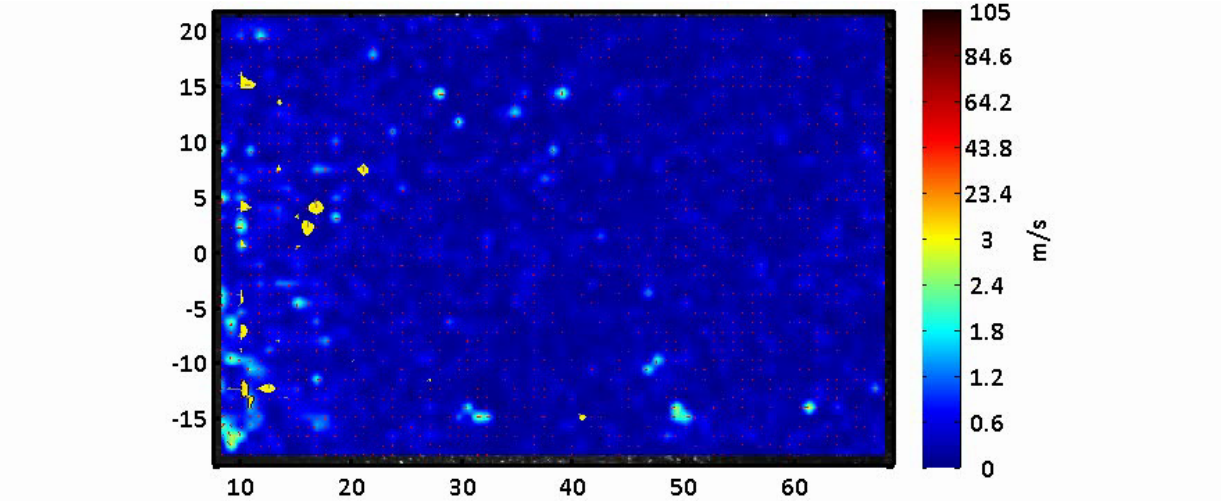
Welcome to ECN2:
Engine Combustion Network
Second Workshop

7-8 September 2012

Heidelberg, Germany



What is the Engine Combustion Network?

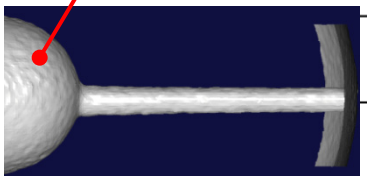
see www.sandia.gov/ECN

- An internet library for data storage intended to be used for CFD model improvement and validation.
  - Detailed boundary condition data and results, consolidated from multiple papers, years of research, available online.
- An experimental and modeling collaboration dedicated to improving understanding and predictive capability of engine/spray CFD models.
- Voluntary cooperative, not a funding agency.
  - But please use the idea to attract support for ECN work from your sponsor!

ECN research involves specific target conditions. Why?

Injector

90 C, 1500 bar

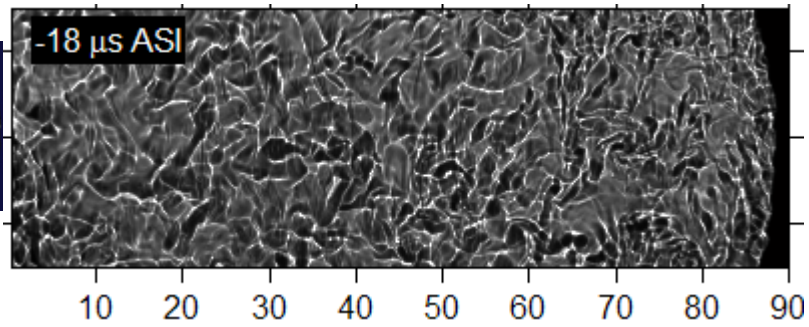


Internal nozzle geometry

Ambient

900 K, 60 bar

Spray A



Other defined targets:

- Spray H (baseline n-heptane)
- Spray B (3-hole version of Spray A).
- Gasoline and engine targets TBD.

- Opportunity for the greatest exchange and deepest collaboration.
  - Understanding facilities/boundary conditions.
  - Understanding diagnostics and quantification.
  - Standardize methodologies for post-processing.
- Leverages the development of quantitative, complete datasets.
  - Unique diagnostics to build upon past understanding.
  - Moves from “qualitative” to “quantitative”.
  - Sharing results/meshes/code/methods saves time and effort.
- Pathway towards predictive spray and engine CFD.

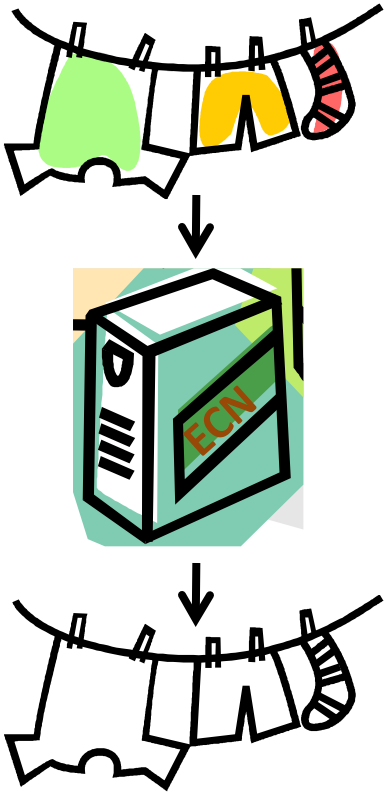
Measurements to date for Spray A conditions.

