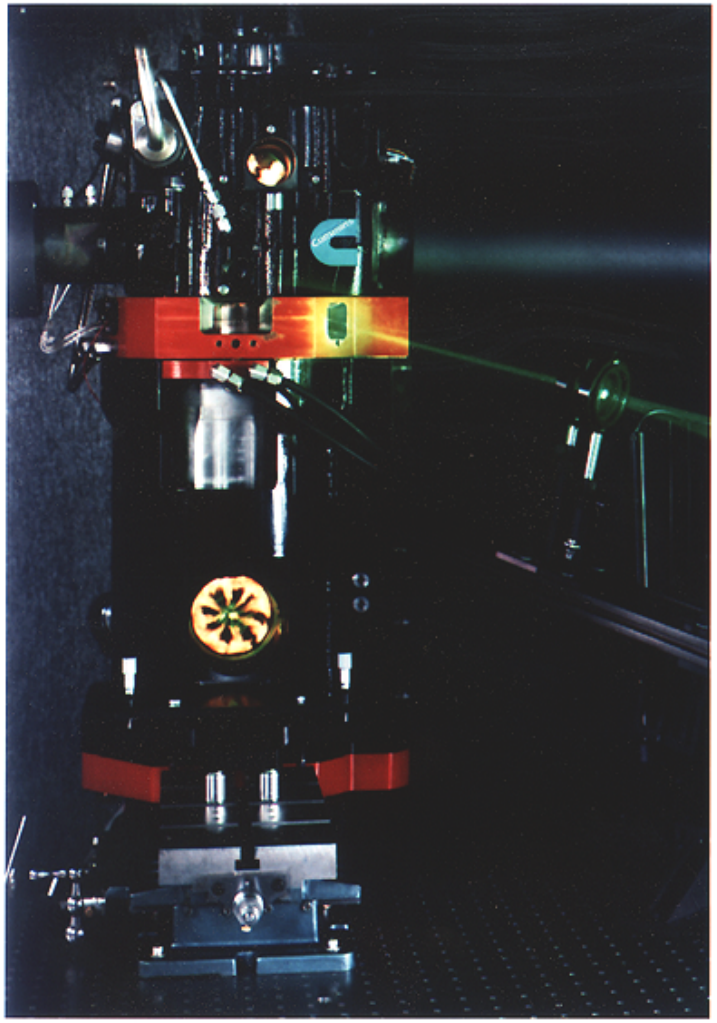
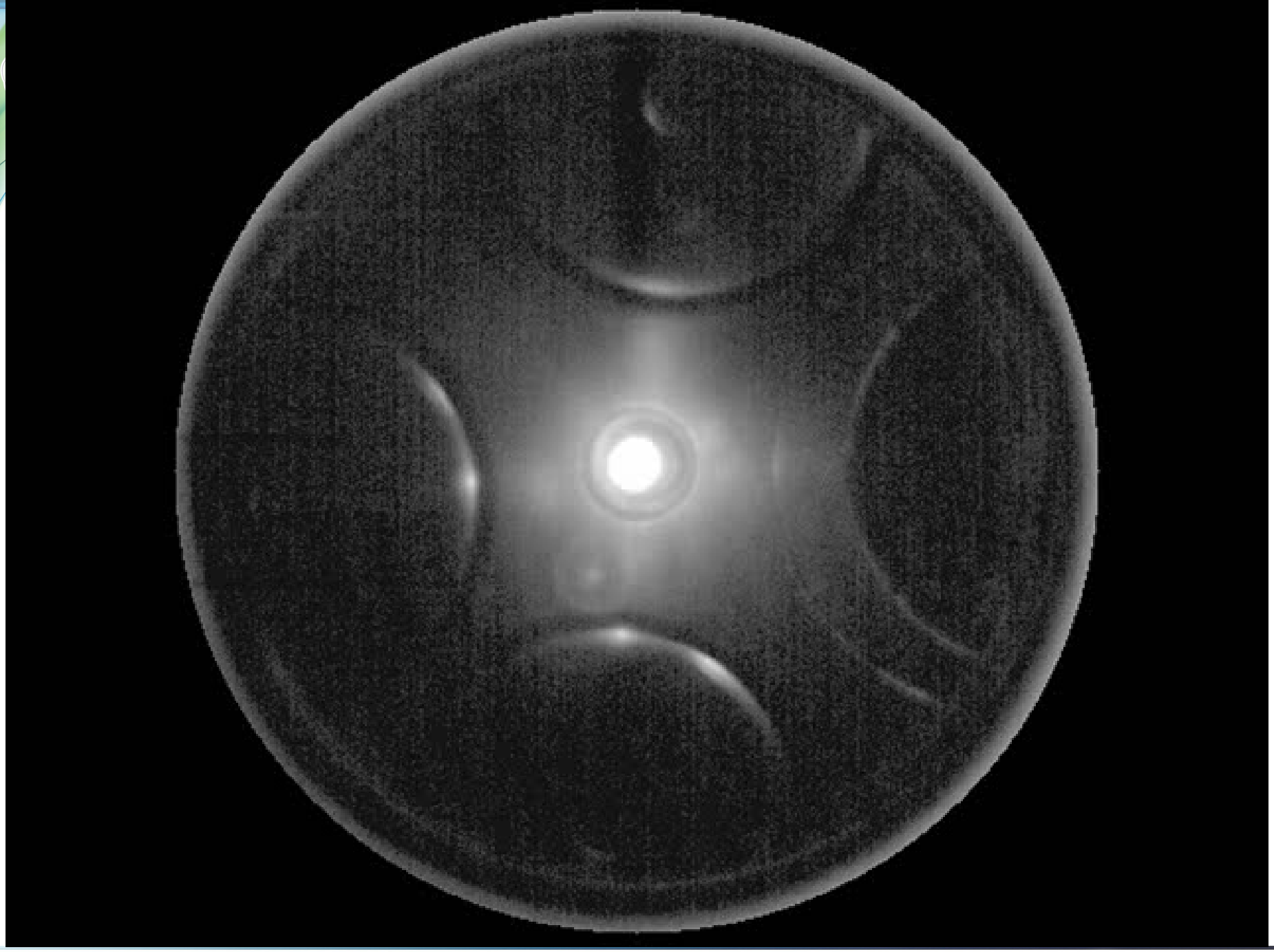
May 3, 2012, Las Positas College

