Introduction to CONVERGE

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Welcome to IC Engine Training

- For those who are new to CONVERGE or CONVERGE Studio for internal combustion (IC) engine modeling
- Focus on setting up an IC engine case and analyzing the results
- The plan for today and tomorrow
  - Introduction to Convergent Science and CONVERGE
  - Engine-specific surface preparation
  - Case setup
  - Post-processing

} Including hands-on practice in CONVERGE Studio

IC Engine Training Topics (two days)

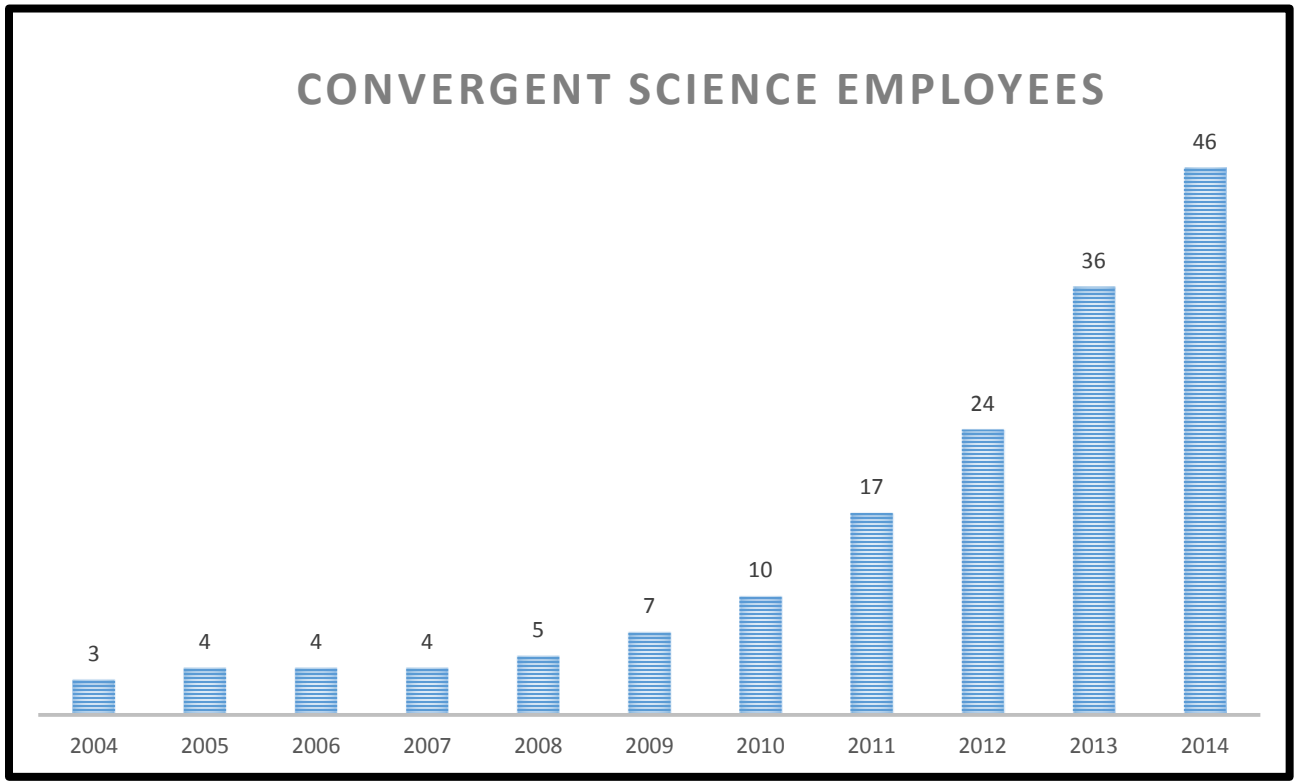
- Introduction to CONVERGE
- Engine sector surface preparation utilities
- Preparing the piston and valves for motion
- File overview and case setup
- Boundaries
- Regions
- Initialization and mapping
- Grid control
- Turbulence
- Spray
- Combustion
- Sources
- CHT
- VOF
- Advanced engine modeling
  - Multi-cycle simulations
  - Multi-cylinder simulations
  - Engine knock
- Post-processing

A Brief History of Convergent Science (1/2)

- 1997: Graduate students at the University of Wisconsin – Madison found Convergent Science (as Convergent Thinking LLC)
- 2001: Start developing CONVERGE to address CFD bottlenecks
- 2008: Sell first CONVERGE licenses
- 2012: Open Texas office
- 2013: Sign IDAJ as Asian distributor (Japan, China, Korea)

A Brief History of Convergent Science (2/2)

- 2014: Move headquarters to a 40,000 square foot building in Madison, Wisconsin
- 2014: Merge with Ignite3D to form Convergent Science GmbH (Linz, Austria)
- 2014: Hold first CONVERGE user conference
- 2015: Open Detroit office

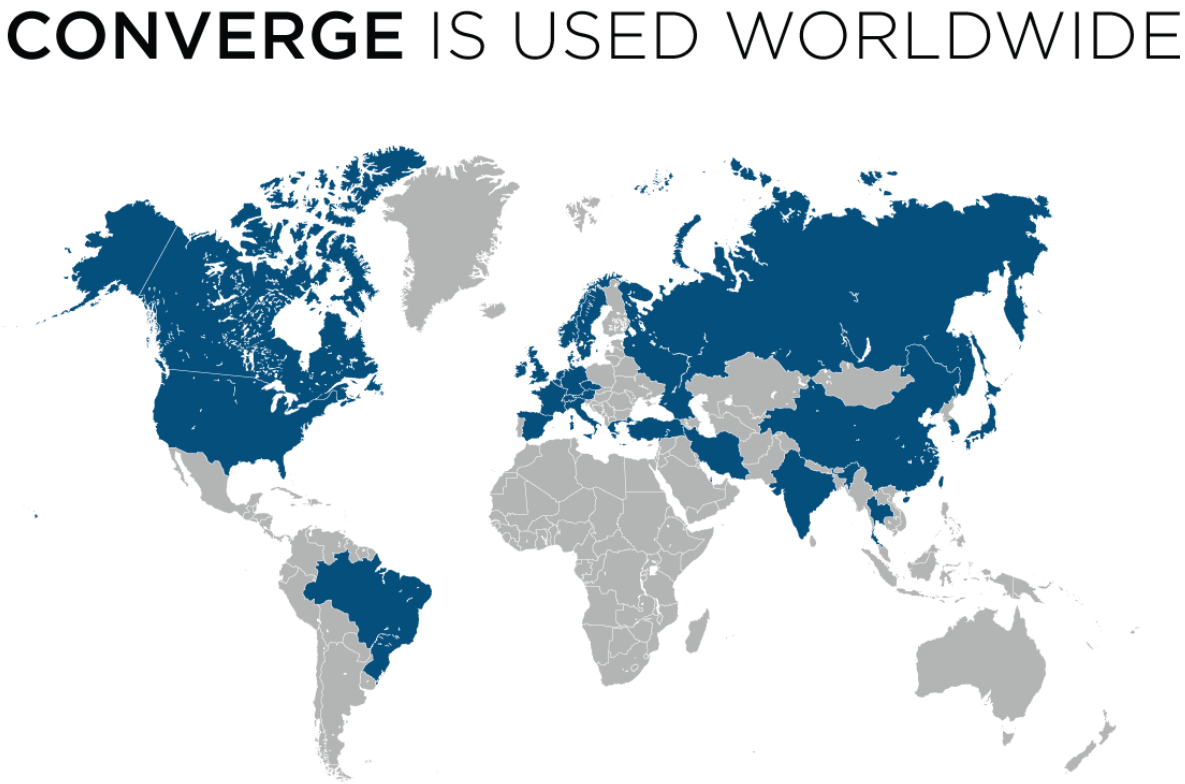


Convergent Science Offices and Distributors

CONVERGE CFD SOFTWARE

Convergent Science Today

- Most US, European, and Asian automotive and engine companies are using CONVERGE
- Use of CONVERGE in other industries is rapidly increasing



What is CONVERGE?