26 different measurements
8 different institutions

Quantity	Experiment	Contributors (Inst. and/or person)
Gas T distribution	fine-wire TC, variable diameter TC	CAT, CMT, Sandia, IFPEN, TU/e
Ambient gas minor species existence and effects	kinetics modeling	Mich. Tech. U. (Jaclyn Nesbitt Johnson)
Nozzle internal temperature	thermocouple	Sandia, CAT, IFPEN, CMT, TU/e, Aachen
Nozzle surface temperature	laser-induced phosphorescence	IFPEN (Louis-Marie Malbec, Gilles Bruneaux)
Nozzle geometry	x-ray tomography	CAT (Tim Bazyn)
Nozzle geometry	phase-contrast imaging	Argonne (Alan Kastengren, Chris Powell)
Nozzle geometry	silicone molds	CMT (Raul Payri, Julien Manin)
Nozzle exit shape	optical microscopy, SEM	Sandia (Julien Manin, Lyle Pickett)
Educated nozzle grids	Smoothing and analysis of all data	GaTech, Umass-Amherst, Sandia Argonne
Mass rate of injection	bosch tube method	CMT (Raul Payri, Julien Manin)
Rate of momentum	force piezo	CMT, Sandia, CAT
Total mass injected	gravimetric scale	CMT, Sandia, IFPEN
Nozzle Cd, Ca	momentum + mass	CMT, Sandia
Liquid penetration	Mie scatter	IFPEN, Sandia, CMT, CAT, TU/e
Liquid penetration	Diffuser back illumination	Sandia, CMT, IFPEN, TU/e
Liquid optical thickness	laser extinction	Sandia (Julien Manin, Lyle Pickett)
Liquid structure	long-distance microscopy	Sandia (Julien Manin, Lyle Pickett)
Liquid vol. fraction (300 K)	x-ray radiography extinction	Argonne (Alan Kastengren, Chris Powell)
Vapor boundary/penetration	schlieren / shadowgraphy	Sandia, IFPEN, CAT, CMT, TU/e
Fuel mixture/mass fraction	Rayleigh scattering	Sandia
Velocity (gas-phase)	PIV	IFPEN (L.-M. Malbec, G. Bruneaux, M. Meijer)
Ignition delay	high-speed chemiluminescence	Sandia, CAT, CMT, IFPEN, TU/e
Lift-off length	OH or broadband chemilum.	Sandia, IFPEN, CAT, CMT, TU/e
Transient lift-off/ignition	intensified OH chemiluminescence	Sandia, IFPEN, CAT, CMT, TU/e
Pressure rise/AHRR	high-speed pressure	Sandia, IFPEN, TU/e
Soot luminosity	high-speed luminosity imaging	Sandia, IFPEN, CAT, CMT, TU/e
Soot volume fraction	laser-induced incandescence, laser extinction	IFPEN/Duisberg-Essen (Emre Cenker)

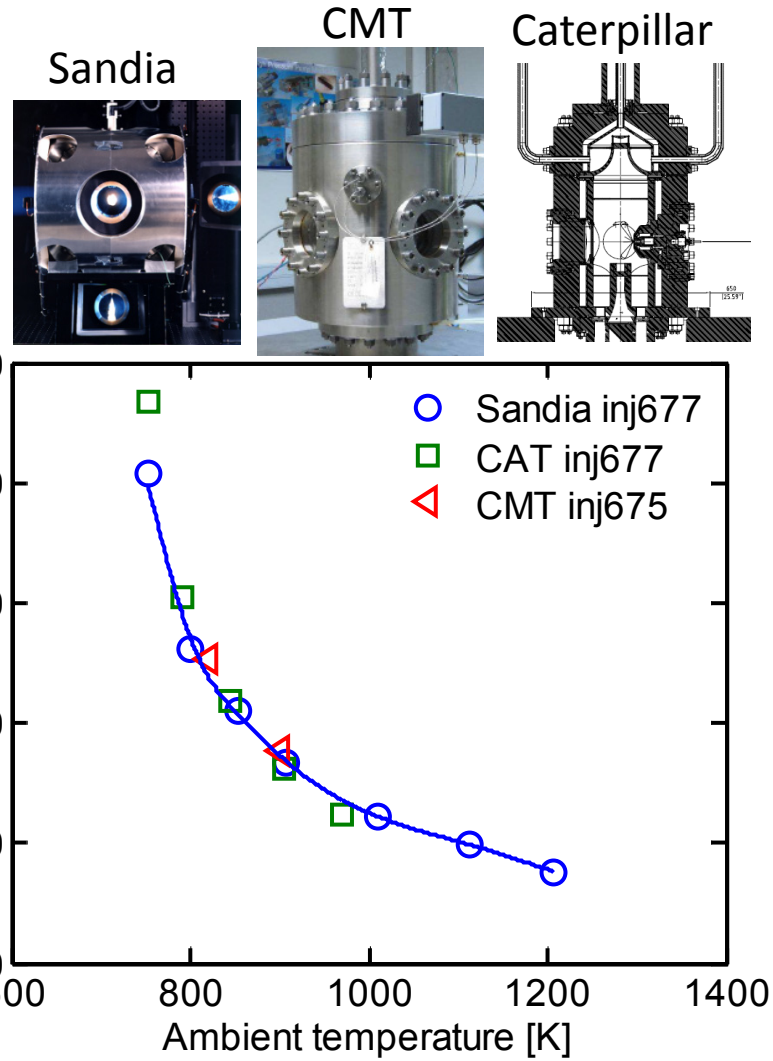
What is the spirit of ECN?