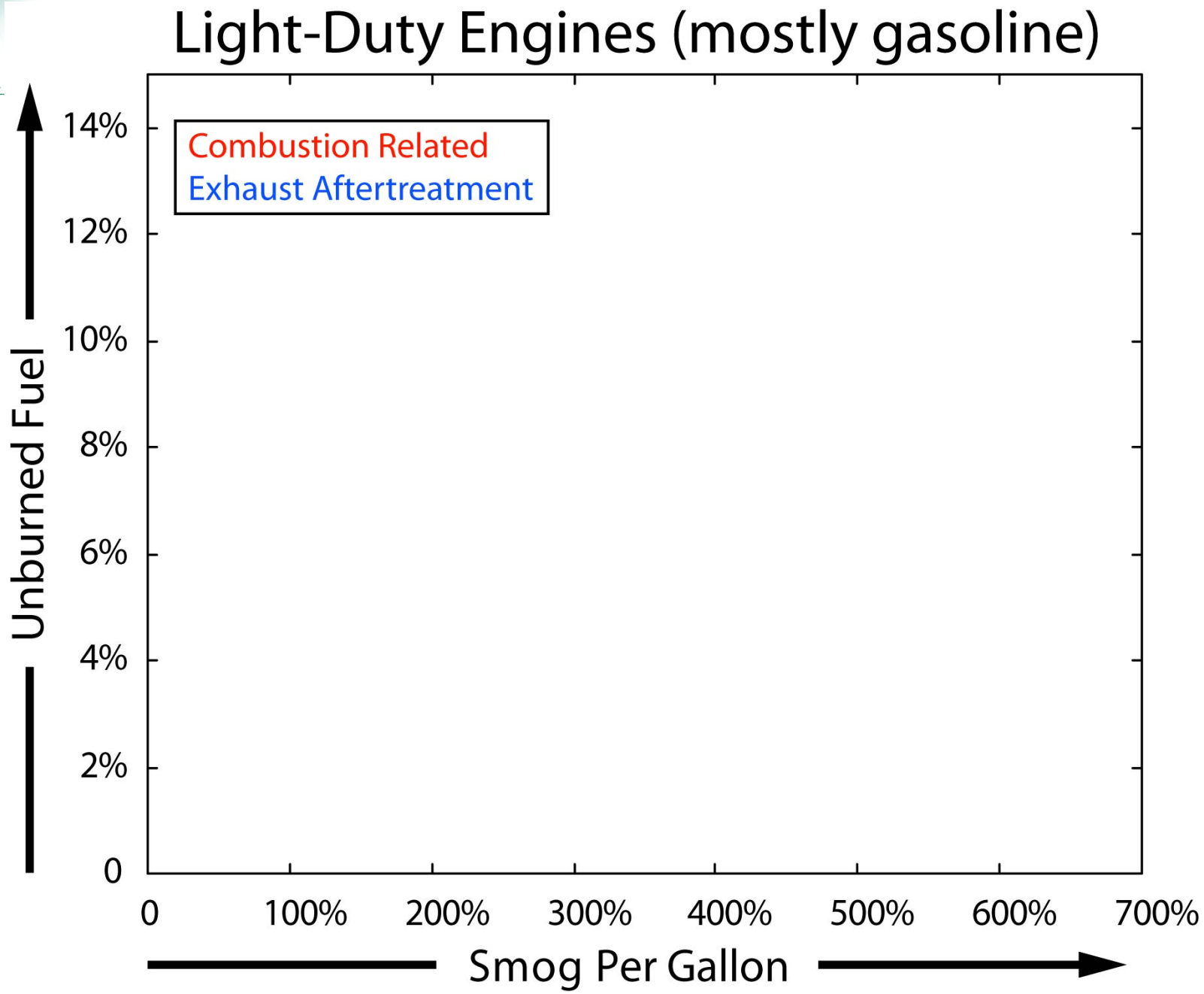


Optically Accessible Heavy-Duty Diesel Engine

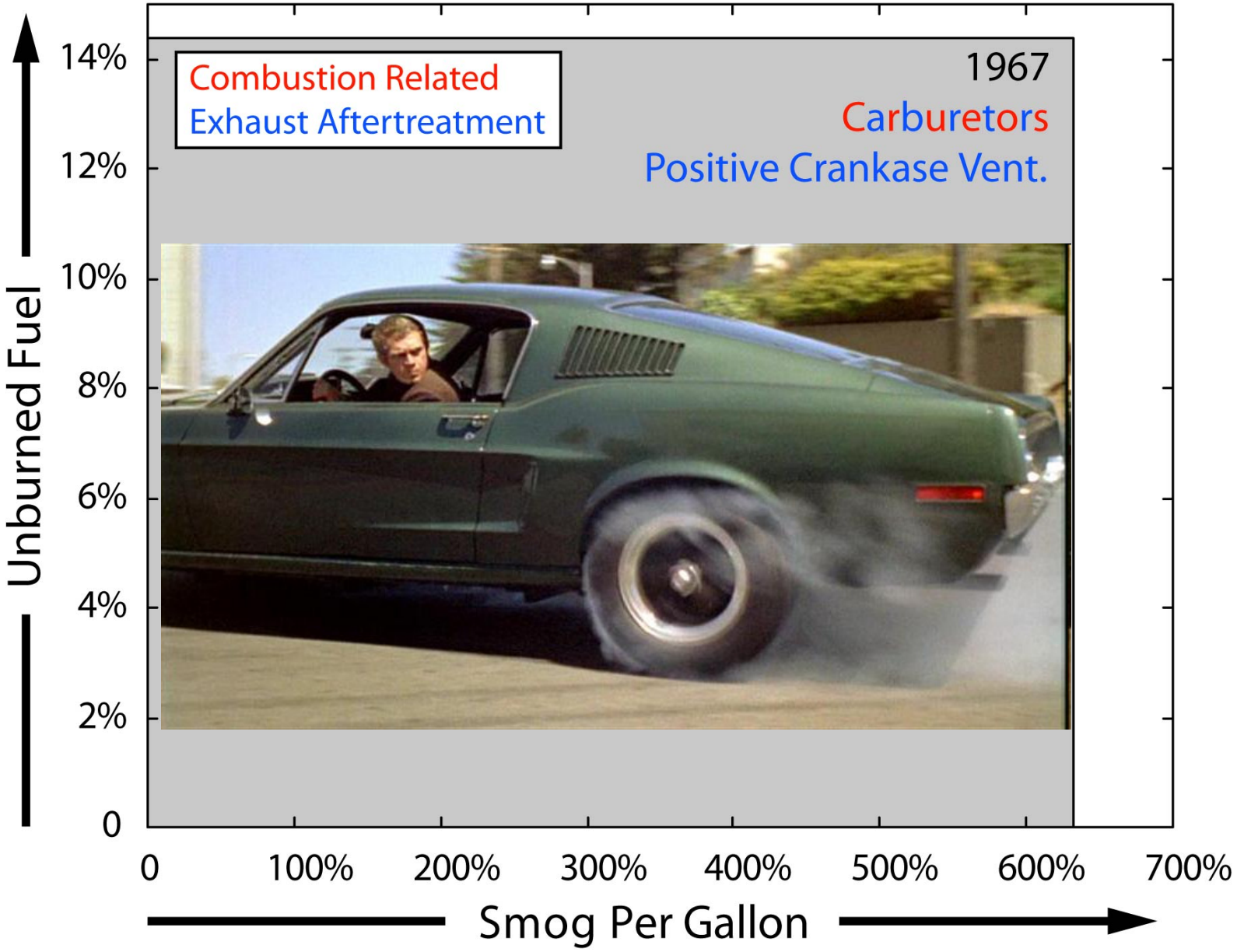




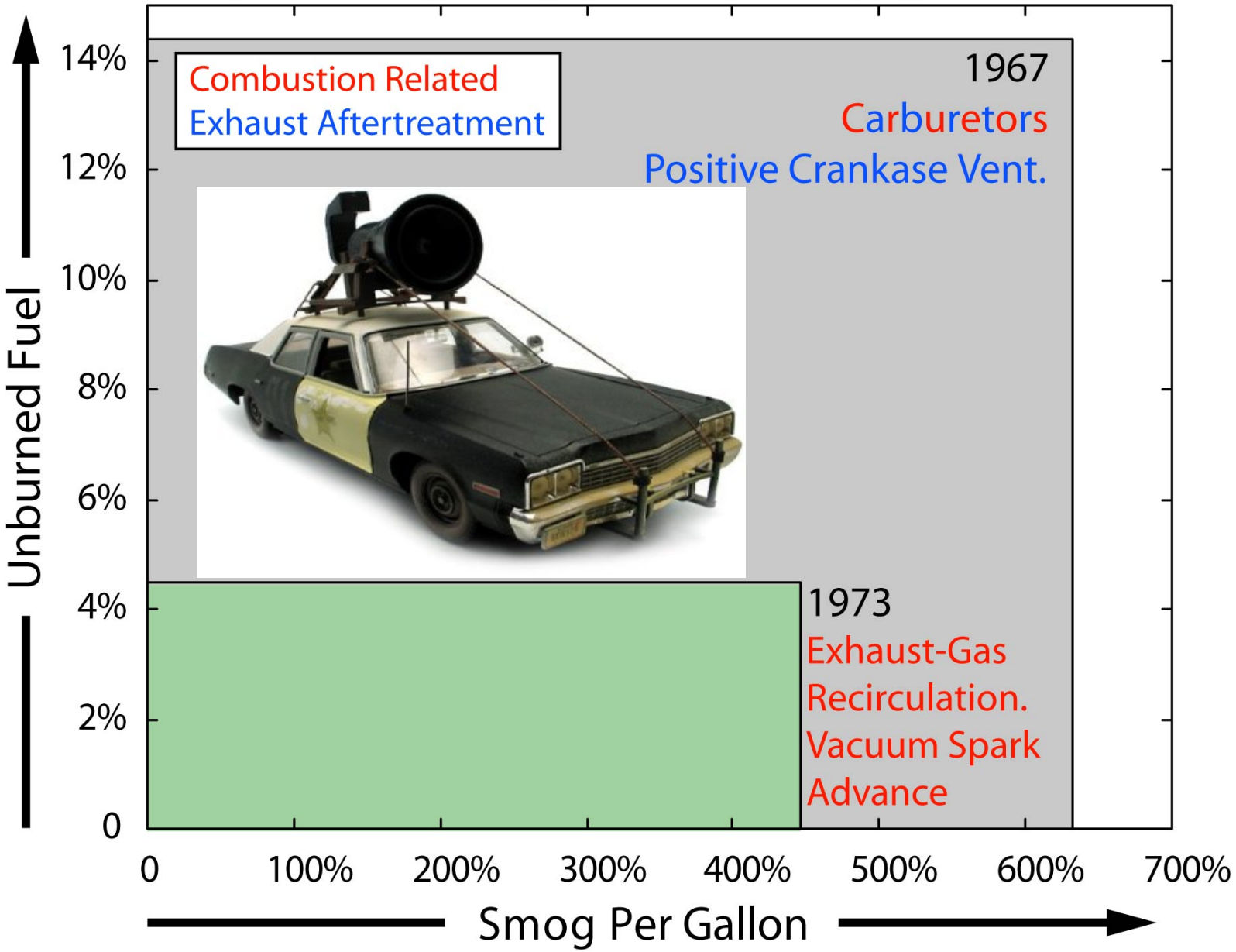



Light-Duty Engines (mostly gasoline)
Combustion Related
Exhaust Aftertreatment
Unburned Fuel
14%
12%
10%
8%
6%
4%
2%
0
0
100%
200%
300%
400%
500%
600%
700%
Smog Per Gallon

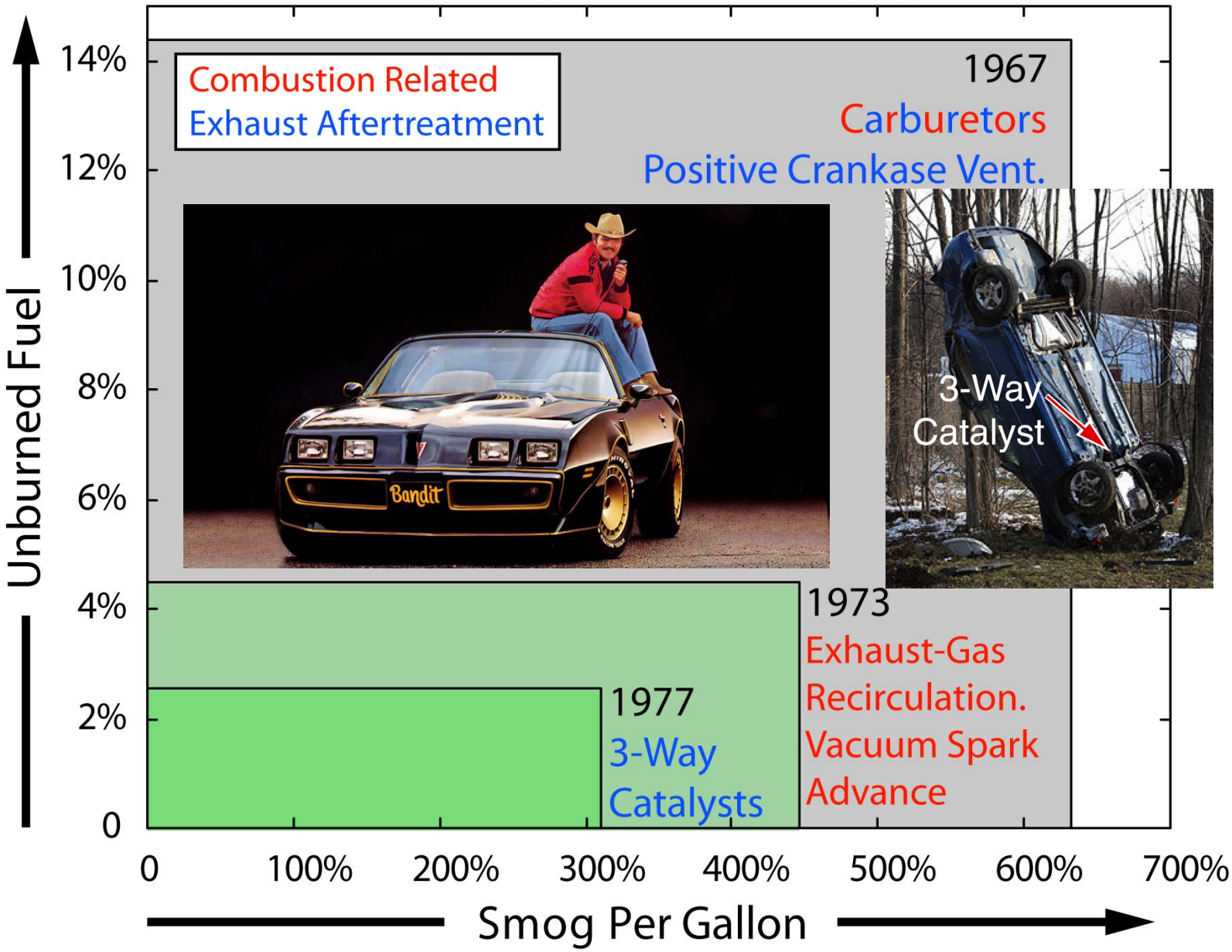
Light-Duty Engines (mostly gasoline)

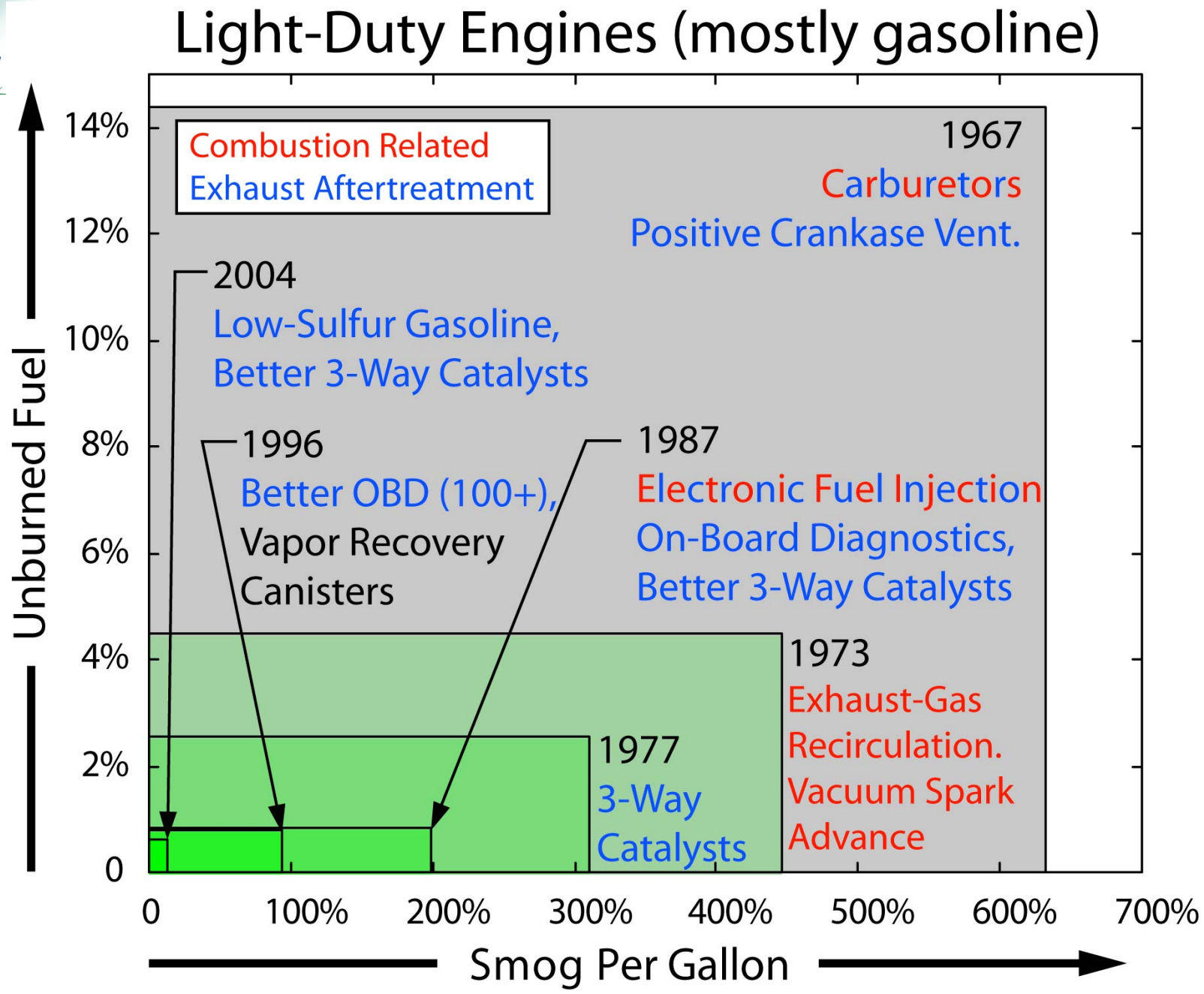


Light-Duty Engines (mostly gasoline)