- CONVERGE is a computational fluid dynamics (CFD) modeling program
  - CFD uses numerical methods and algorithms to solve and analyze problems involving fluid flow
- The CONVERGE package includes

pre-processor, including Polygonica* and Sculptor*
post-processor, including a license for EnSight

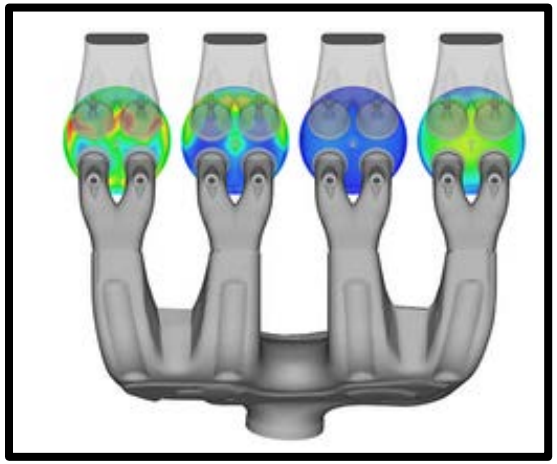
solver
utilities

*separate licenses may be required

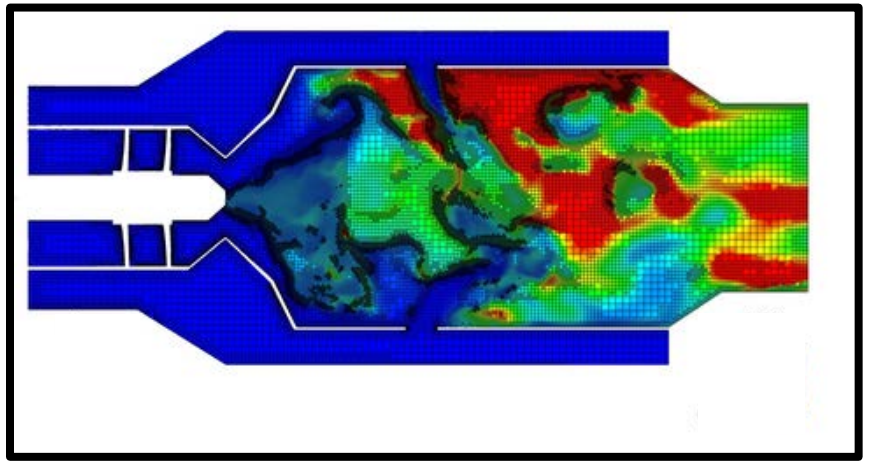
CONVERGE Collaborators

What are some applications for CONVERGE?

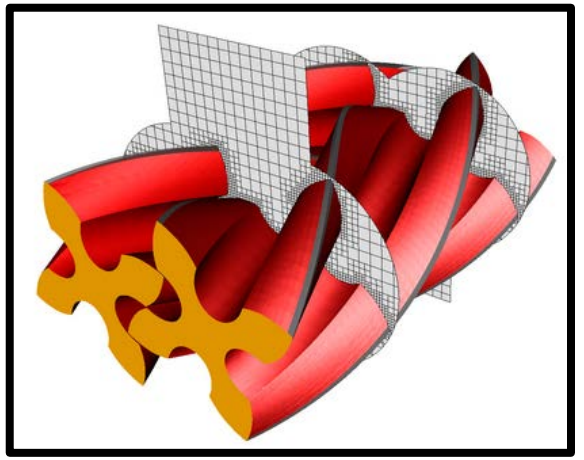
Internal Combustion Engines



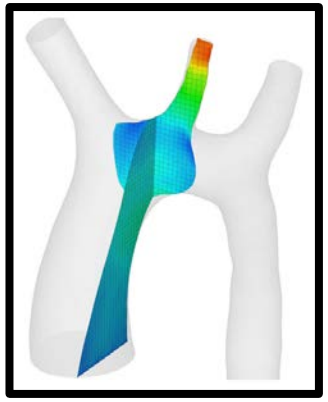
Gas Turbines



Pumps and Compressors



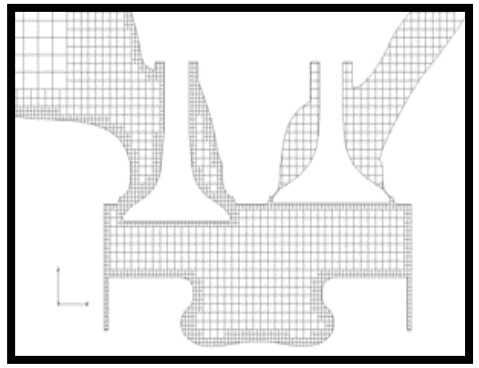
Biomedical Engineering

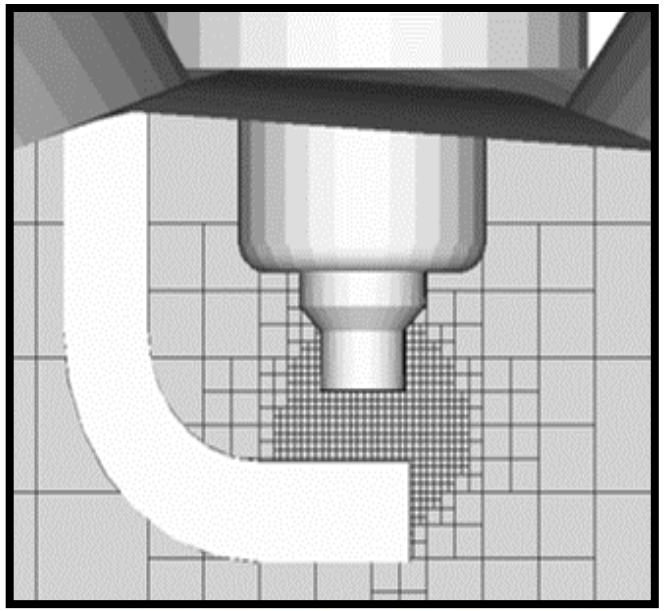


Exhaust Aftertreatment

What makes CONVERGE better? (1/2)

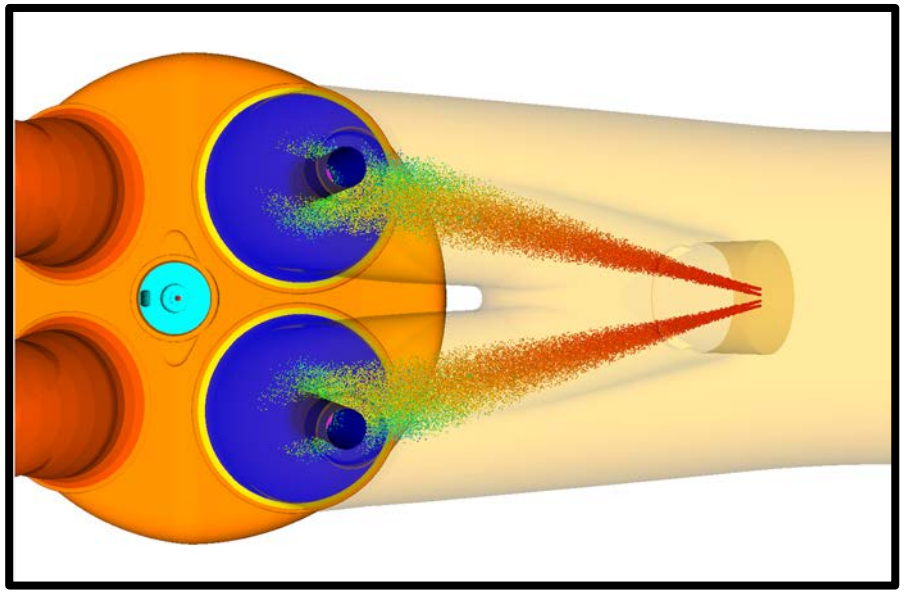
- Automated meshing at runtime
  - No user meshing
  - CONVERGE automatically increases mesh resolution in key areas (Adaptive Mesh Refinement [AMR])
  - With automated meshing, you can run simulations with more cycles and larger geometries
- User-friendly pre- and post-processor
  - Set up the geometry and input files
  - Visualize simulation results





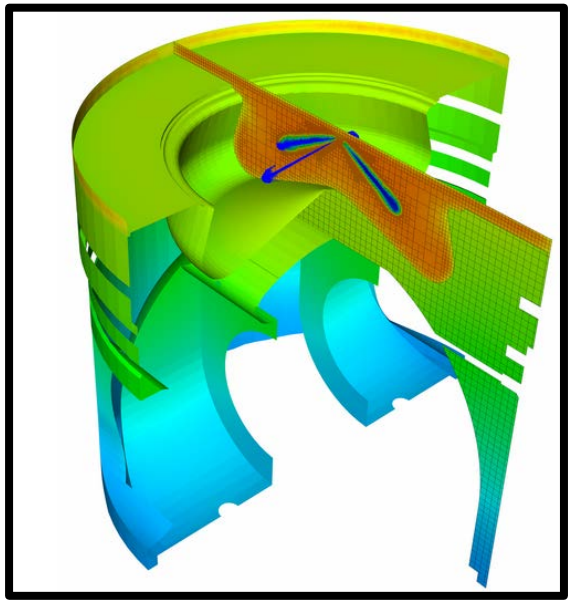
What makes CONVERGE better? (2/2)