- A forum for open discussion and synthesis of modeling and experimental results, not usually found at conferences.
  - Synthesis creates expert reviews on topics.
  - We want to know what does NOT work, what is broken.
  - Airing our dirty laundry, so that it can be cleaned!
  - Policy is to not duplicate ICLASS conference presentations.
  - Not highlighting individual laboratories or groups, but rather, common research problems.



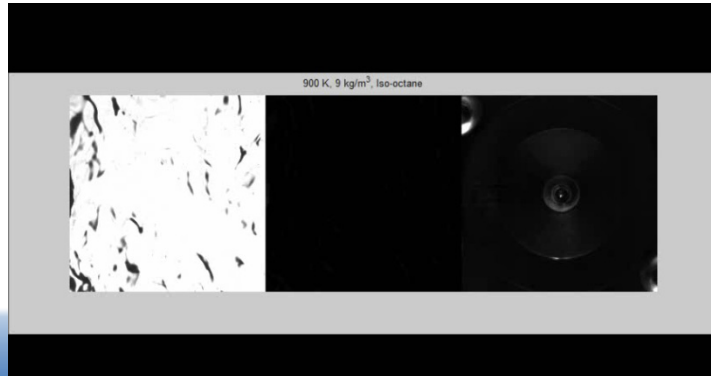
Summary of ECN activities during 2012

- Workshops sponsored
  - May 2011 (ECN1): 60 participants met for 2-day event before ILASS meeting.
  - Jan 2012: 120 participants attend 3-day web meeting.
- Key findings
  - Facility temperature distribution of gases and fuel is critical.
  - Nozzle geometry, needle movement are provided using multiple comparative diagnostics.
  - Ignition and lift-off length measurements are consistent with different types of HP-HT facilities.
    - Datasets can be linked and leveraged!
- Preparation for ECN2
  - Spray A and parametrics
  - 8 experimental, 16 modeling teams participate voluntarily



Where do we want to go?

- Continue the effort
  - Standardize the experiments, improve their accuracy
  - Add new data to the online database
  - Provide guidelines for model comparisons
- But also go further
  - Define new directions, new needs
    - Advanced diagnostics at specific (Spray A) conditions
      - Velocity, liquid volume fraction, liquid structure, soot, individual species, …
    - Parametric variation around Spray A/Spray B conditions
  - Go one step further in the validation of models with ECN experiments
    - Provide best practices to ensure that models and experiments are really addressing the same metric
  - Extend the Spray A methodology to other conditions
    - Gasoline spray
      - Delphi will donate 12 injectors this year
    - Engine flows



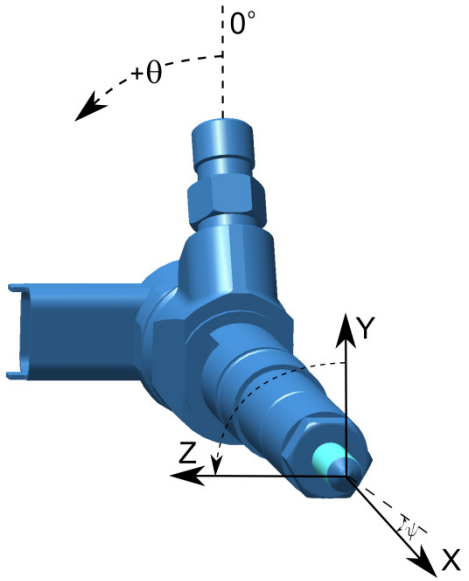
Questions to consider during ECN2

- What measurements are missing and key to model understanding?
  - Do current measurements have the accuracy to guide model advancement appropriately?
- When do imperfections or variation in boundary conditions make a noticeable impact on results versus using idealized, specified conditions?
  - Is it appropriate to merge datasets from different injectors (with the same specification)?
- Can we make spreading angle and penetration predictive?
  - How do we truly connect the tiniest details of internal injector flow to subsequent spray development and combustion?
- How do high-performance simulations guide engineering-level modeling?