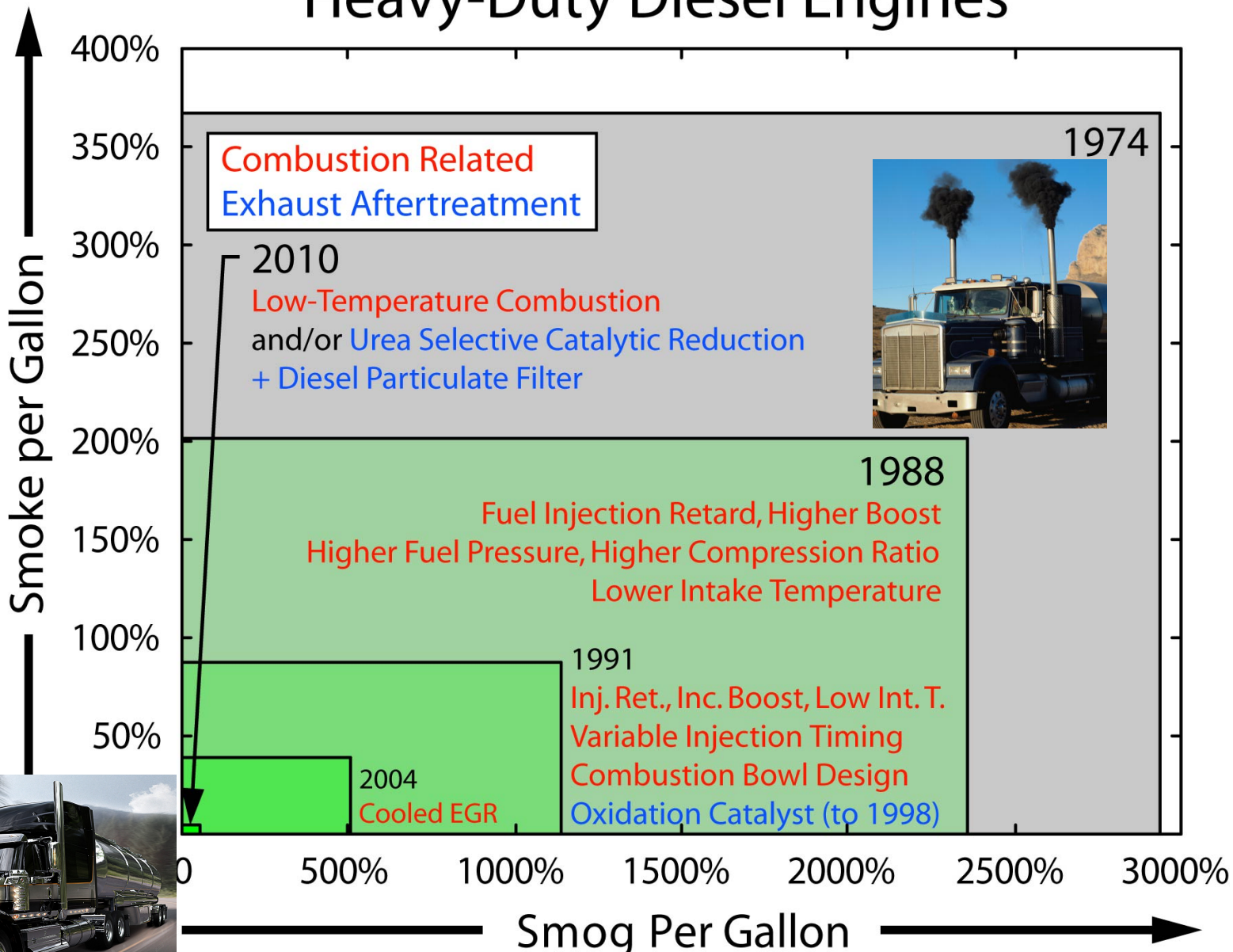


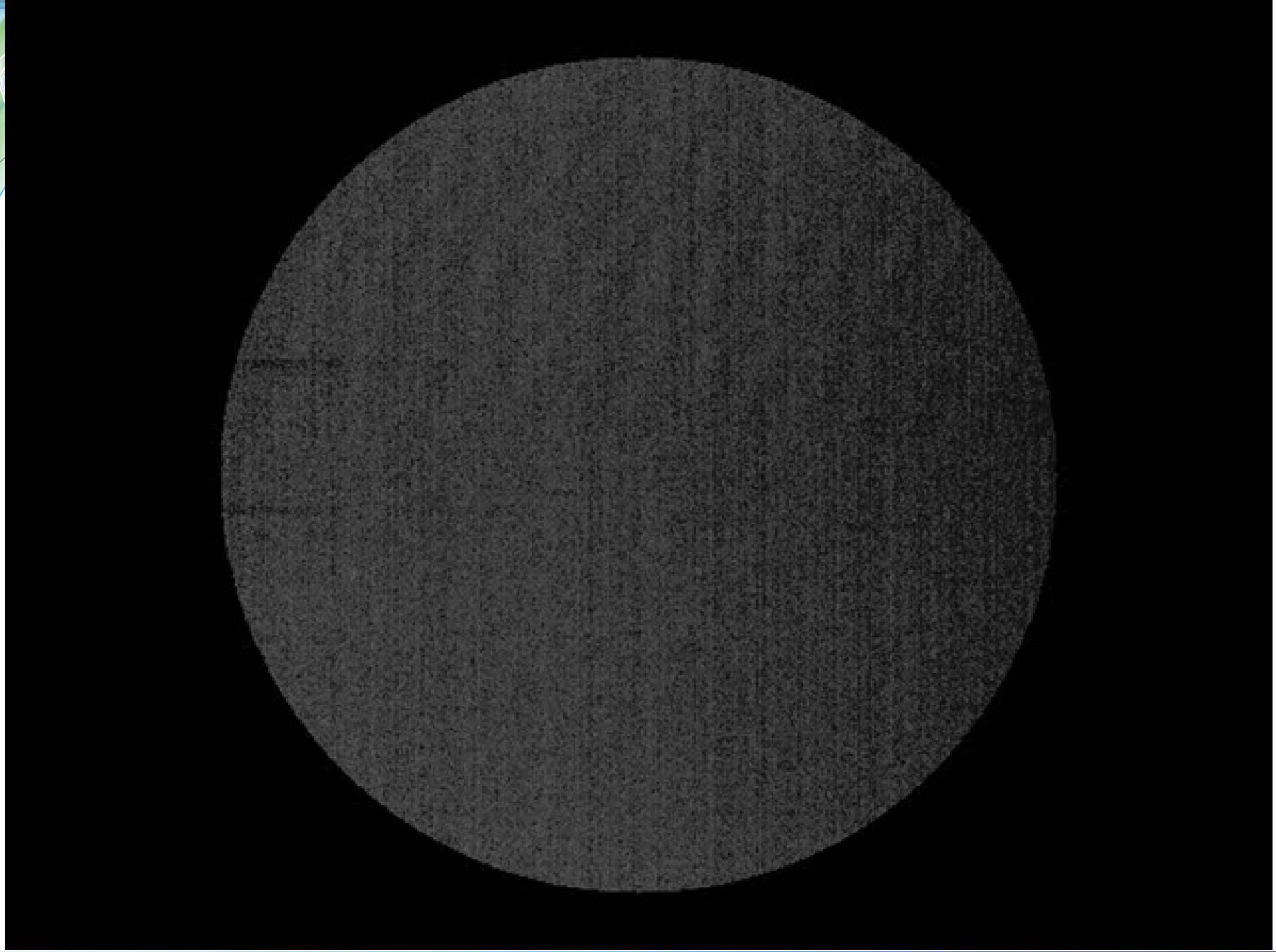
Light-Duty Engines (mostly gasoline)



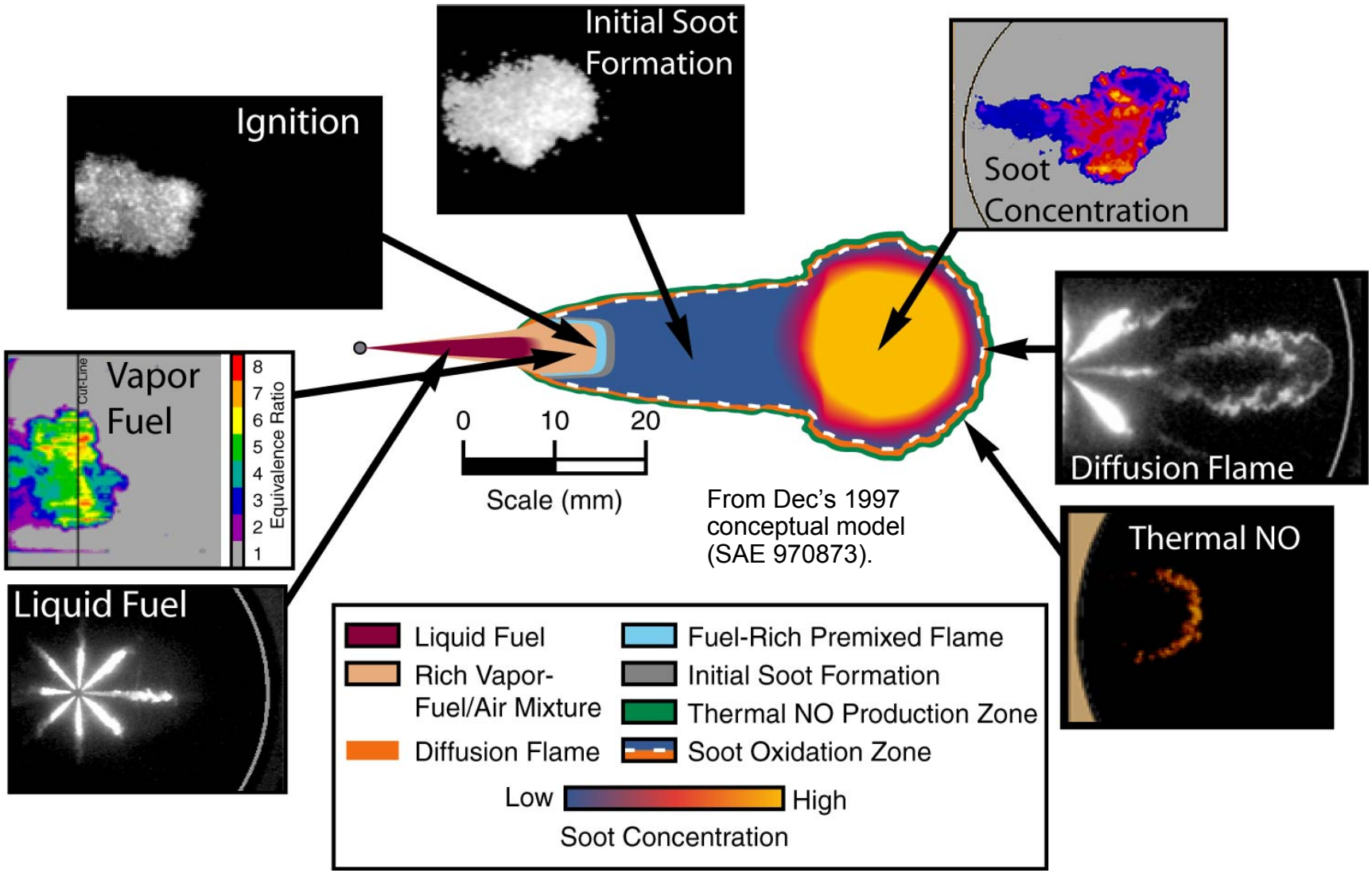

Light-Duty Engines (mostly gasoline)
Unburned Fuel
14%
12%
10%
8%
6%
4%
2%
0
Combustion Related
Exhaust Aftertreatment
1967
Carburetors
Positive Crankase Vent.
2004
Low-Sulfur Gasoline,
Better 3-Way Catalysts
1996
Better OBD (100+),
Vapor Recovery
Canisters
1987
Electronic Fuel Injection
On-Board Diagnostics,
Better 3-Way Catalysts
1973
Exhaust-Gas
Recirculation.
Vacuum Spark
Advance
1977
3-Way
Catalysts
0
100%
200%
300%
400%
500%
600%
700%
Smog Per Gallon