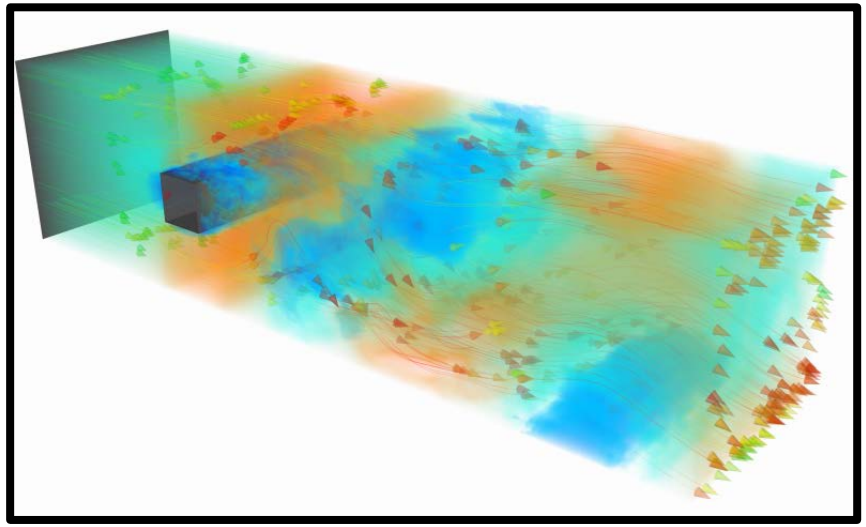
- Automated geometry or parameter optimization (genetic algorithms [GAs])
- Accurate physical models
  - Combustion, turbulence, spray, sources, etc.
- Detailed chemistry with large mechanisms



What can CONVERGE do? (1/3)

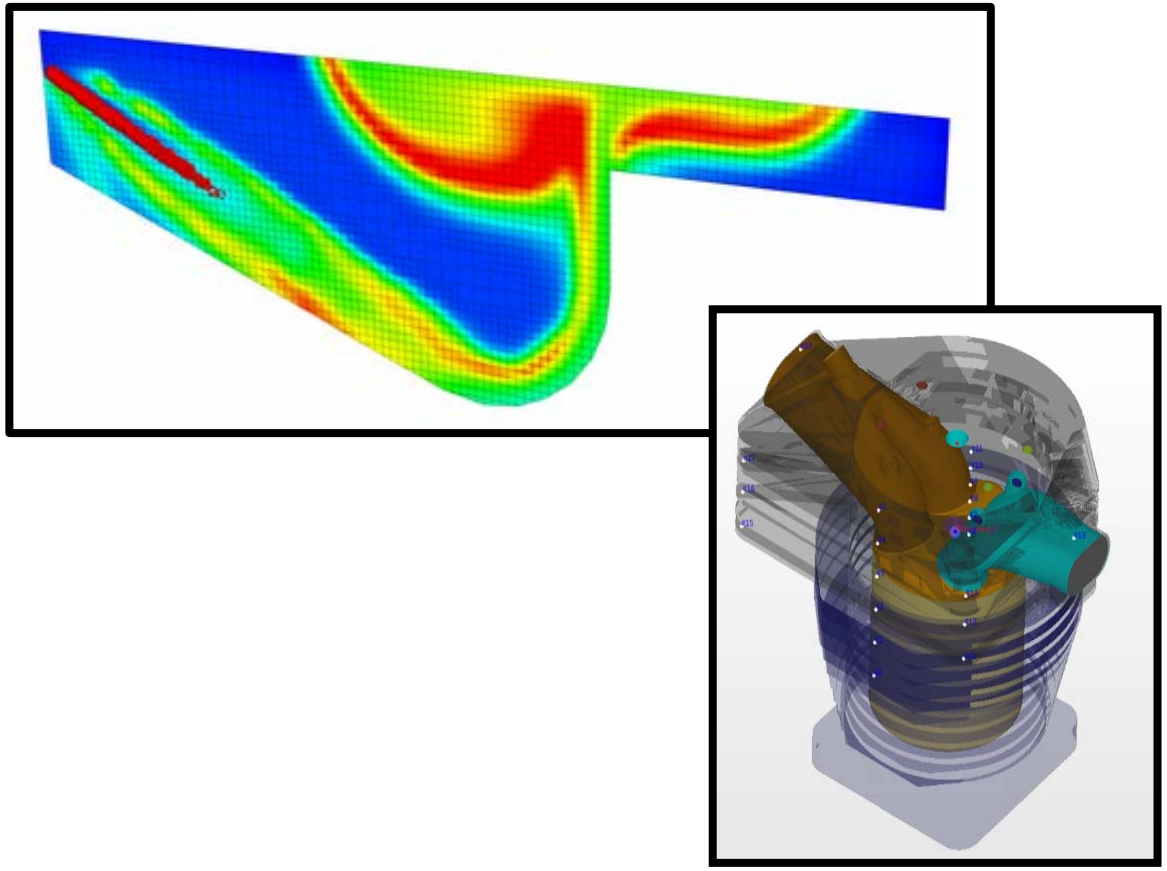
- Customize, repair, or edit surface geometry
- Steady-state or transient simulations
- Simulations with large, moving/changing, and complex surface geometries
- Advanced spray models
- Conjugate heat transfer (CHT)





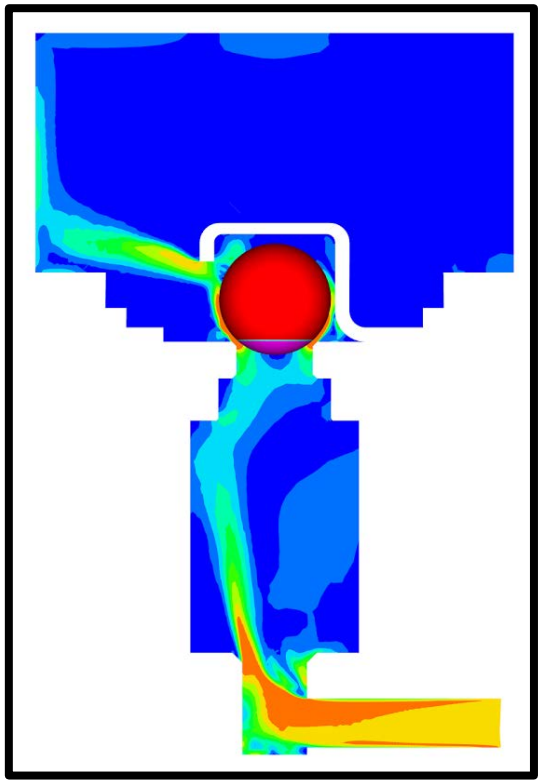
What can CONVERGE do? (2/3)

- Combustion (multi-component fuel, non-premixed, fuel injection)
- Detailed chemistry (SAGE)
- Simplified combustion models (G-Equation, ECFM3Z, etc.)
- Chemistry mechanism reduction
- GT-SUITE coupling
- 2-stroke and rotary engines
- Engine knock analysis