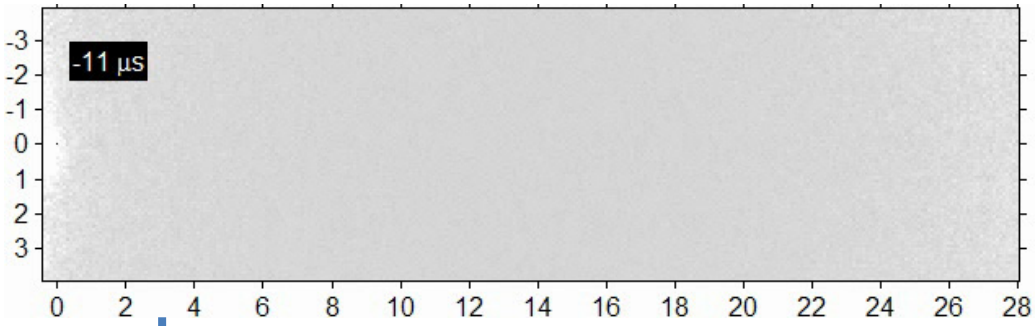
“Real world” effects that need consideration

- Spray A nozzles are not exactly the same and geometry defects impact the spray
- Sac volume is likely partially filled with gas at the start of injection
- Injected fuel lies at one location in injector while upstream tip has higher temperature

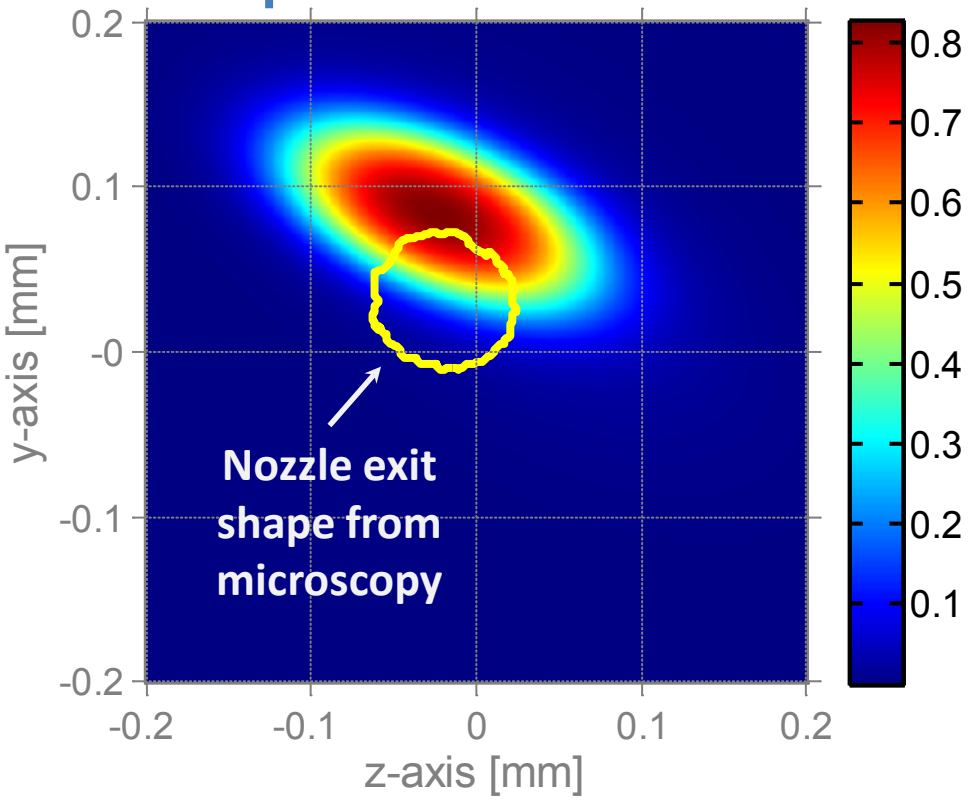
Spray asymmetry explanations



SEM of nozzle



x = 3.2 mm

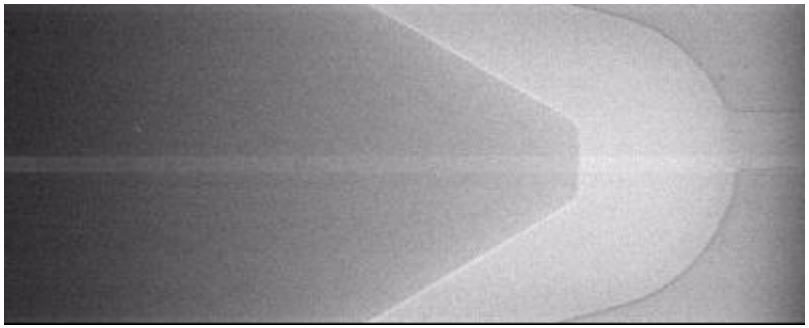


Mixture fraction derived from x-ray radiography

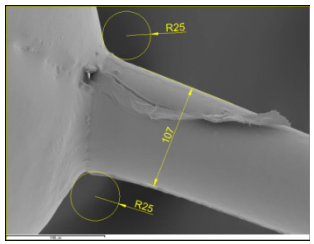
Argonne:
Chris Powell,
Alan Kastengren

How do nozzle shape features affect exit flow?