Heavy-Duty Diesel Engines

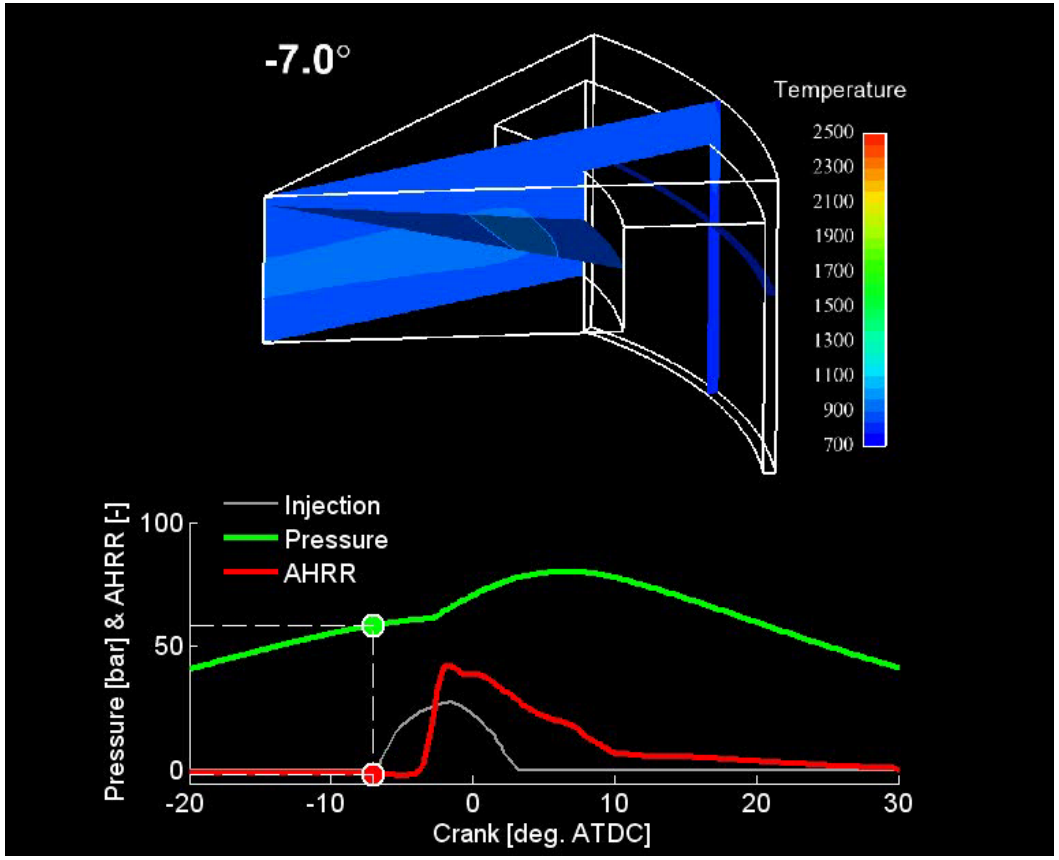


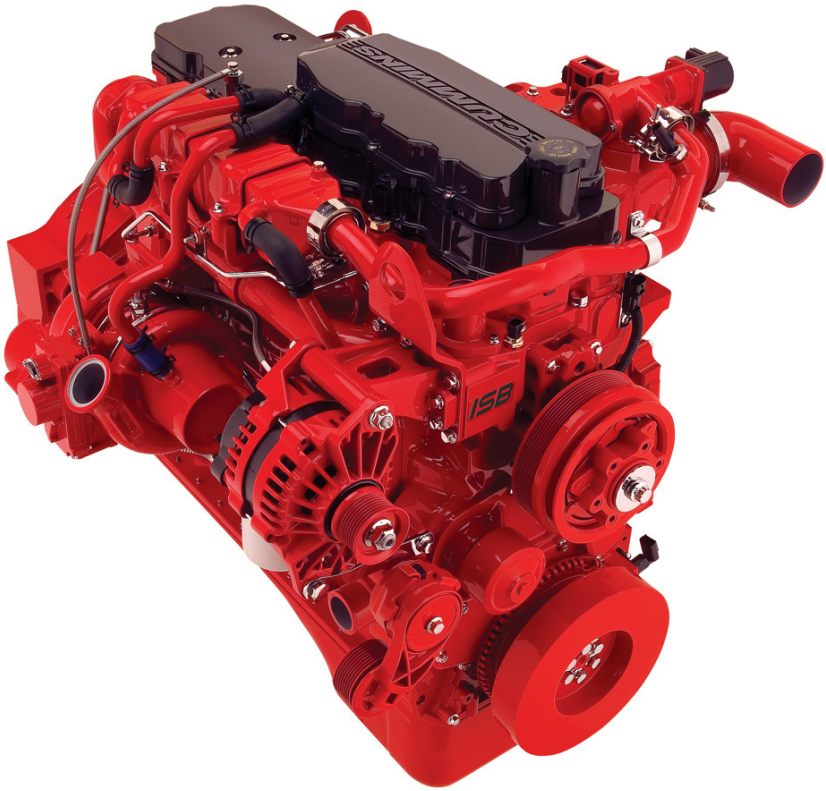


Laser diagnostics of diesel combustion (John Dec and coworkers)



Cummins 2007 ISB Engine
(computer designed, testing only after build)





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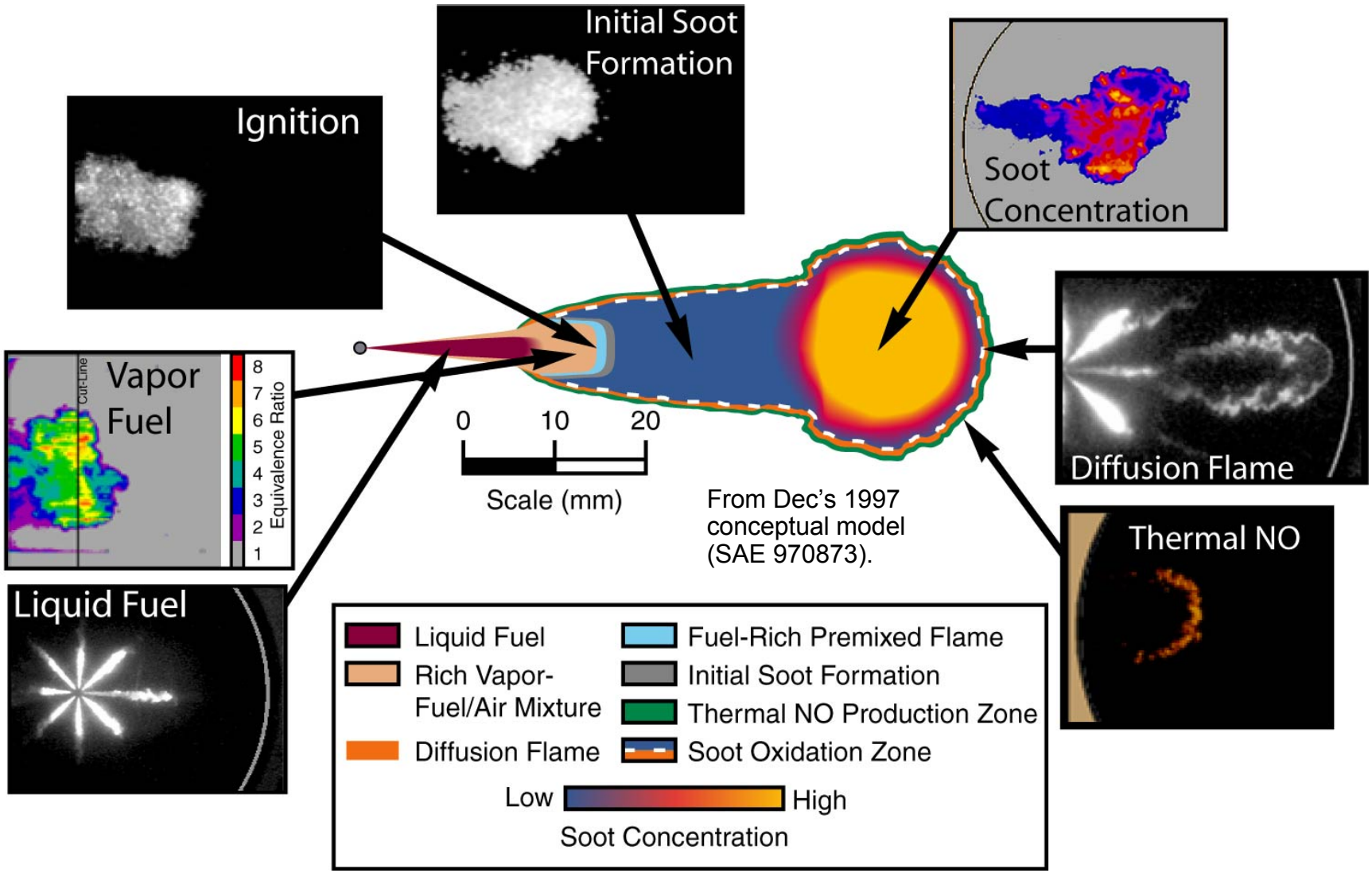
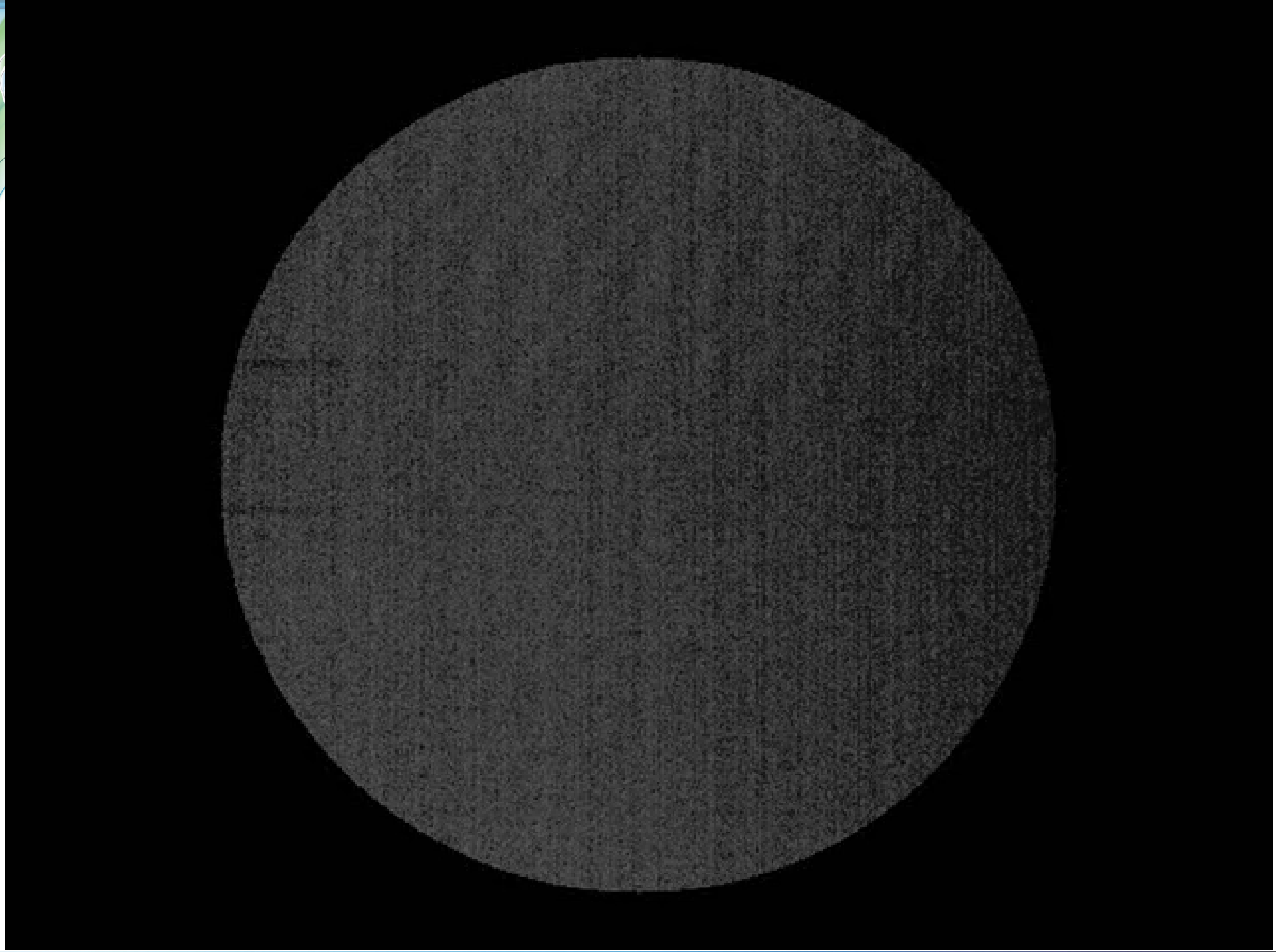
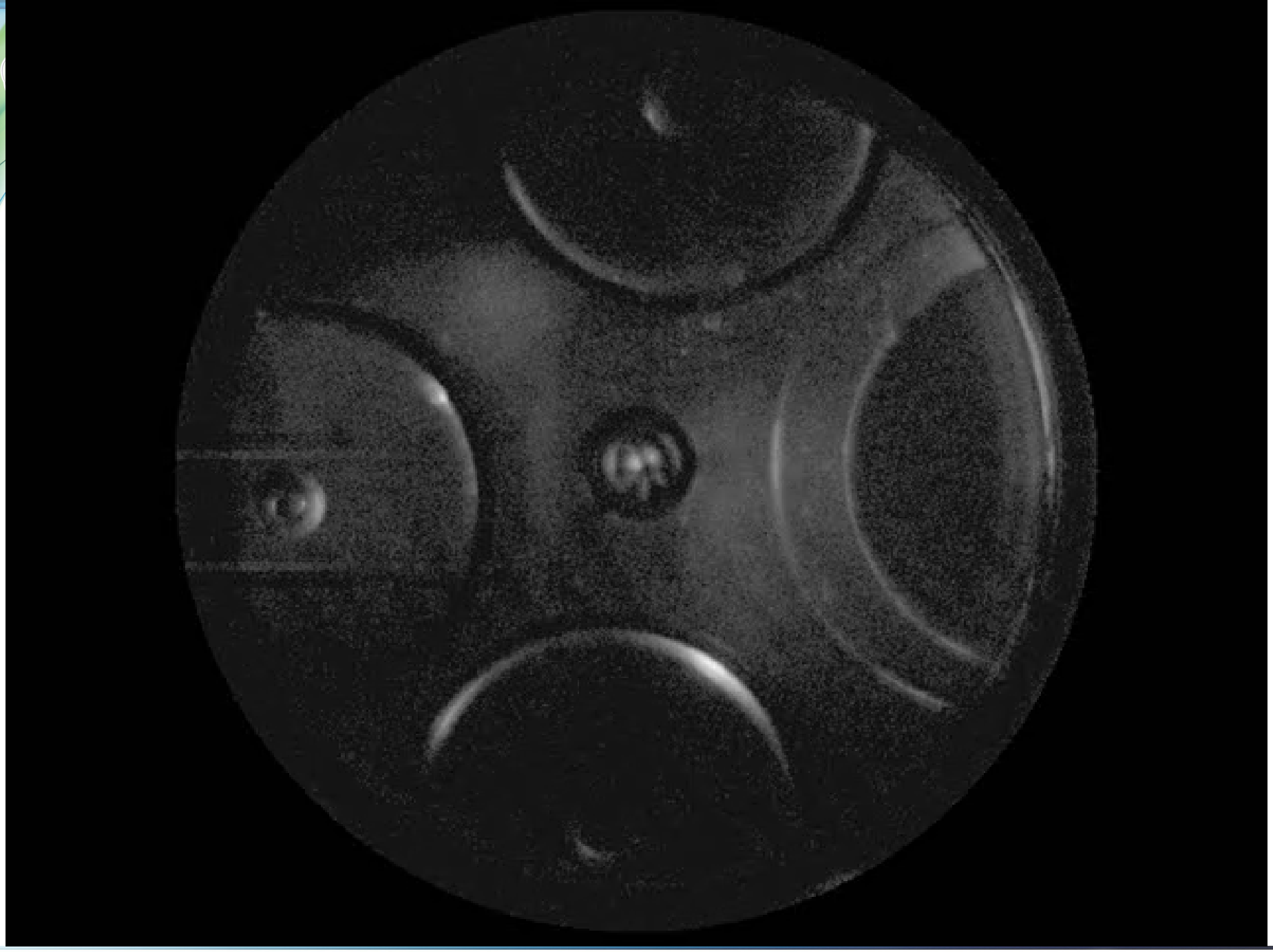
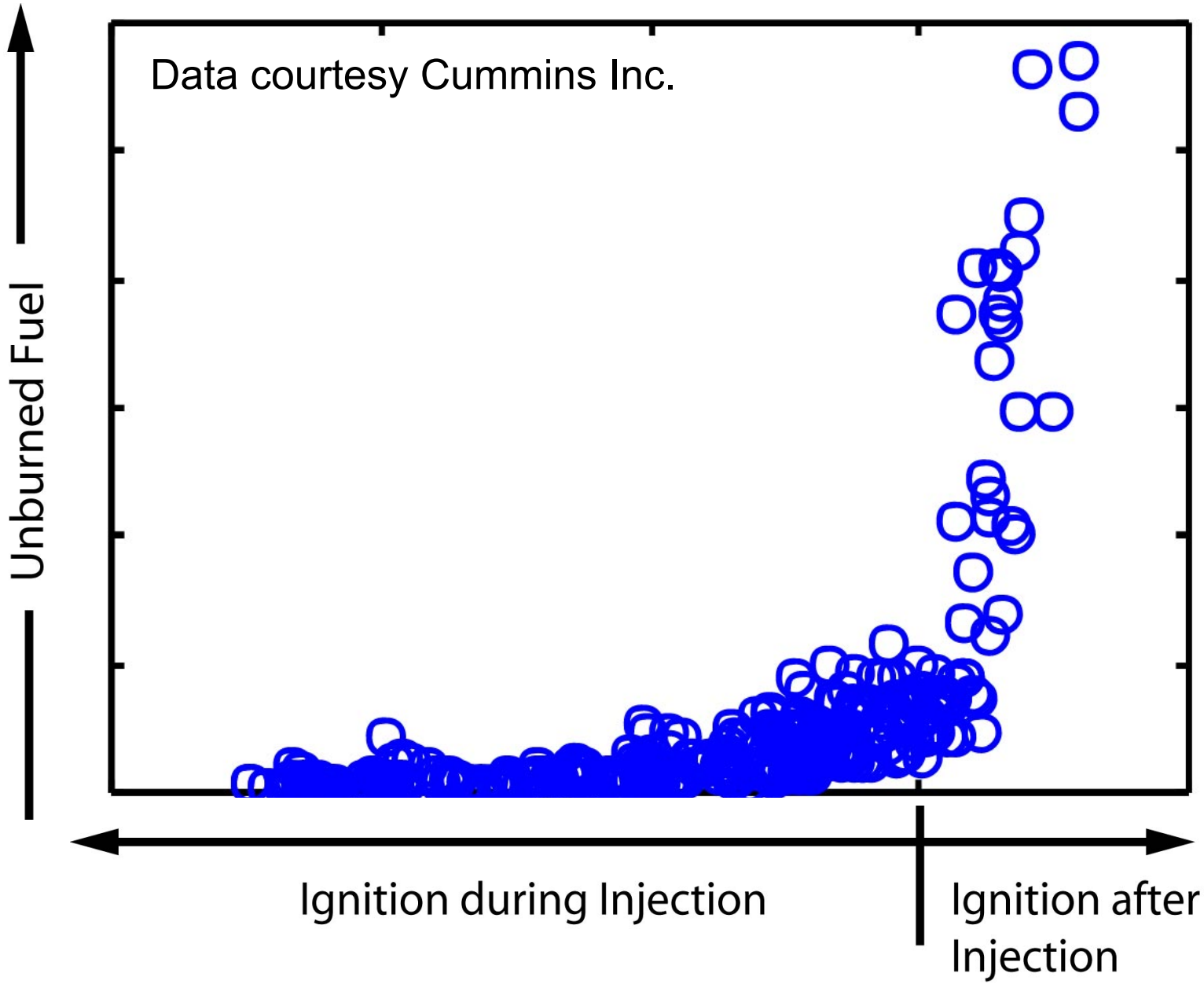
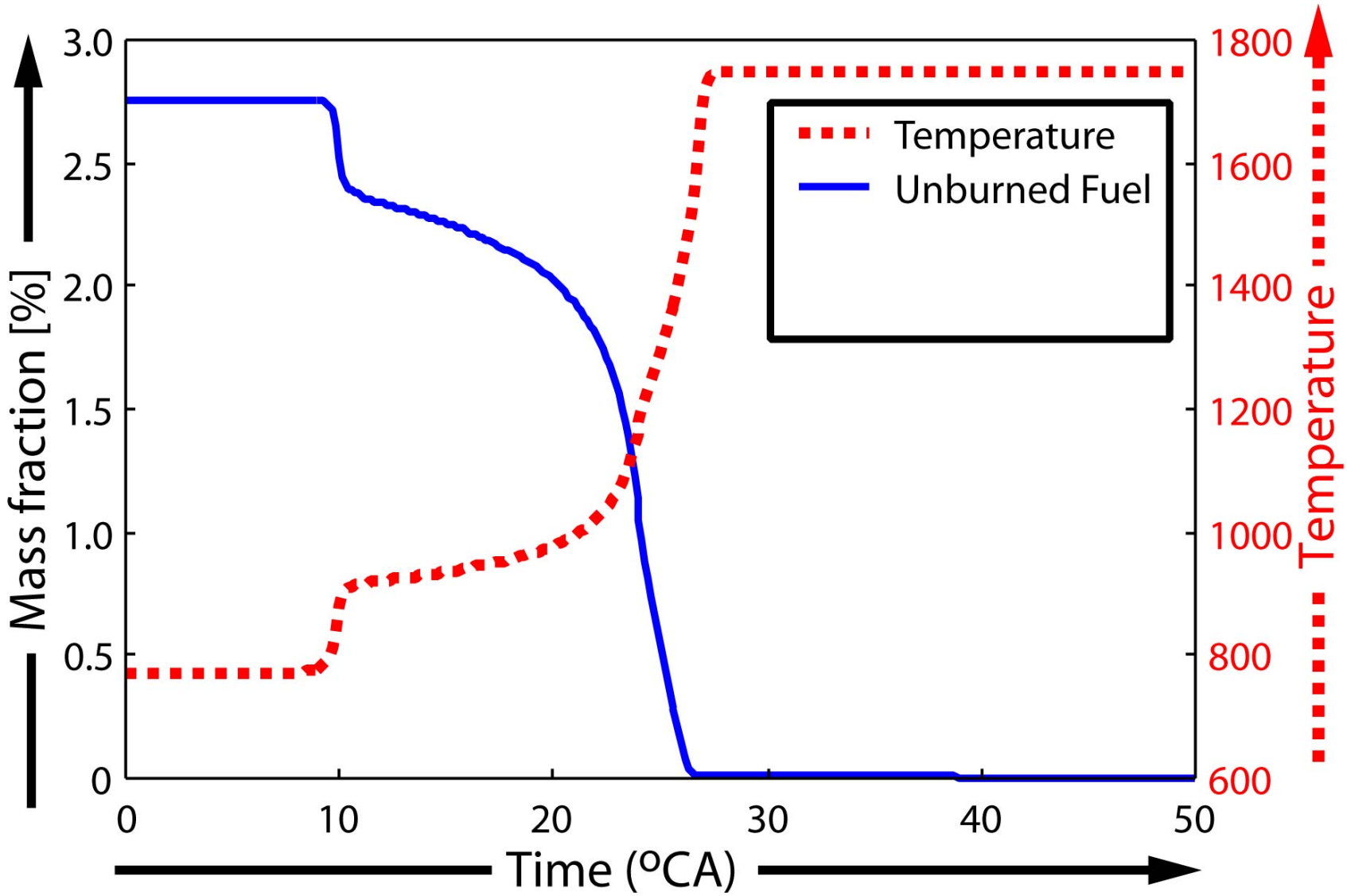