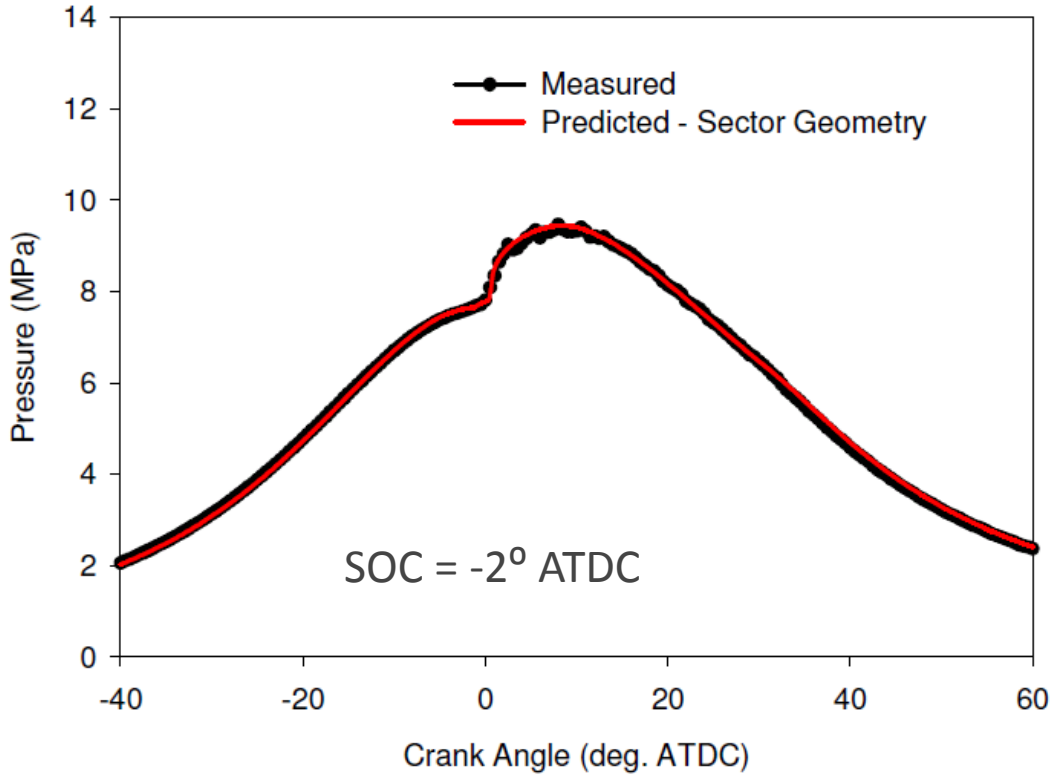
What can CONVERGE do? (3/3)

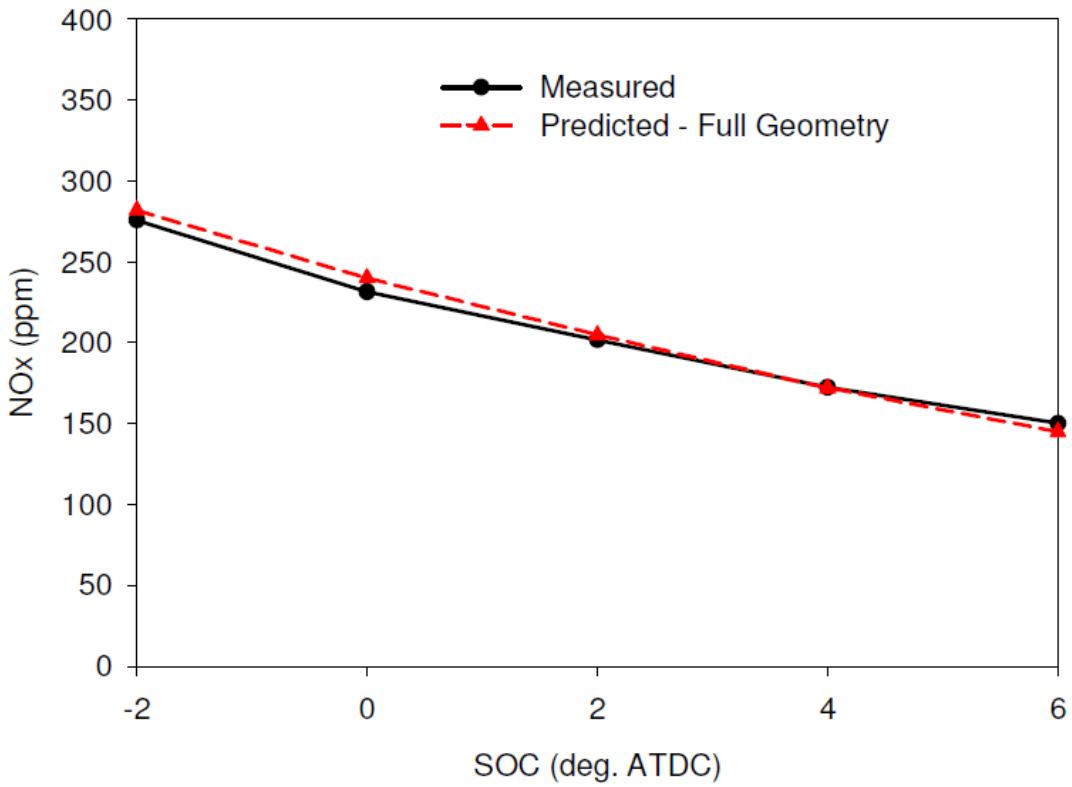
- Multi-phase flow simulations
  - Cavitation
  - Incompressible/compressible flows
  - Condensation/evaporation
- Complex mixing simulations (realistic turbulence)
- Fluid-structure interaction (FSI)
- User-defined functions (UDFs)



Why CONVERGE for IC Engine Modeling?

- Diesel Engine Validation





Authors' affiliations: Caterpillar Inc., Sandia National Laboratories
(ASME ICEF 2013-19129)

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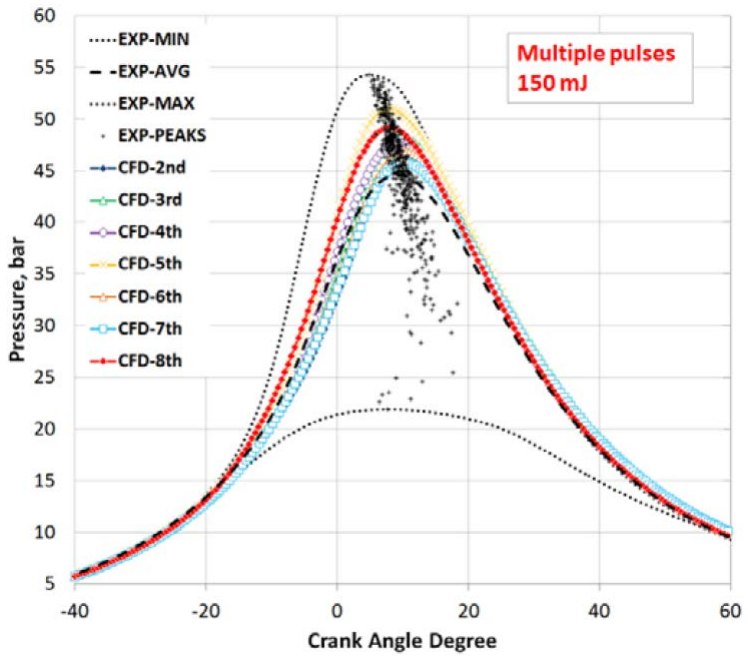
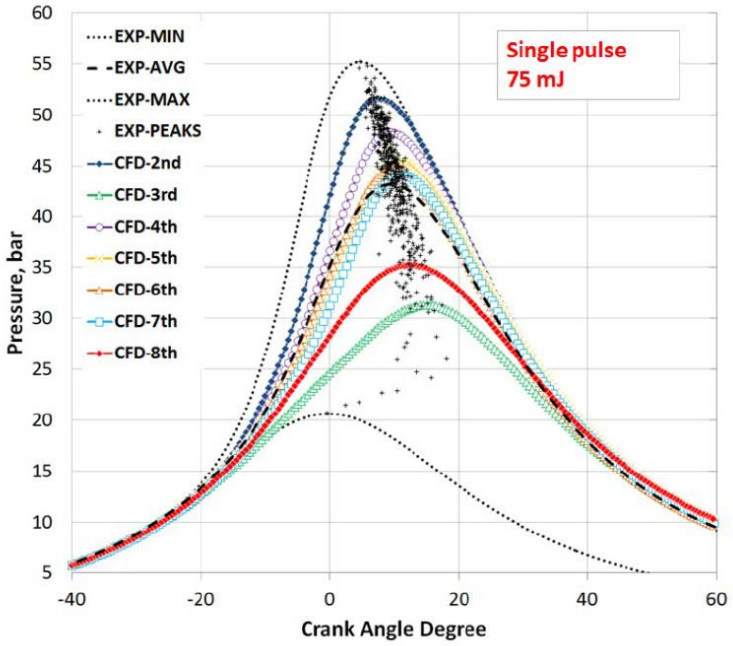
Why CONVERGE for IC Engine Modeling?