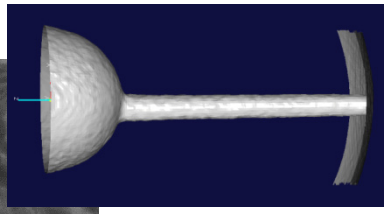
X-ray phase-contrast (Argonne)

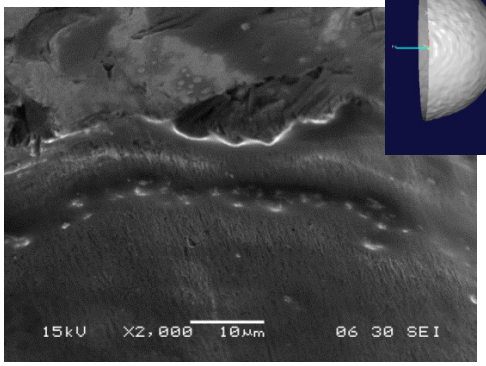


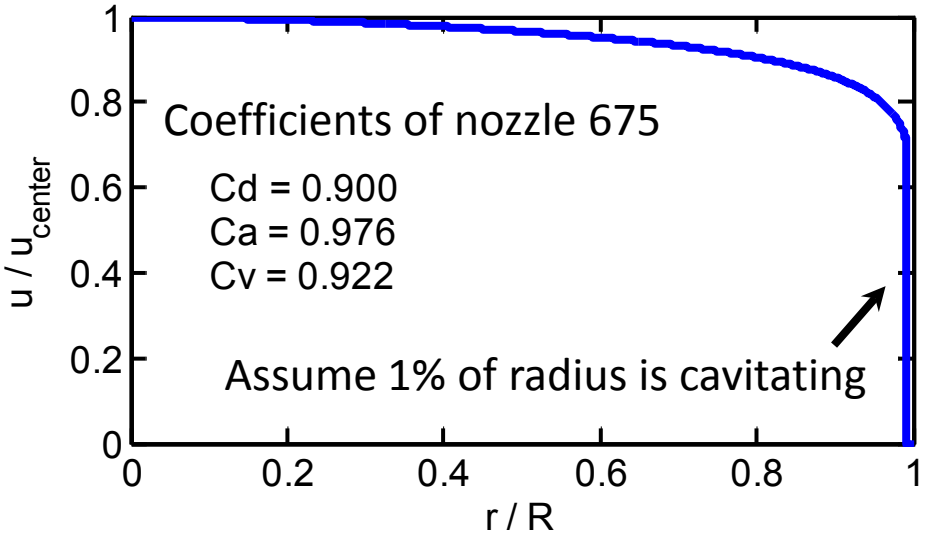
Silicone molds (CMT)

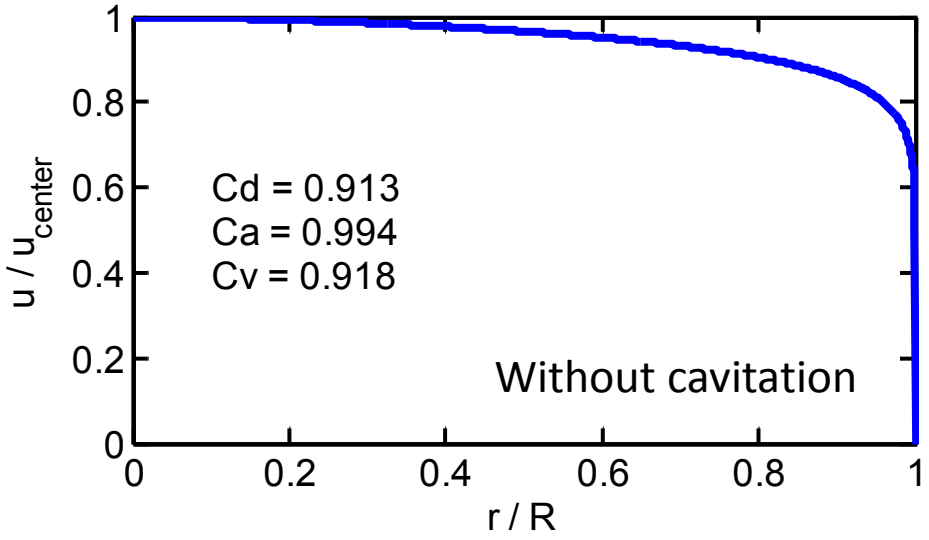


X-ray tomography (Caterpillar)