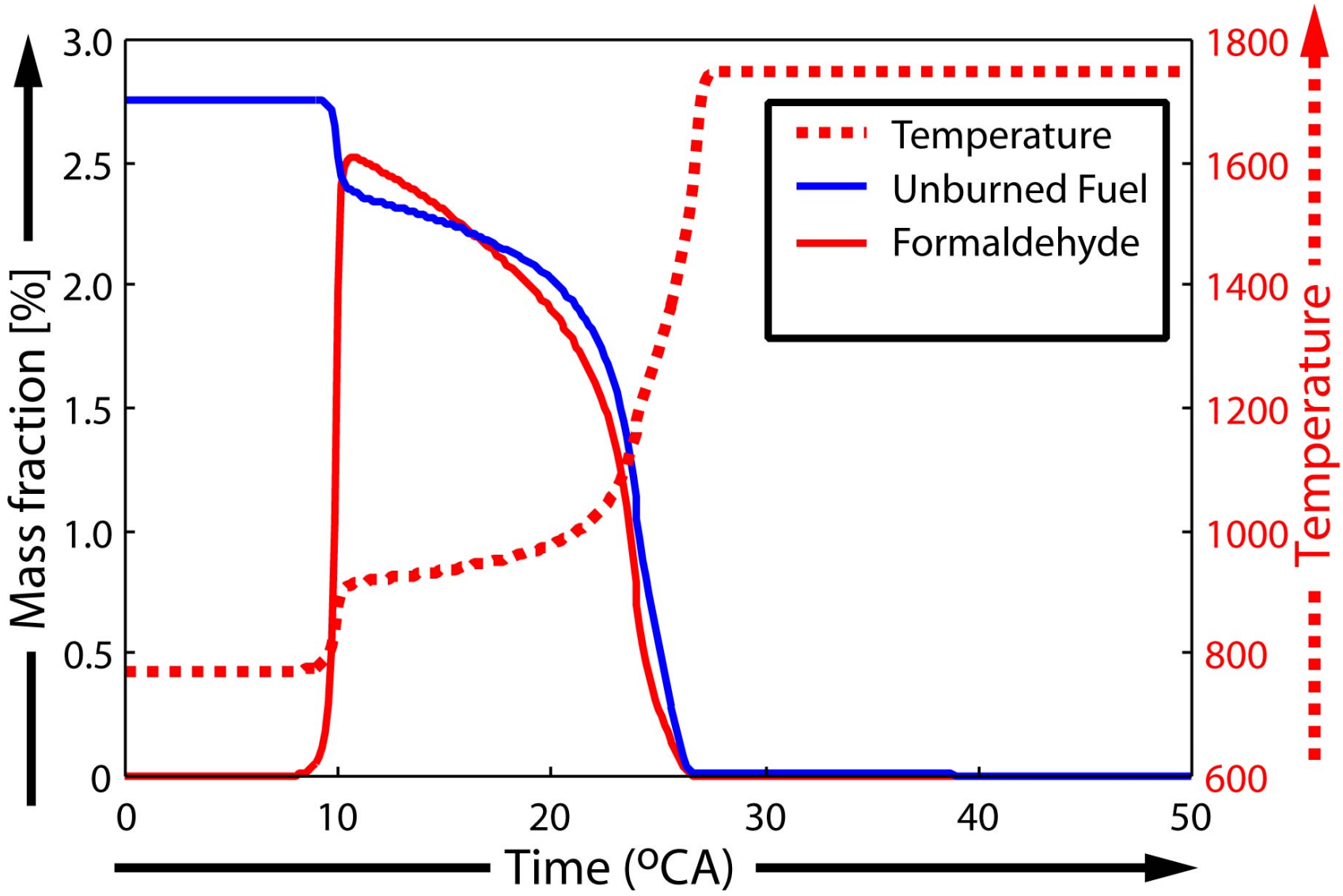



Data courtesy Cummins Inc.
Unburned Fuel
Ignition during Injection
Ignition after Injection