- Gasoline Direct Injection Engine Validation



GDI with 0% EGR (21 simulation cycles, 500 experimental cycles)

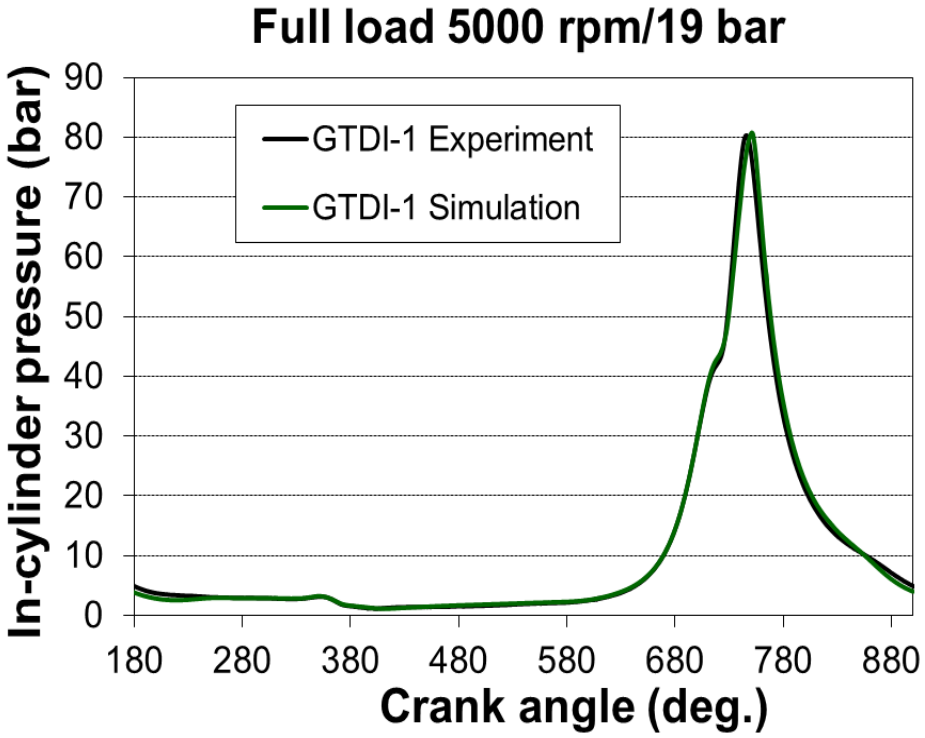


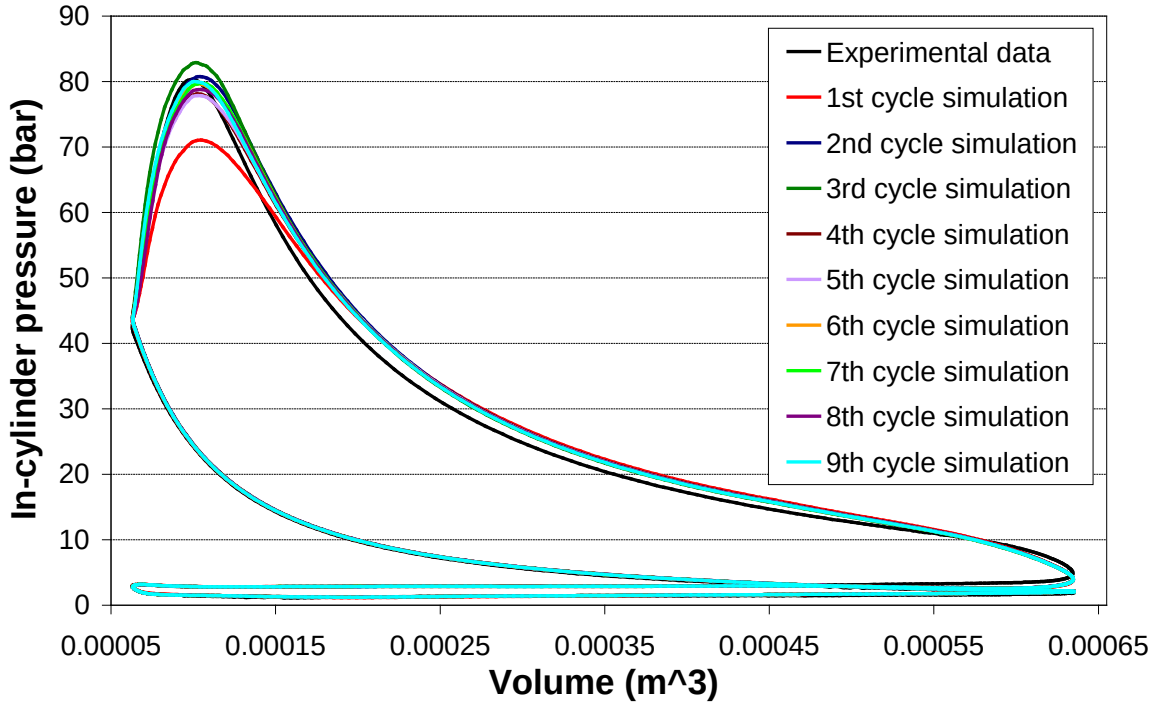
GDI with 18% EGR (21 simulation cycles, 500 experimental cycles)

Authors' affiliation: Argonne National Laboratory
(ASME ICEF 2014-5607)

Why CONVERGE for IC Engine Modeling?

- Gasoline Direct Injection Engine Validation

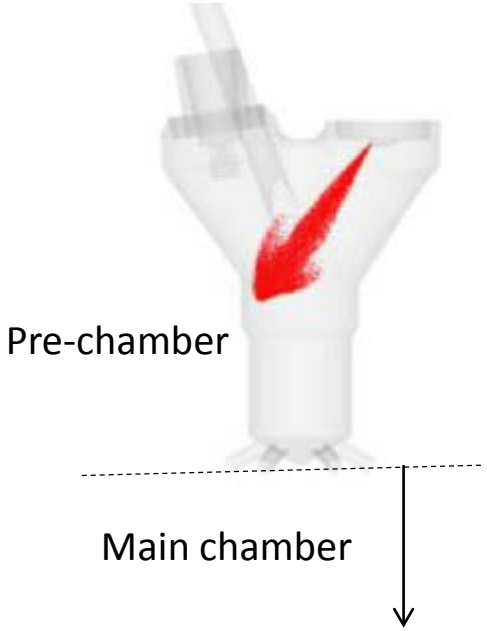


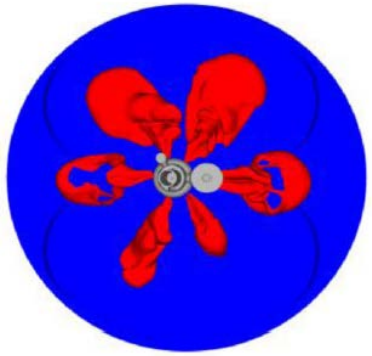


Researchers' affiliation: FORD

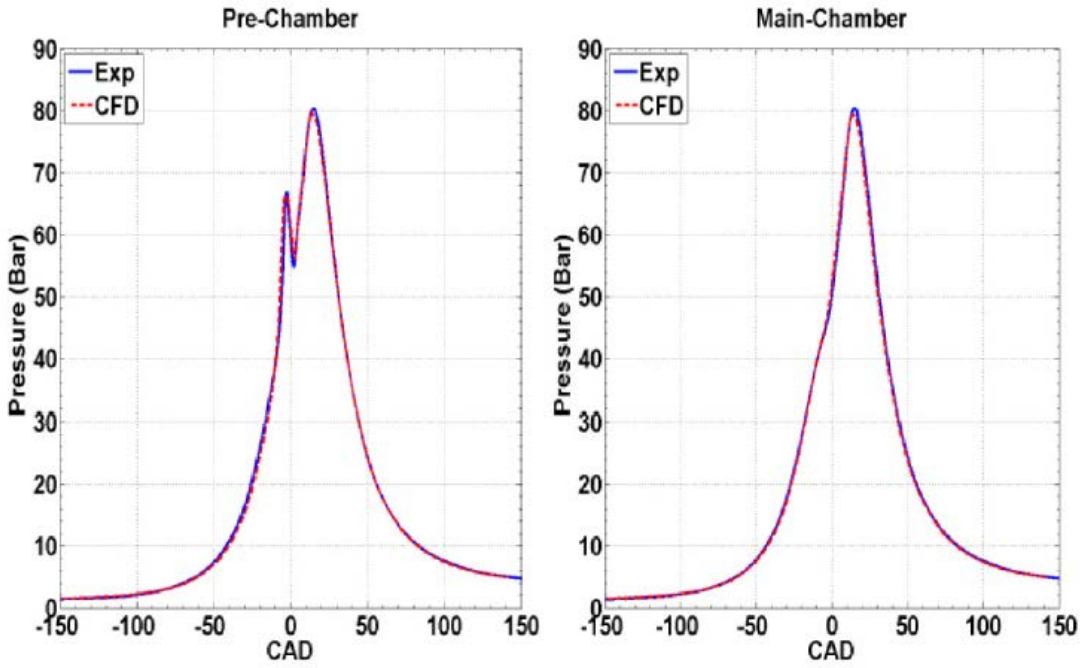
Why CONVERGE for IC Engine Modeling?