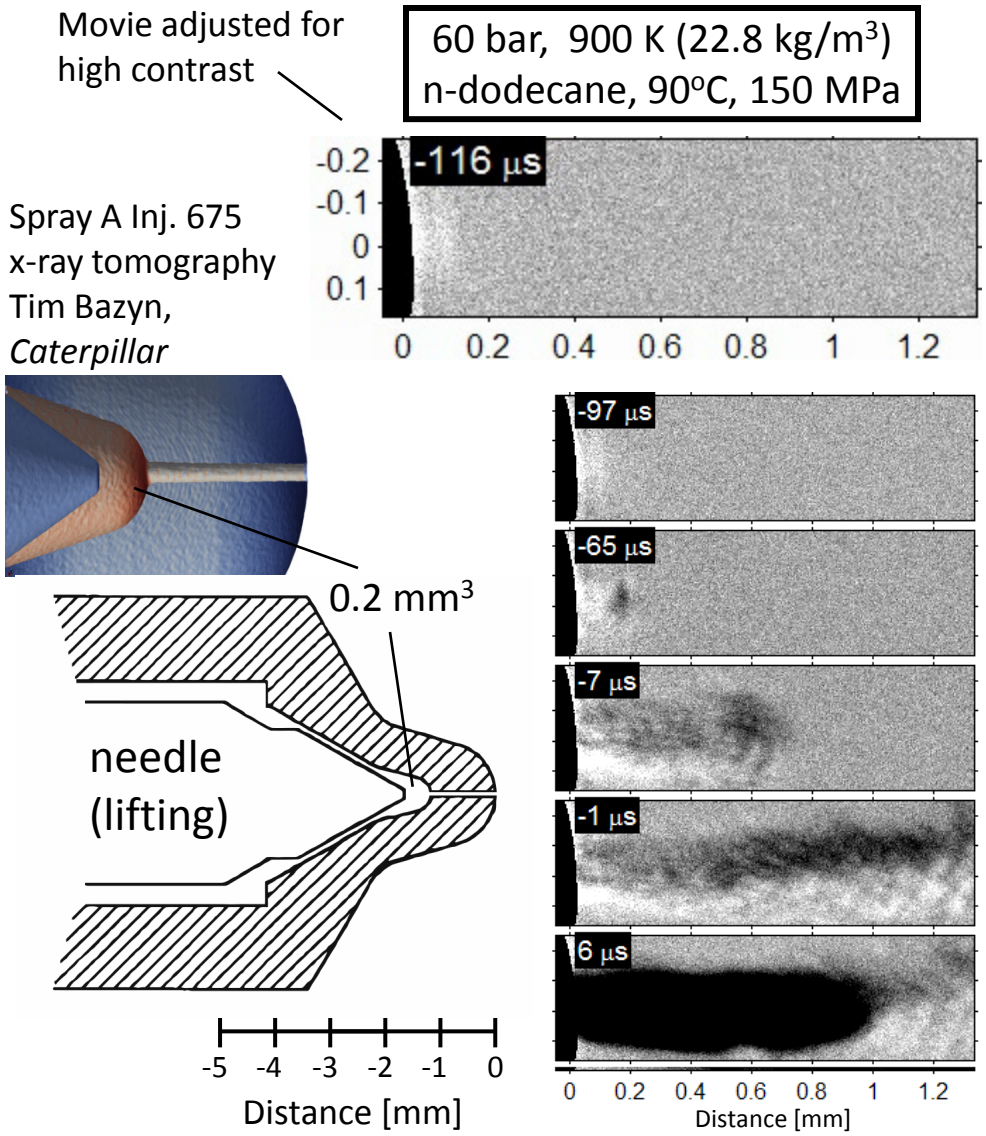






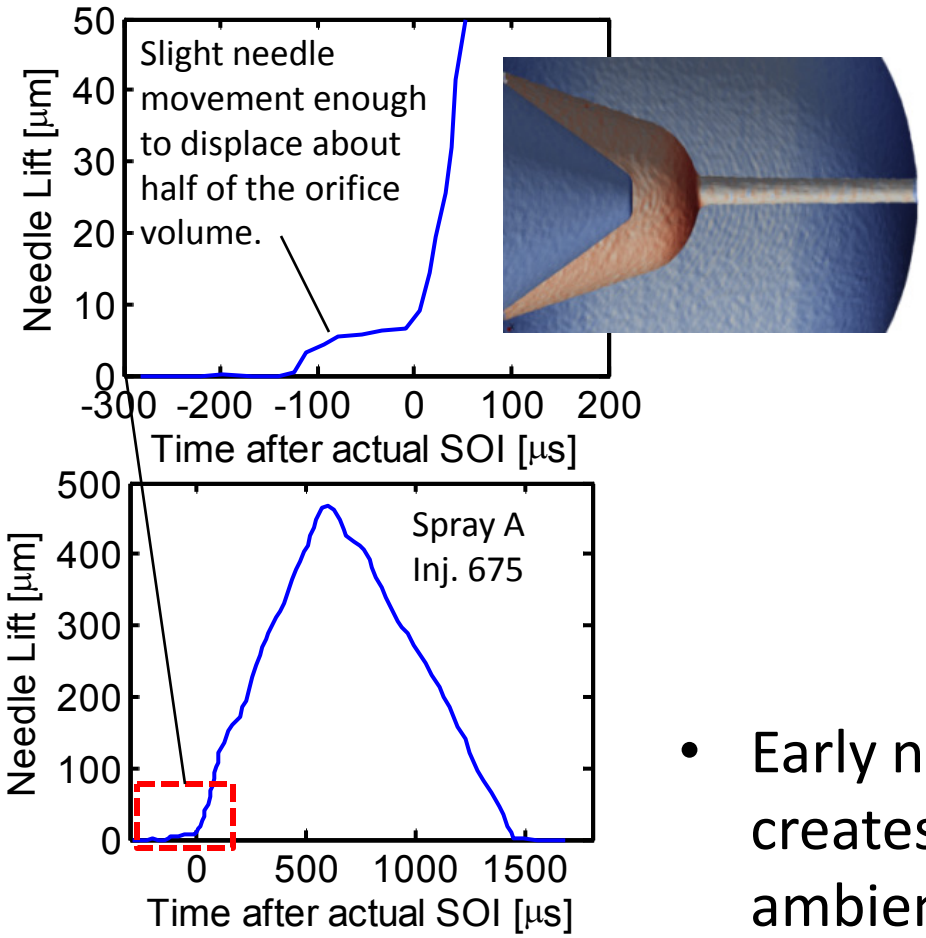
The beginning stages of injection show a vapor injection leading a liquid injection.

- How much gas is in the sac at the start of injection?
  - Some facilities use vacuum at the start of precombustion
- Gases in the sac are pushed out by incoming liquid as the needle valve opens.
  - Vapor jet precedes liquid by approximately 10 μs.
  - Some venting/gas exchange starts at about -70 μs.
  - Will affect initial rate of injection and penetration.
    - Typical targets for experimental/ modeling comparison.