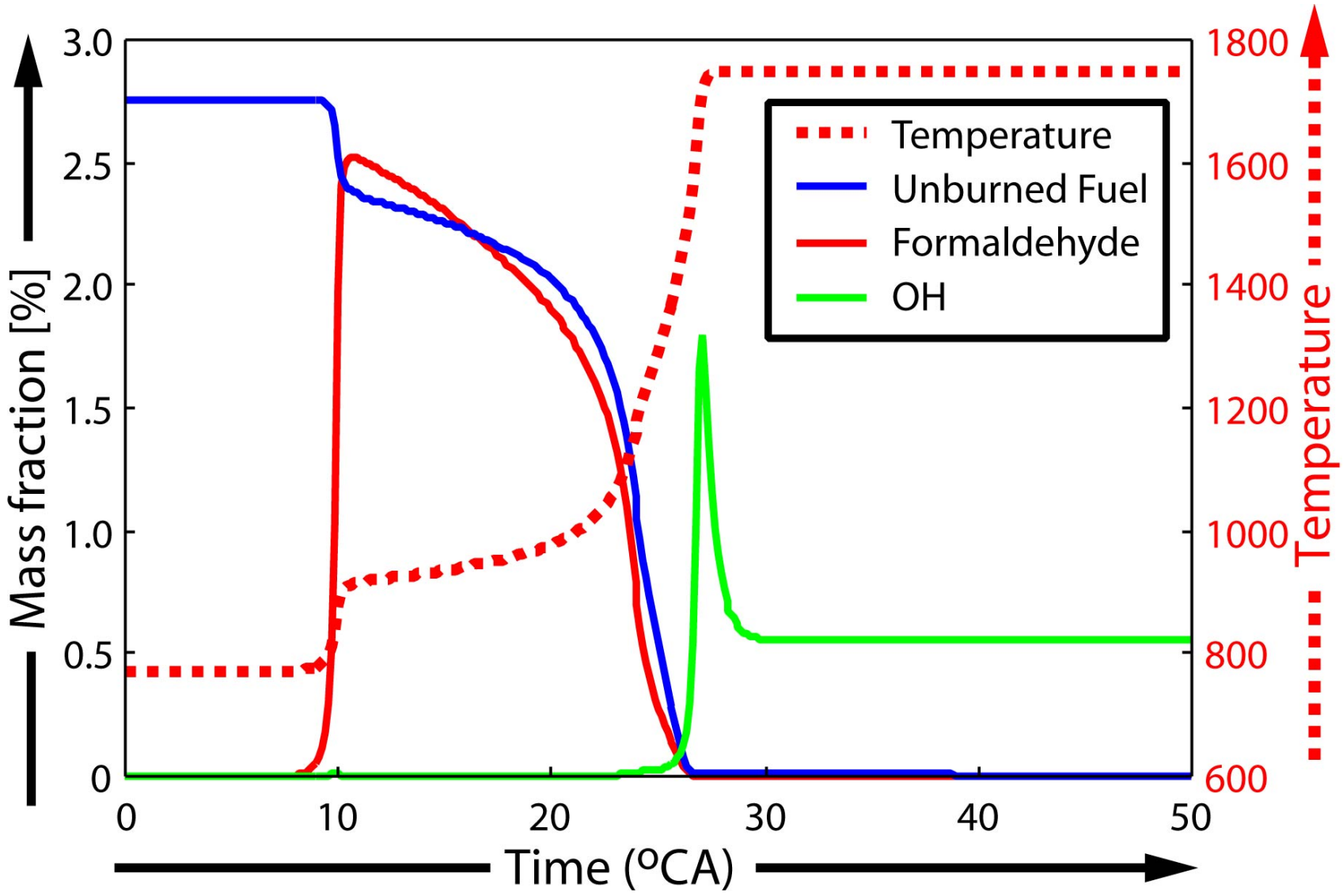
Diesel fuel ignition kinetics (LLNL model)



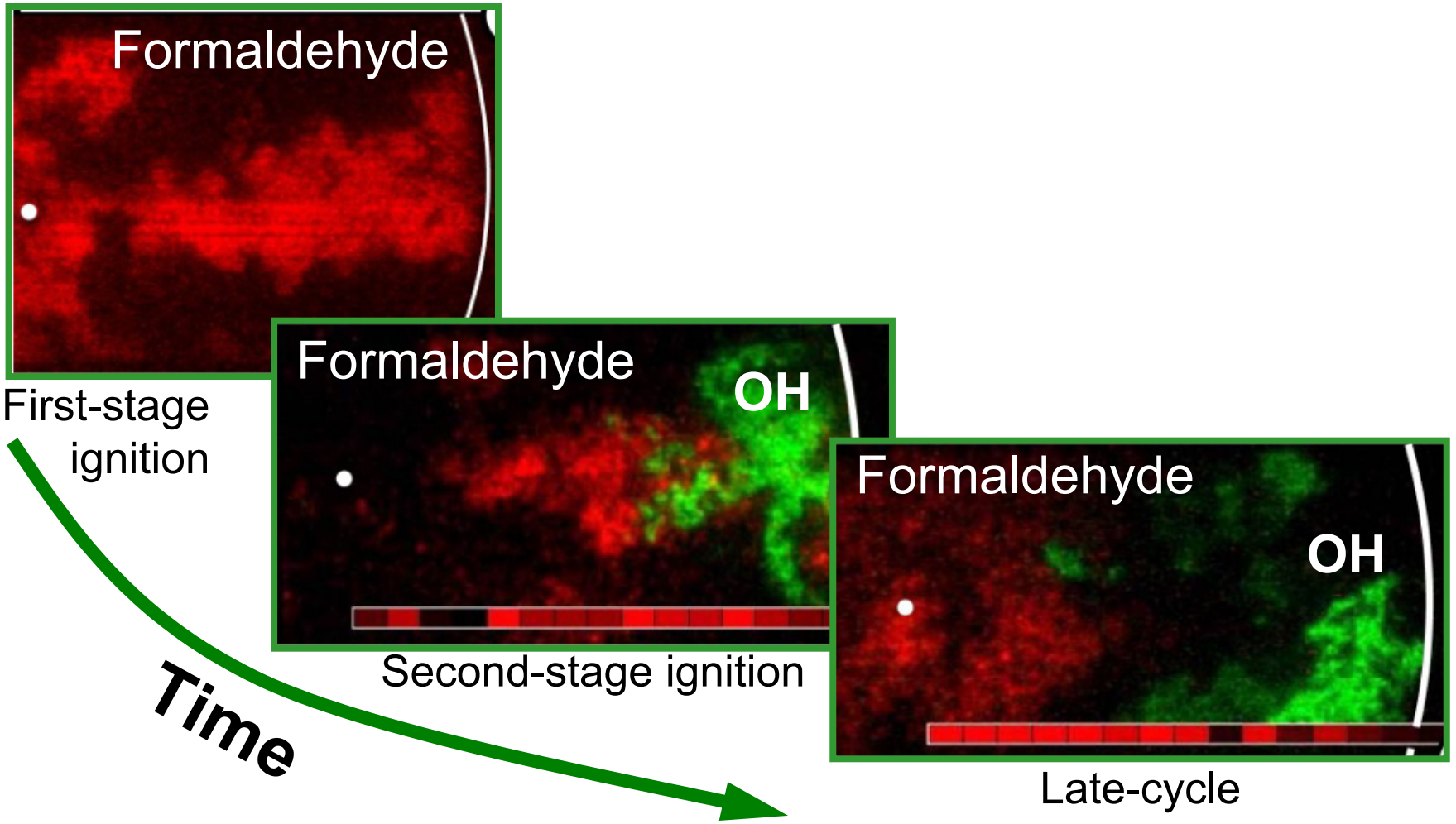
Formaldehyde (CH_2O) marks unburned fuel



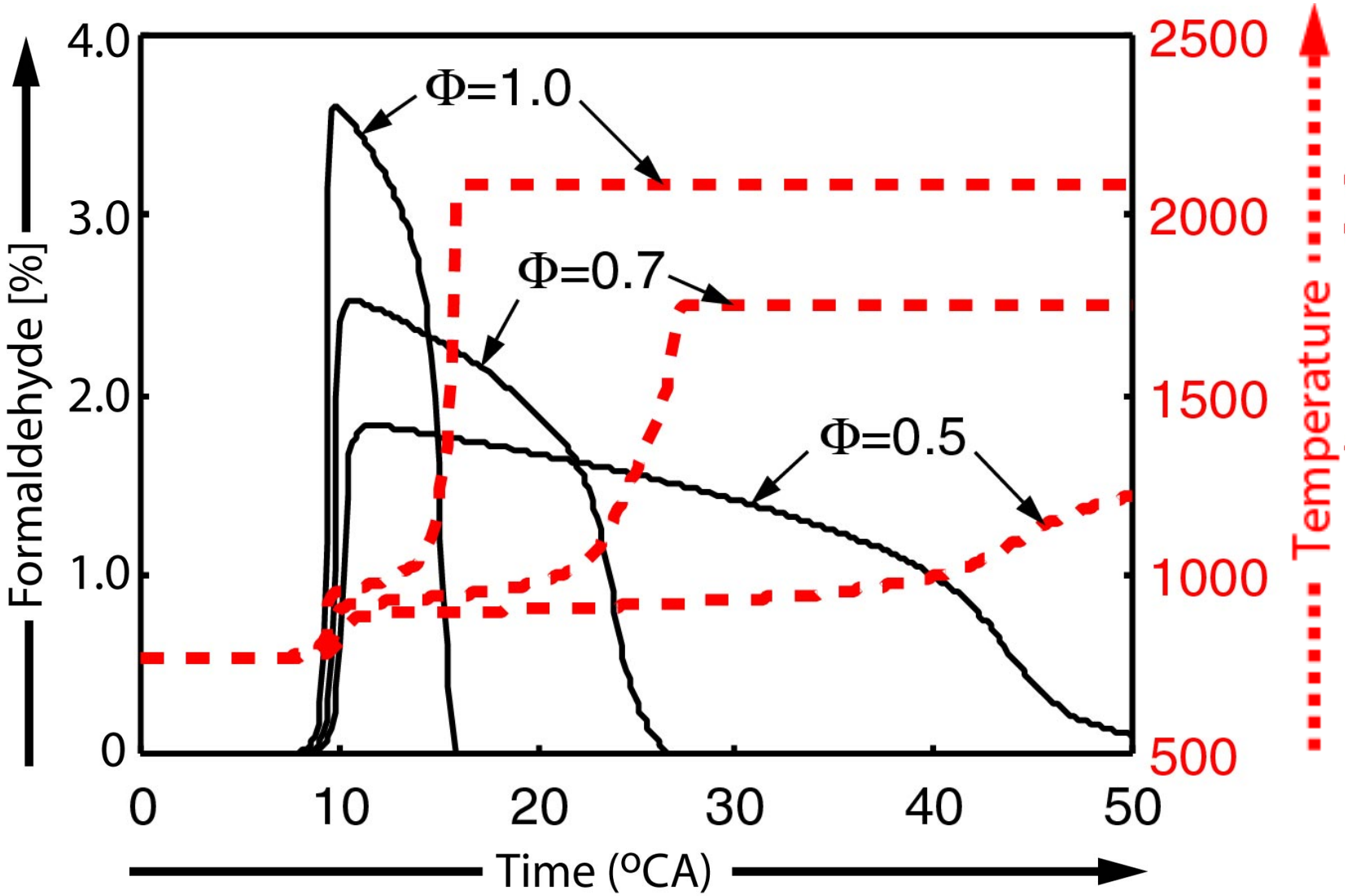
OH appears when unburned fuel is gone



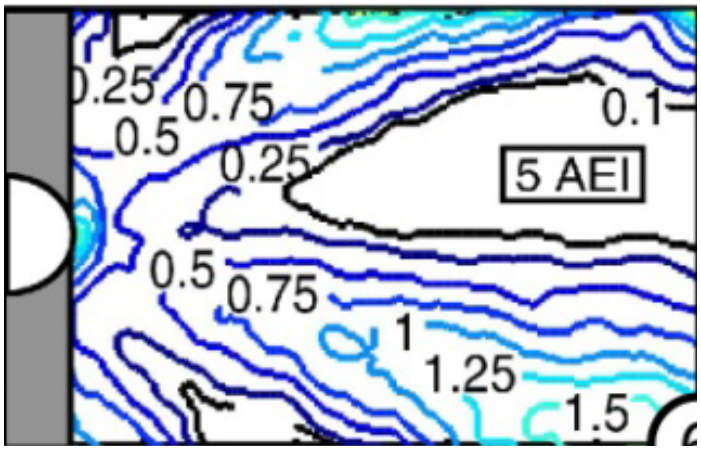
Formaldehyde (unburned fuel) near injector

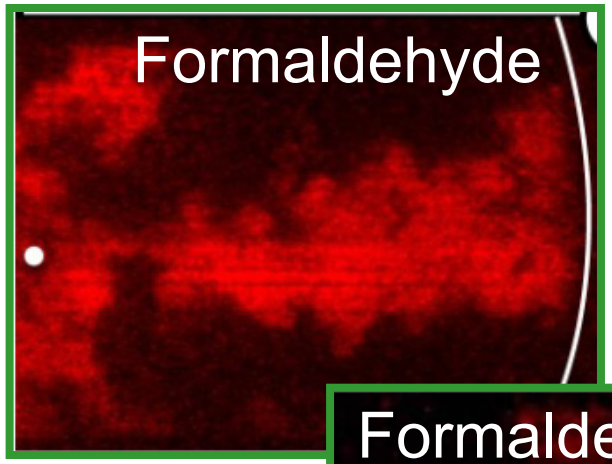


Formaldehyde stays around a long time when mixtures are fuel-lean

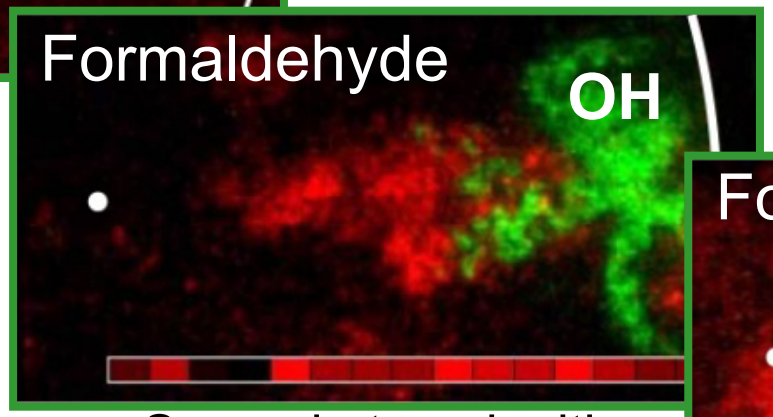


Fuel concentration too low near injector!