- Gasoline Pre-Chamber Engine Validation





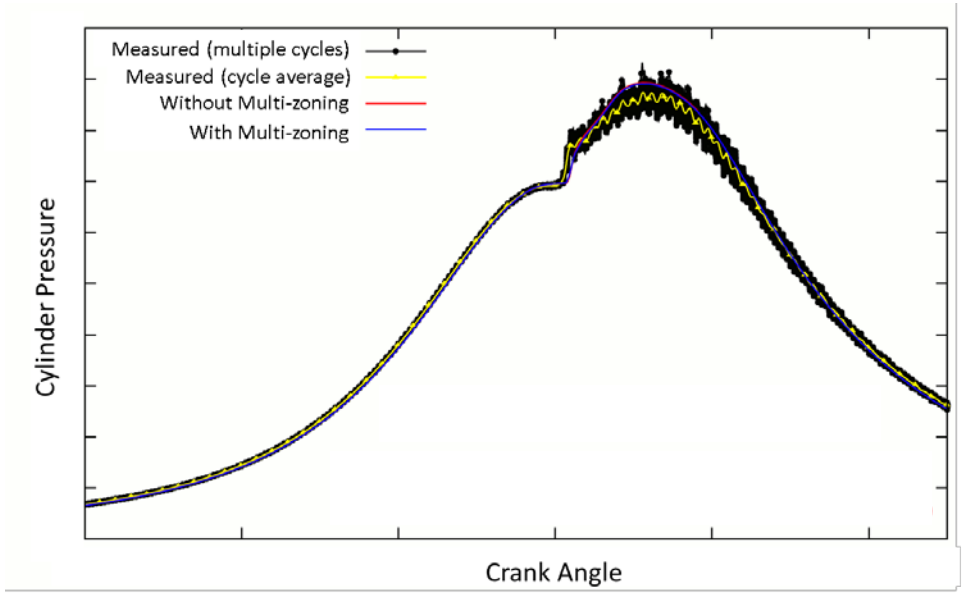
Flame jets from the pre-chamber in to the main chamber



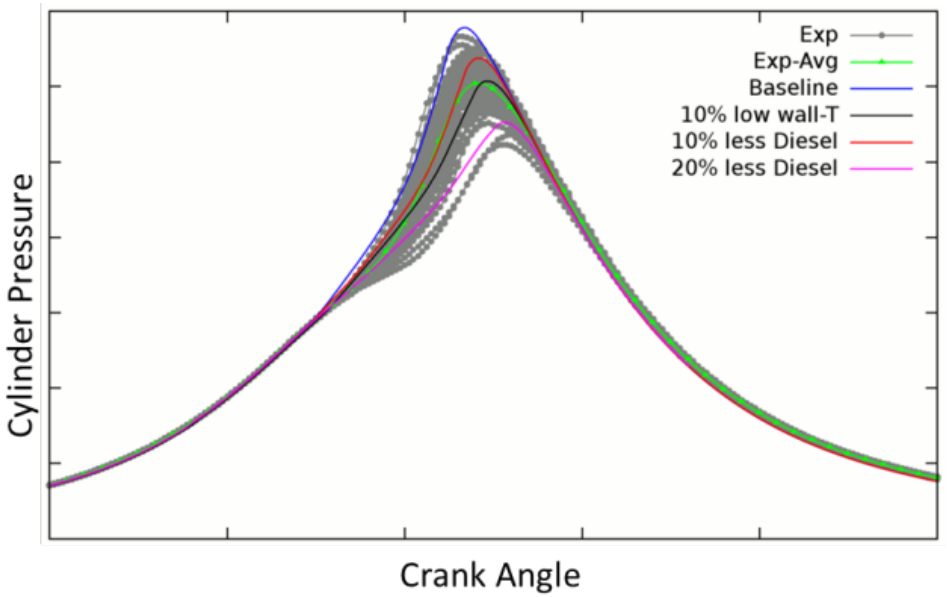
Authors' affiliation: MAHLE Powertrain LLC
(SAE 2015-01-0386)

Why CONVERGE for IC Engine Modeling?

- Dual-Fuel Engine Validation



60% Premixed Natural Gas,
40% Direct Injected Diesel

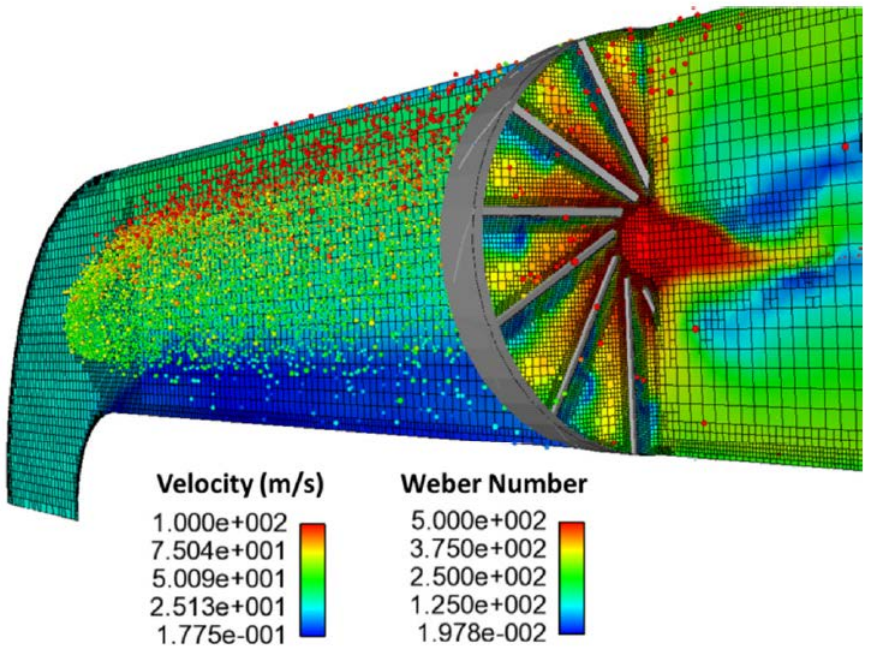


93% Premixed Natural Gas,
7% Direct Injected Diesel

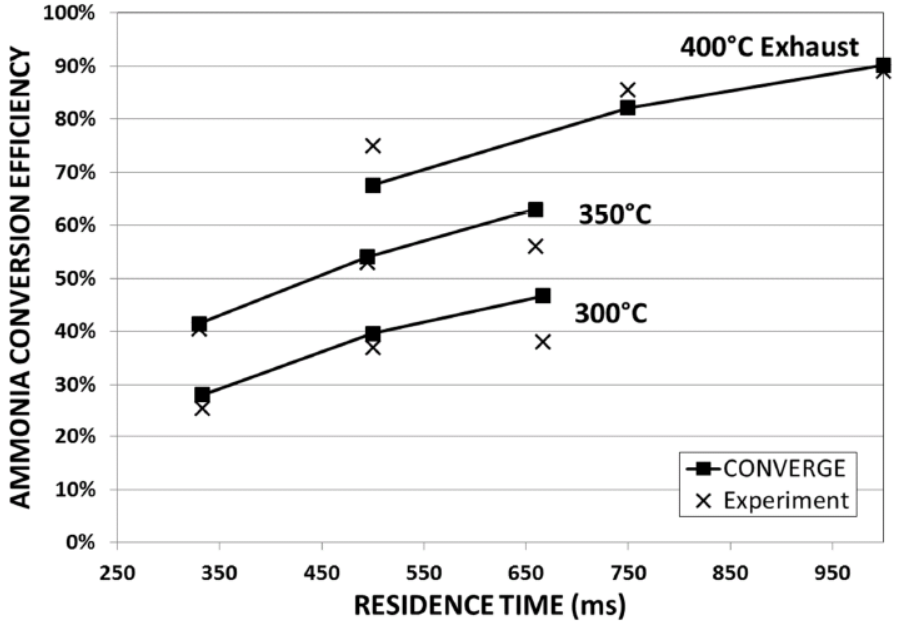
Authors' affiliation: GE
(ASME ICEF 2015-1077)

Why CONVERGE for IC Engine Modeling?