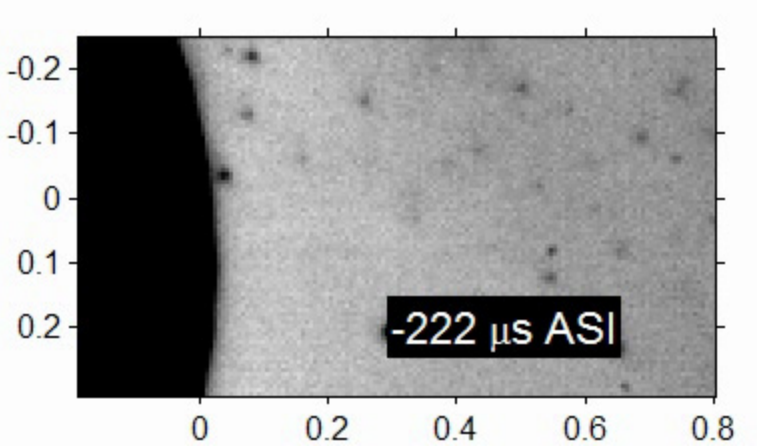
Leading vapor injection also shown recently by Crua et al. [SAE 2010-01-2247]

Needle movement actually pulls gas into the sac/orifice during first opening.



Multiple injection situation: earlier injections have left droplets inside the chamber.

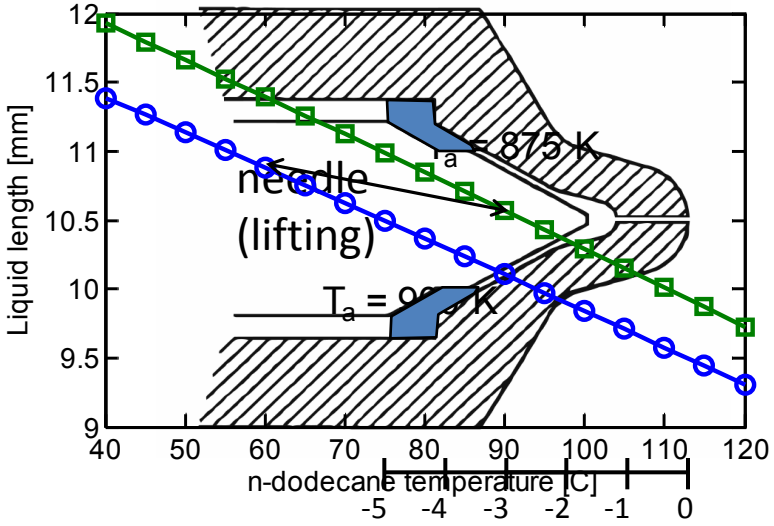
440 K, 29 bar

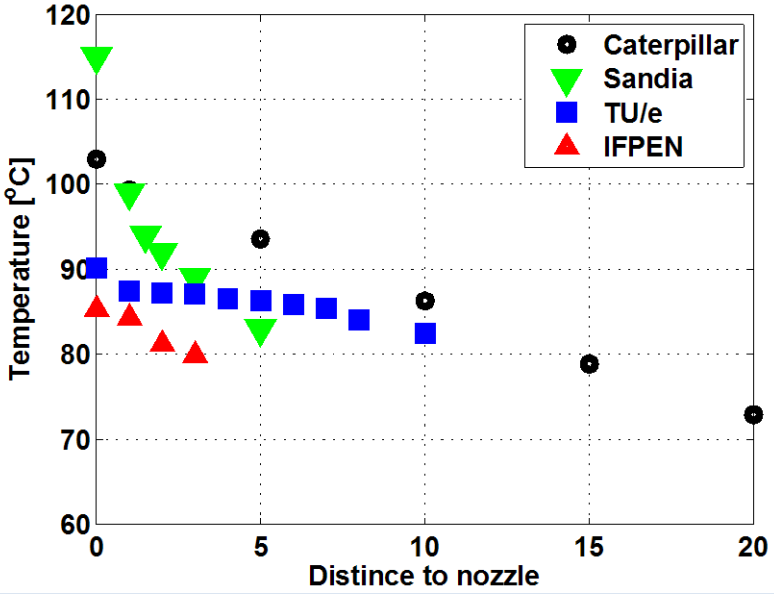


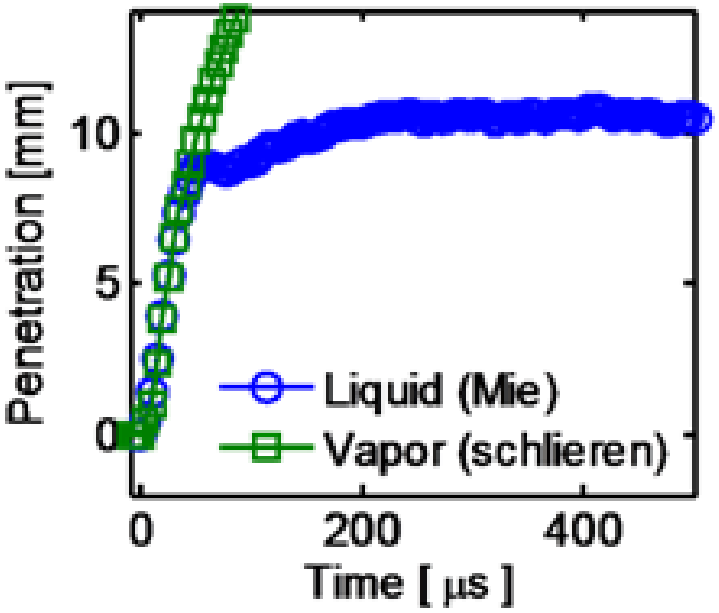
- Early needle movement momentarily creates a vacuum to pull droplet (and ambient gases) into the injector.