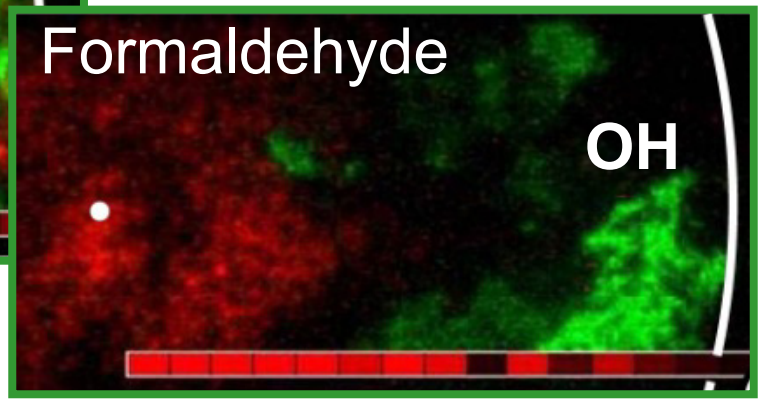




First-stage ignition



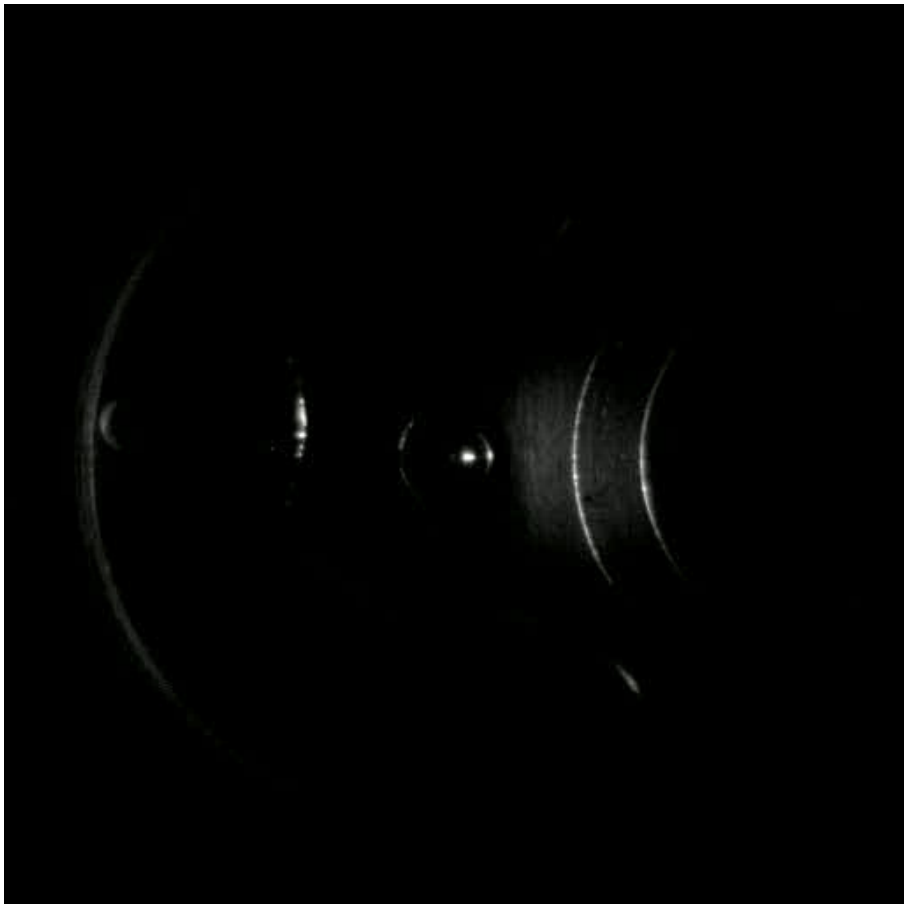
Second-stage ignition



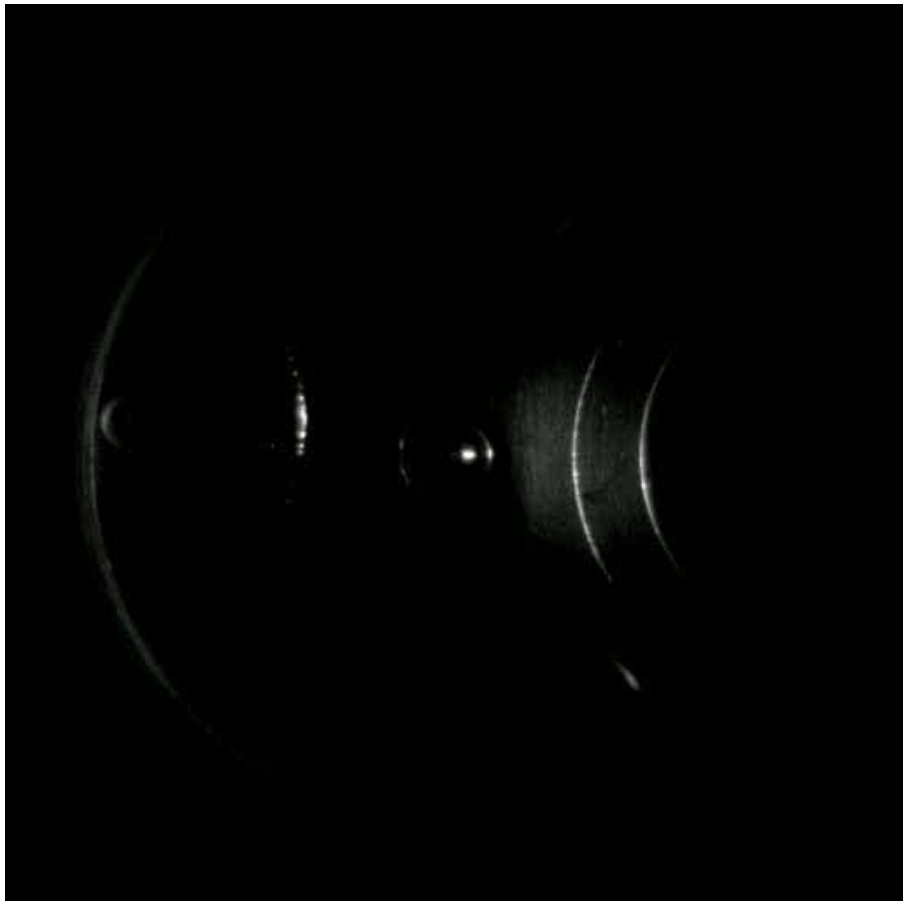
Late-cycle

Time

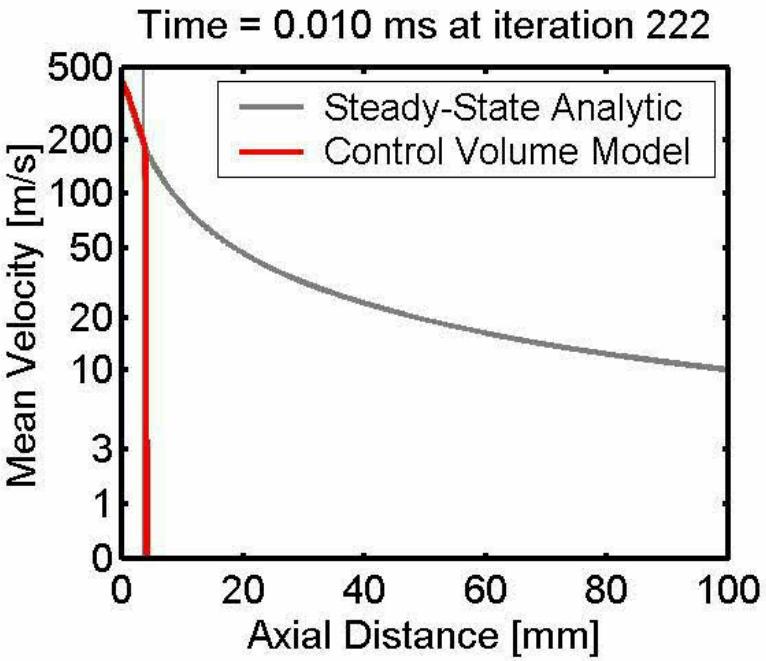
Single Injection

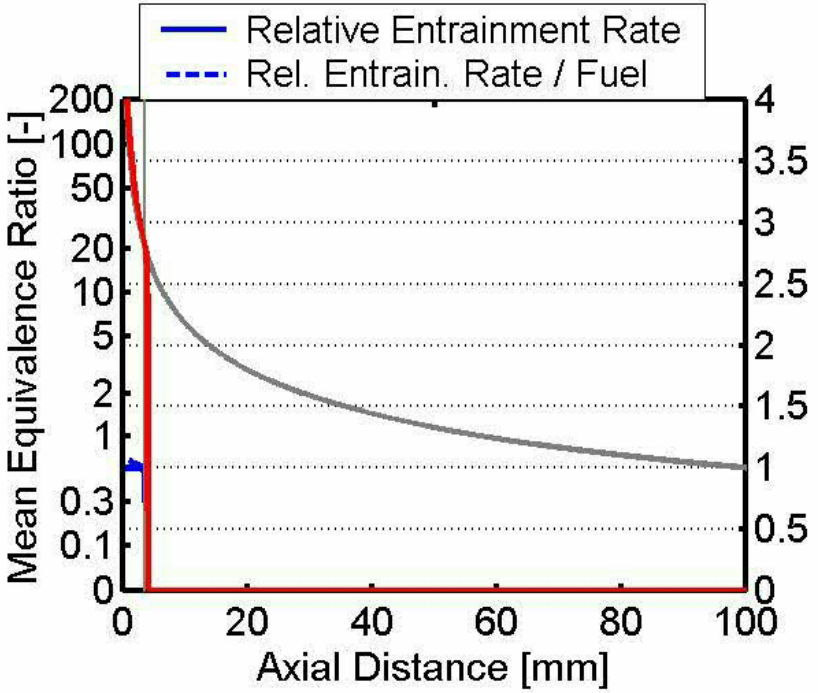


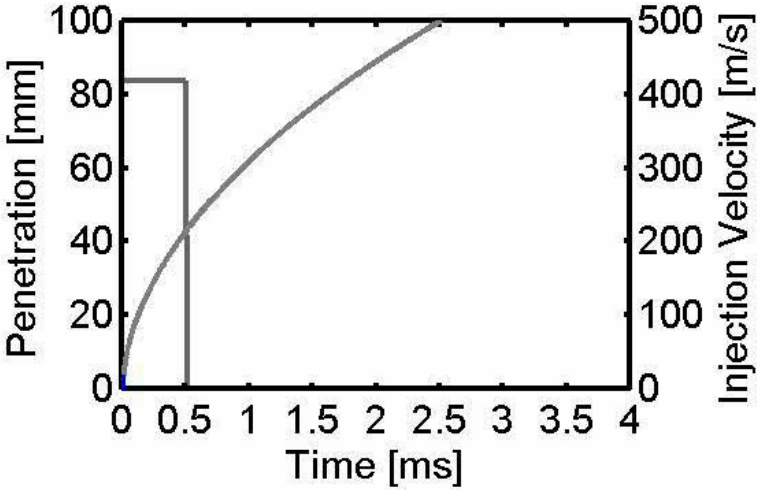
Single+Post Injection

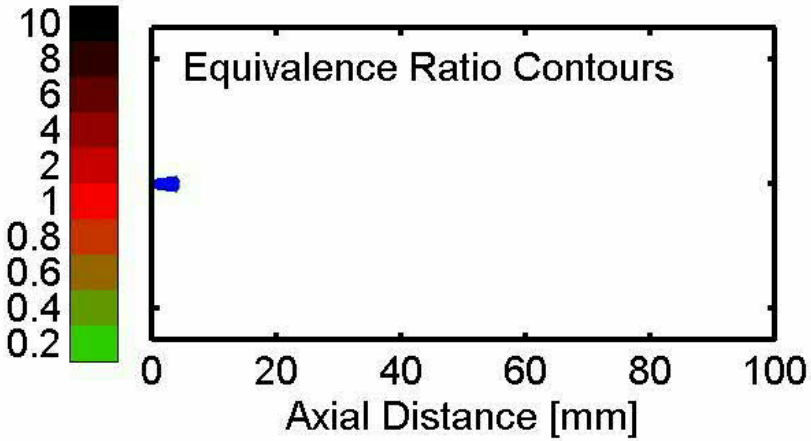


1-D jet model


Time = 0.010 ms at iteration 222
Steady-State Analytic
Control Volume Model
Mean Velocity [m/s]
500
200
100
50
20
10
3
1
0
0
20
40
60
80
100
Axial Distance [mm]