- IC Engine Aftertreatment: SCR



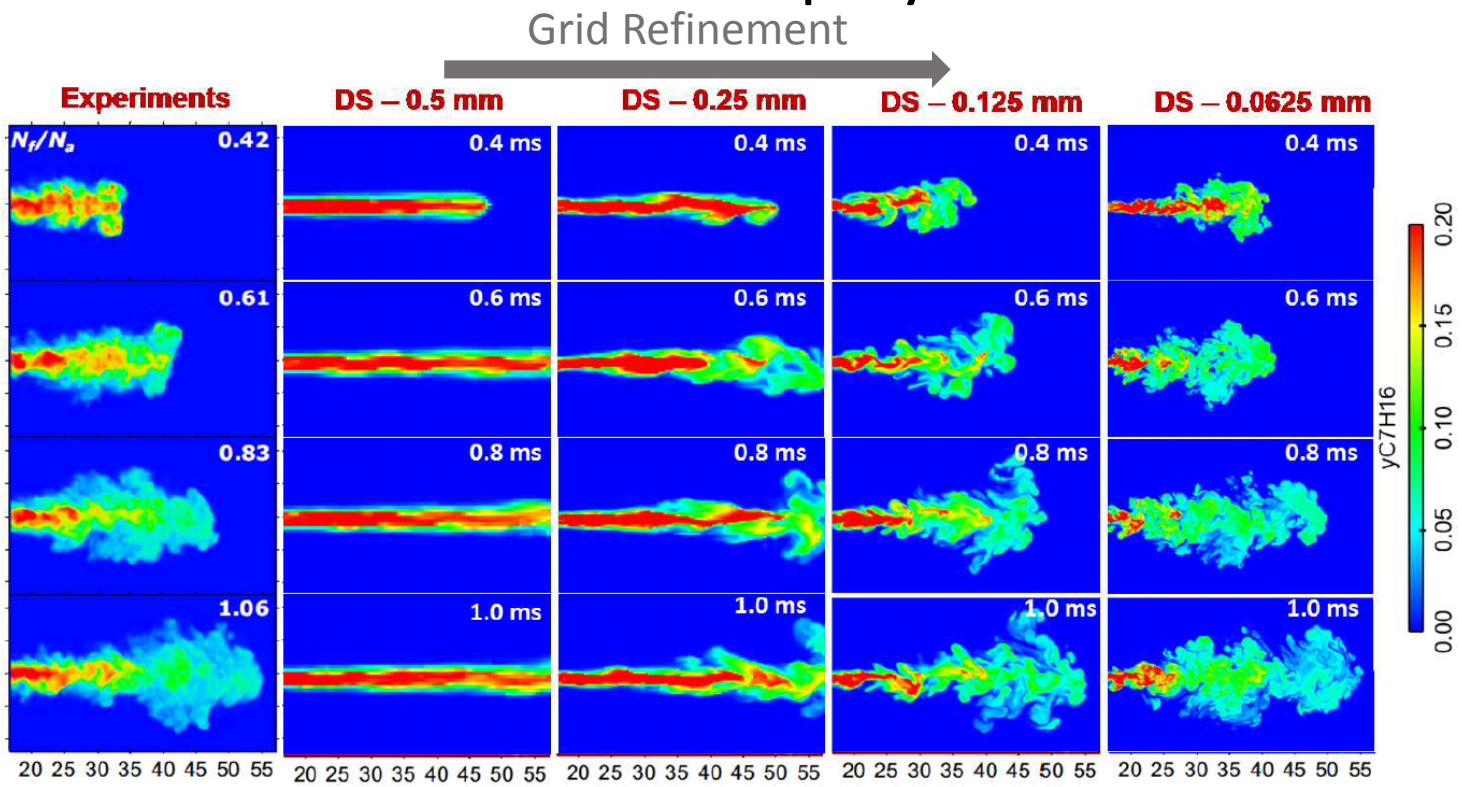
Gas Velocity and Droplet Weber Number

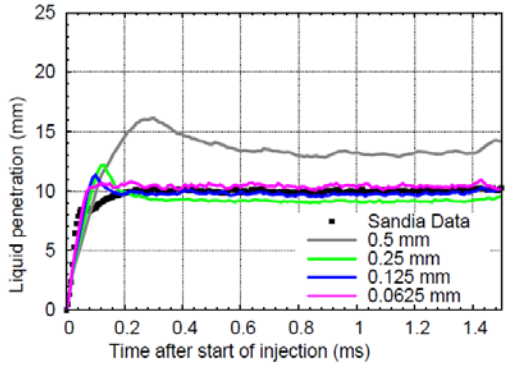


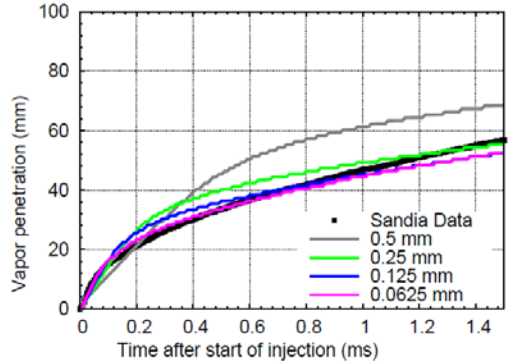
(ASME ICEF 2015-1077)

Why CONVERGE for IC Engine Modeling?

- Realistic and Accurate Spray and Turbulence Modeling





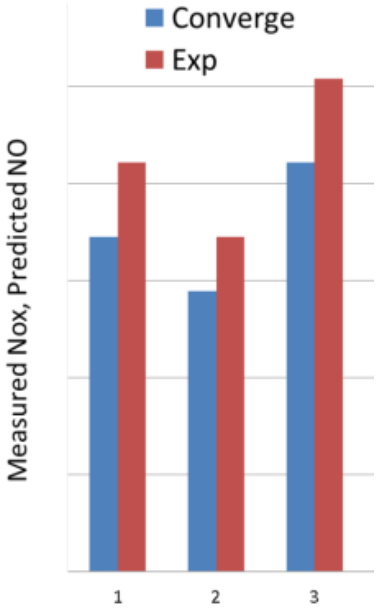


Authors' affiliation: Argonne National Laboratory
(Atomization and Sprays, 23(10): 925-955 (2013))

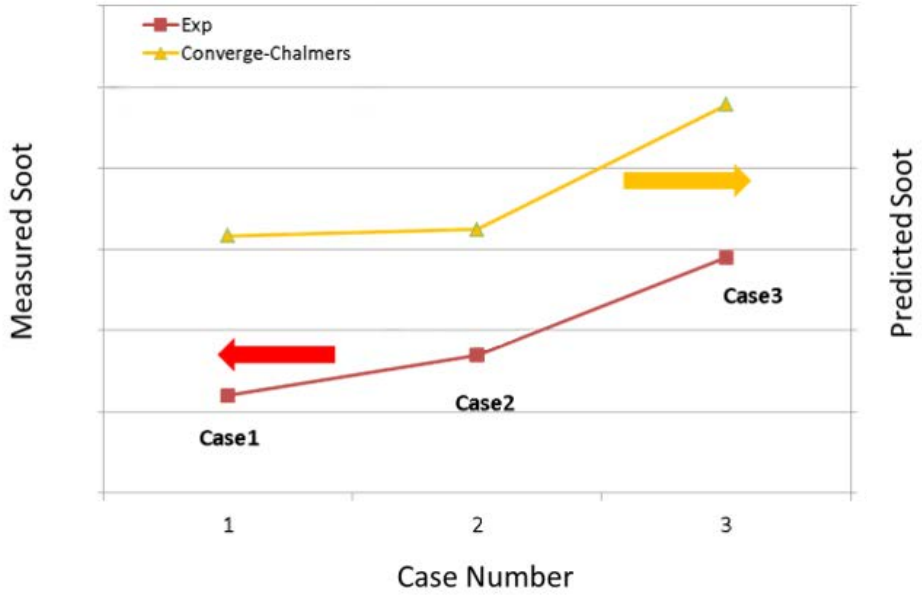
CONVERGE CFD SOFTWARE

Why CONVERGE for IC Engine Modeling?