The temperature is not uniform in the injector

- The fuel temperature effect is significant
- But the temperature is not uniform in the injector (also different between facilities)
- What is the consequence?

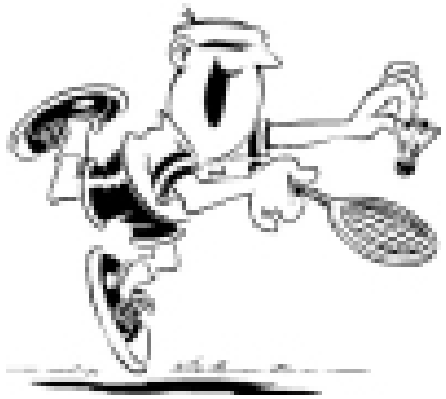






Why ECN2?

- Because we need deadlines to move forward!!
- Because a lot of work is carried out in ECN and requires coordination
- Because we like to see each other
- Because we have had enough web meetings
- Because we also want to have fun
  - Saturday 3pm official session: Birdie/vortex interaction in strongly accelerating flows



ECN2 Objectives

- Evaluation of modeling and experimental results at parametric conditions beyond Spray A.
  - Ambient temperature (e.g., Spray A-800 K, Spray A-1000 K), injection pressure (e.g., Spray A-1000 bar).
- Direct comparison of modeling and experiment based on the topic, rather than conditions.
  - Force/reinforce communication between experiments and modeling (common language in terms in metrics).
- Early results and planning activities for gasoline sprays and engine flows activities, including the selection of common hardware and operating conditions.

ECN2 organization: Session Organizers

- Overall
  - Gilles Bruneaux (IFPEN), Lyle Pickett (Sandia):
- Internal Nozzle Flow
  - Chris Powell (Argonne), David Schmidt (UMassAmherst), Marco Arienti (Sandia)
- Spray Development and Vaporization
  - Julien Manin (Sandia) , Sibendu Som (Argonne), Chawki Habchi (IFPEN)
- Mixing and Velocity
  - Louis-Marie Malbec (IFPEN), Gianluca D'Errico (Pol. Milano)
- Ignition and Lift-off Length
  - Michele Bardi (CMT), Evatt Hawkes (UNSW), Christian Angelberger (IFPEN)
- Soot
  - Emre Cenker (Duisburg/IFPEN), Dan Haworth (Penn St.)
- Gasoline Sprays
  - Scott Parrish (GM)
- Engine Flows
  - Sebastian Kaiser (Duisburg-Essen)

Sessions focus

- Explanation of experiment and uncertainties
- Standardization of experiment methodology and variance between facilities
- Best way to compare experimental results to modeling results
- Standardization of models and boundary conditions
- Side by side comparison of results
- Conclusions and recommendations, with guidelines for future experiments and modeling efforts

ECN2 organization: Workshop Logistics

- Gilles Bruneaux, Frederique Léandri (IFPEN)
- Eva Gutheil (ICLASS 2012 chair) & Team

ECN2 Program

- Friday 7 Sept.
  - 8:00-9:00 Registration
  - 9:00-9:20 Introduction and mechanics
  - 9:20-9:50 Engine flows
  - 9:50-10:00 Discussion
  - Diesel spray target conditions
  - 10:00-11:20 Internal flow and geometry
  - 11:20-11:50 Discussion
  - 11:50-13:00 **Lunch**
  - 13:00-14:20 Spray development and vaporization
  - 14:20-14:50 Discussion
  - 14:50-15:30 **break**
  - 15:30-16:50 Mixing and velocity
  - 16:50-17:20 Discussion
  - ….

ECN2 Program

- Friday 7 Sept.
  - 17:20-17:50 Gasoline spray combustion
  - 17:50-18:00 Discussion
  - 18:00 end of first day technical sessions
  - 19:00 **Dinner in a Kulturbrauerei** (sponsored by workshop)

- Saturday 8 Sept.
  - 9:00-10:20 Ignition and lift-off length
  - 10:20-10:50 Discussion
  - 10:50-11:10 **break**
  - 11:10-12:00 Soot
  - 12:00-13:00 **lunch**
  - 13:00-13:30 Soot continued
  - 13:30-14:00 Discussion
  - 14:00-15:00 Future directions
  - 15:00---- **Birdie/vortex interaction in strongly accelerating flows**

After ECN2

- ECN2 proceedings made available to the group.
  - Decisions, recommendations, presentation material and discussions summarized through short writeups or slides.
  - Will session organizers please do this?
  - Please take notes of discussions to include them in the proceedings
- Continue the work until…
- ECN3