Relative Entrainment Rate
Rel. Entrain. Rate / Fuel
Mean Equivalence Ratio [-]
200
100
50
20
10
5
2
1
0.3
0.1
0
4
3.5
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
Axial Distance [mm]

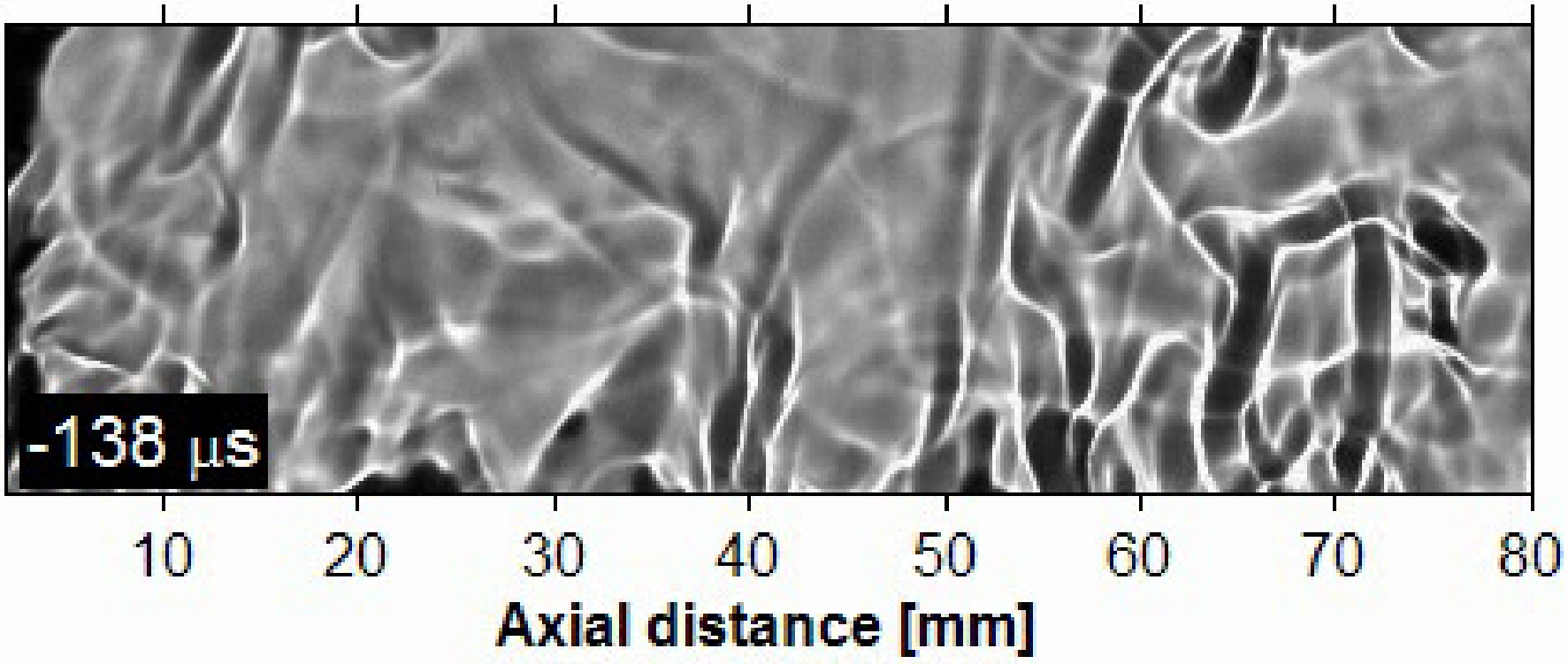

Penetration [mm]
100
80
60
40
20
0
500
400
300
200
100
0
Injection Velocity [m/s]
0 0.5 1 1.5 2 2.5 3 3.5 4
Time [ms]


Equivalence Ratio Contours
10
8
6
4
2
1
0.8
0.6
0.4
0.2
0
20
40
60
80
100
Axial Distance [mm]

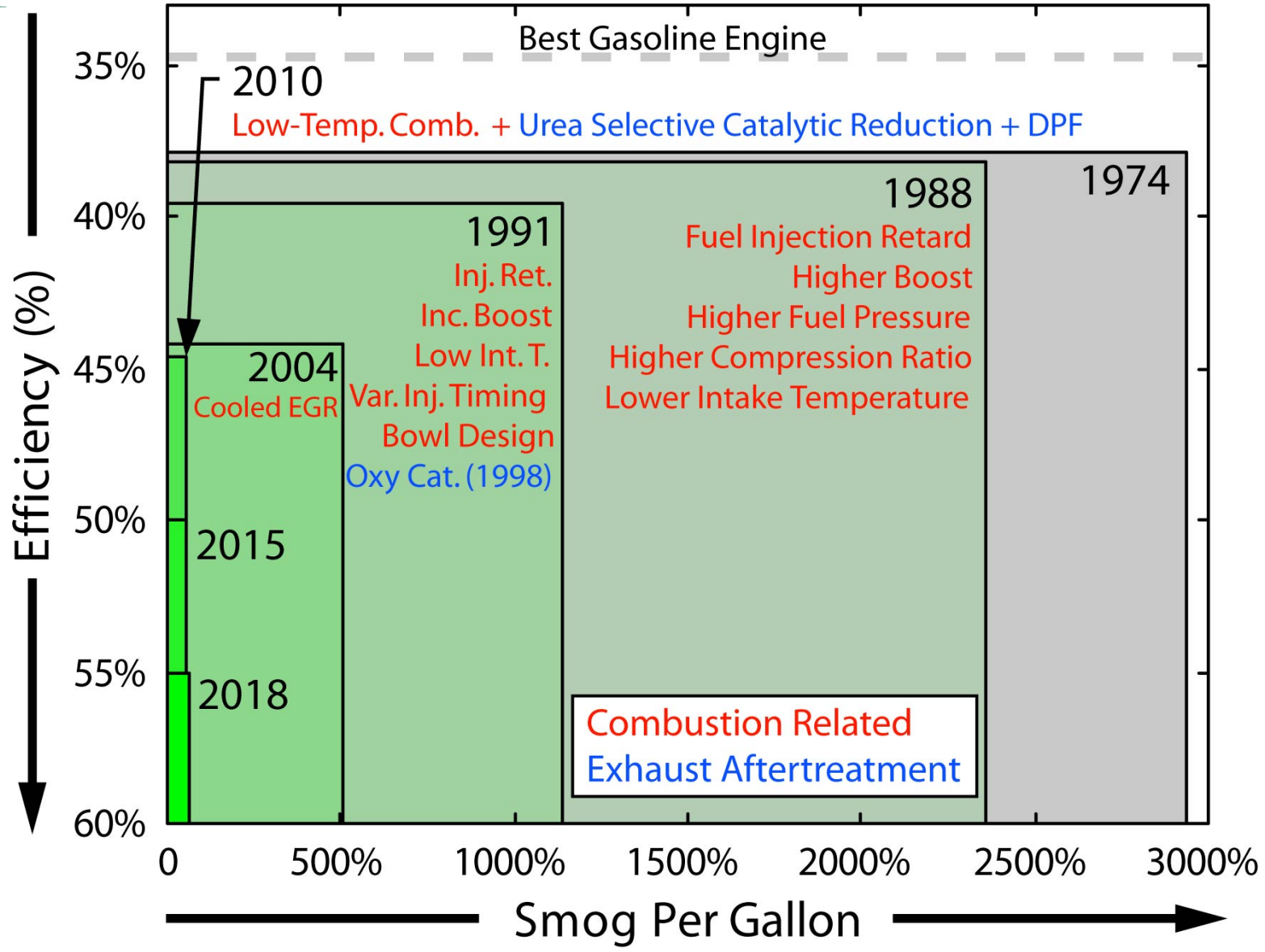
LES air-jet model: λ_2 visualization (Joe Oefelein and Bing Hu)

ms

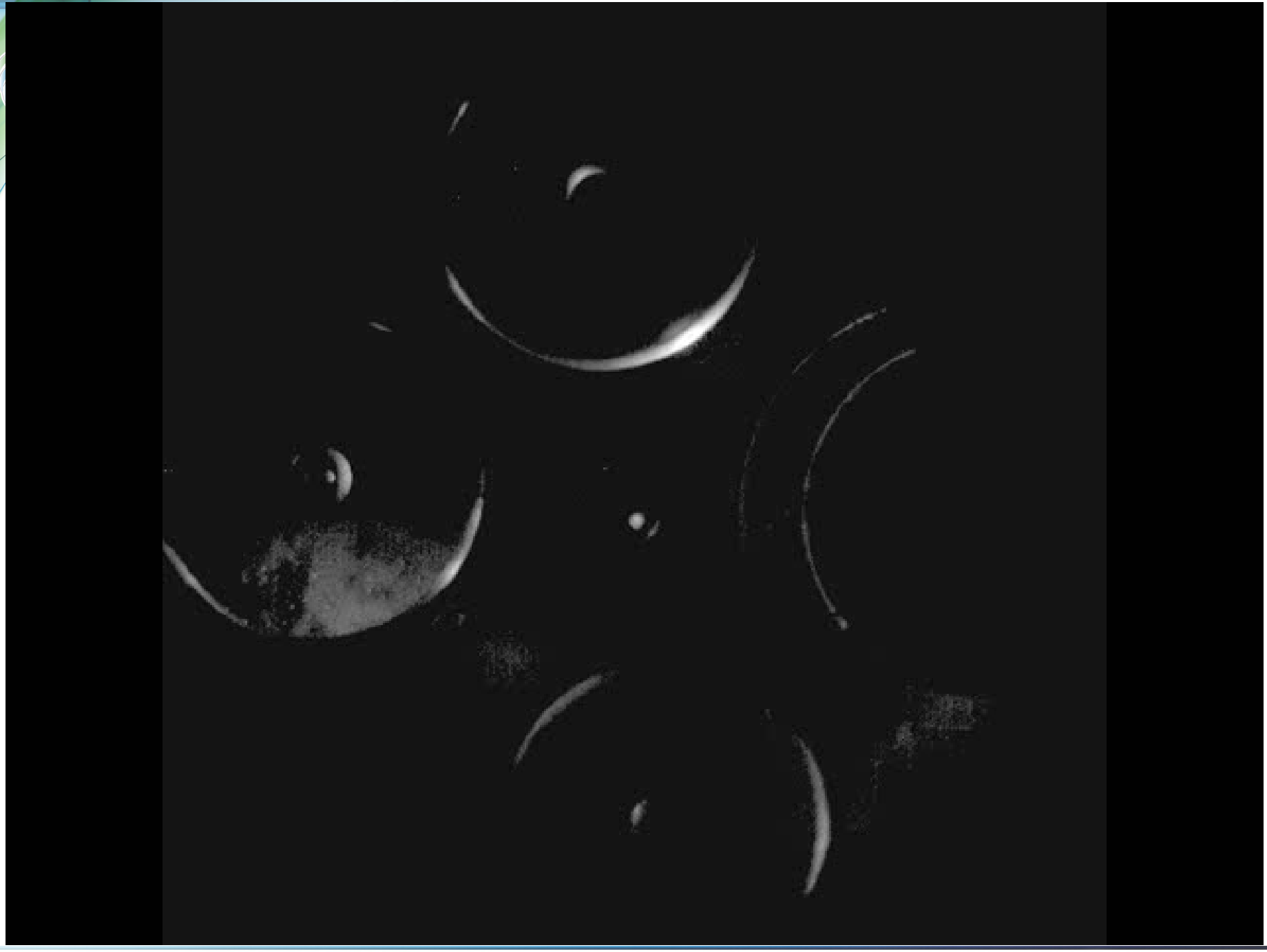
Diesel Shadowgraph (Lyle Pickett and coworkers, available at www.sandia.gov/ecn/)



Heavy-Duty Diesel Engines



$$2NO + (NH_2)_2CO + 1/2O_2 \rightarrow 2N_2 + 2H_2O + CO_2$$



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Non-Sandia or Retired: Mohan Bobba, Jim Boehmke, **Clement Chartier**, Tony Chavez, Lloyd Claytor, April Cunningham, Greg Feichtner, José Maria Garcia, **Caroline Genzale**, Bob Green, Bing Hu, **Eddie Huestis**, Simone Hochgreb, **Kyle Kattke**, Jay Keller, **Sage Kokjohn**, Keith Kuhlengel, Thierry Lachaux, Andy Lutz, Jennie Menns, Bill Pitz, Eldon Porter, Suzie Rexroad, **Francisco Briceño Sanchez**, **Satbir Singh**, Duane Sunnarborg, Dale Tree, Charlie Westbrook, Kathy Yasukawa

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crf.sandia.gov *or Google "Combustion Research Facility"*