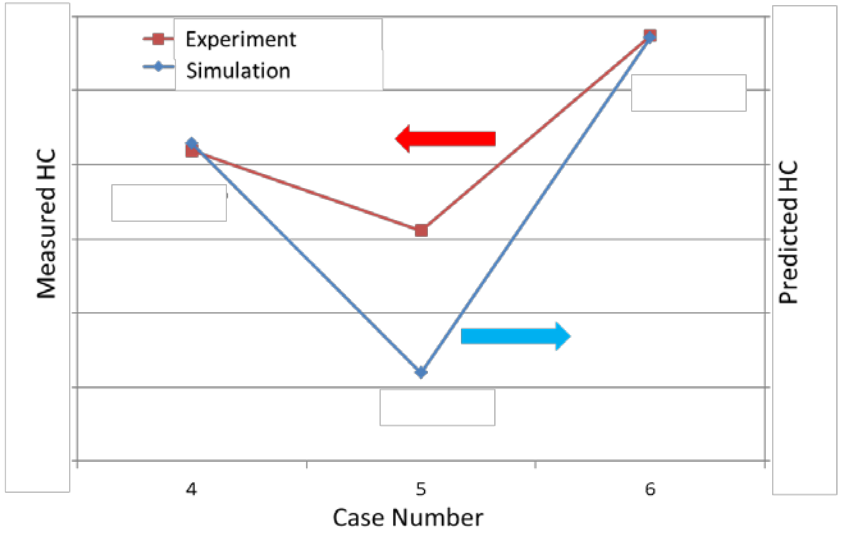
- Emissions Modeling



Diesel NOx



Diesel Soot

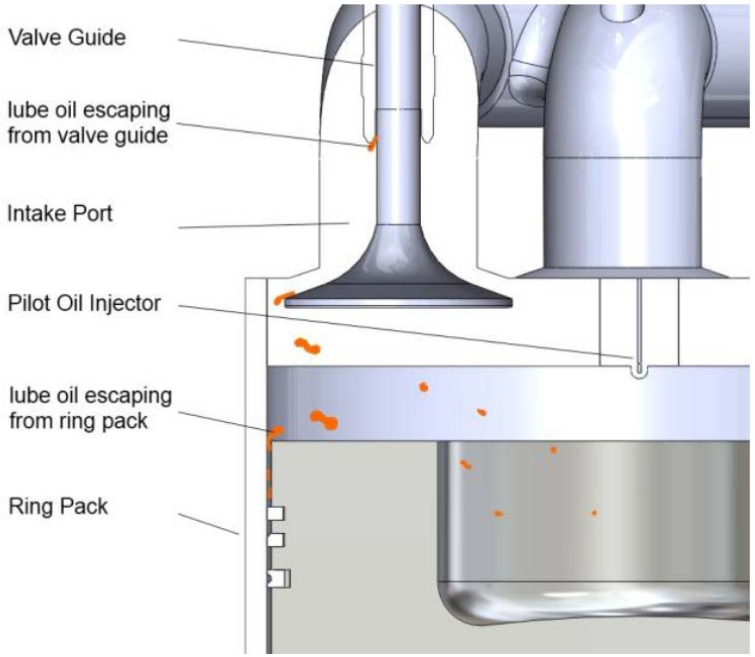


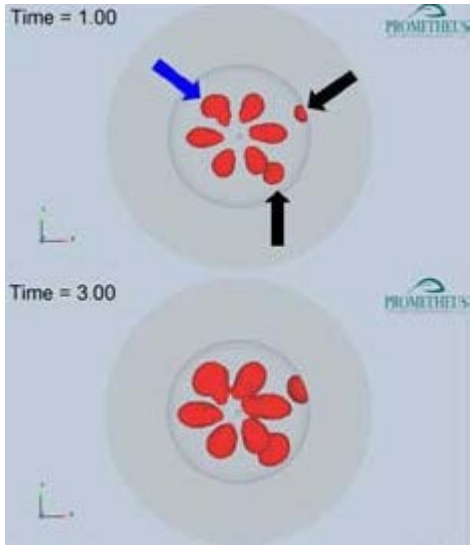
NG+Diesel DF Unburned HC

Authors' affiliation: GE
(ASME ICEF2015-1077)

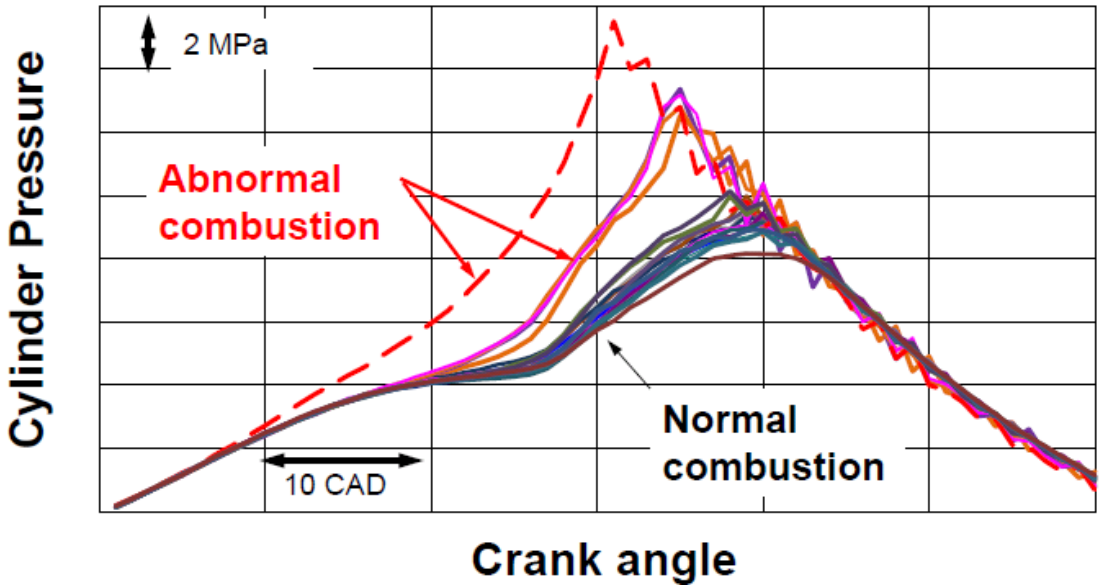
Why CONVERGE for IC Engine Modeling?

- Abnormal Combustion (Lube Oil Autoignition)





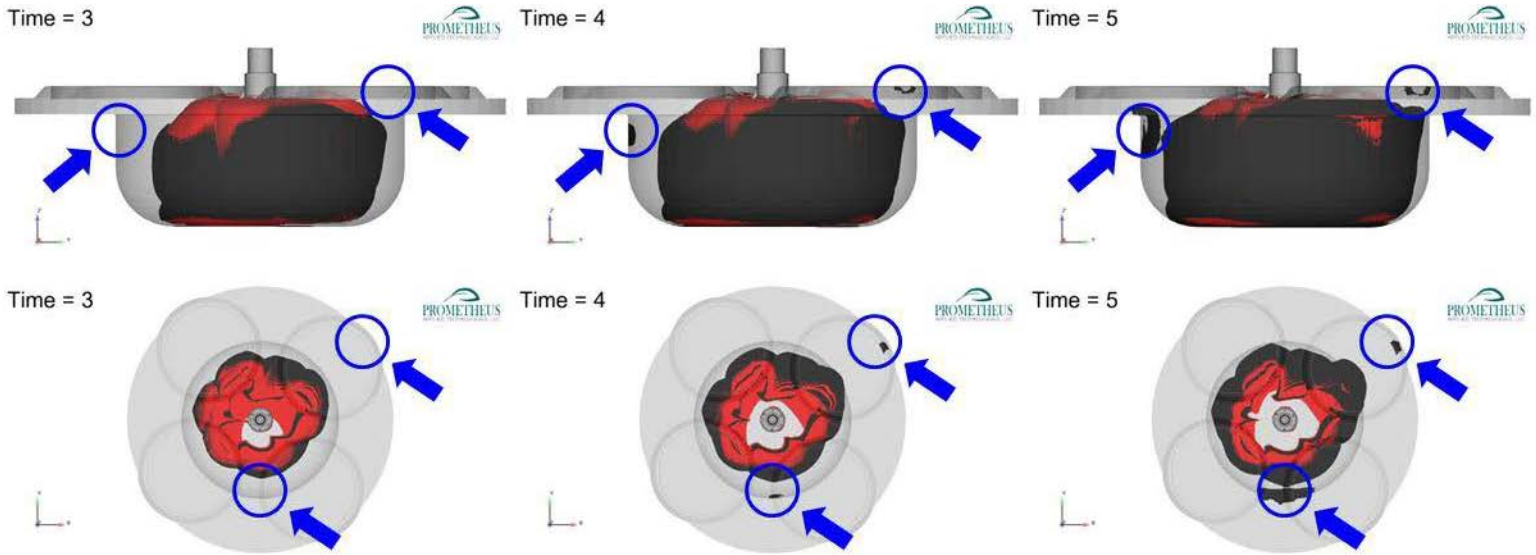
Lube oil autoignition



Authors' affiliation: Prometheus Applied Technologies
(CIMAC 2013, paper #37)

Why CONVERGE for IC Engine Modeling?

- Abnormal Combustion (End Gas Auto-ignition / Knock)



Red temperature iso-surface: Flame is shown using the

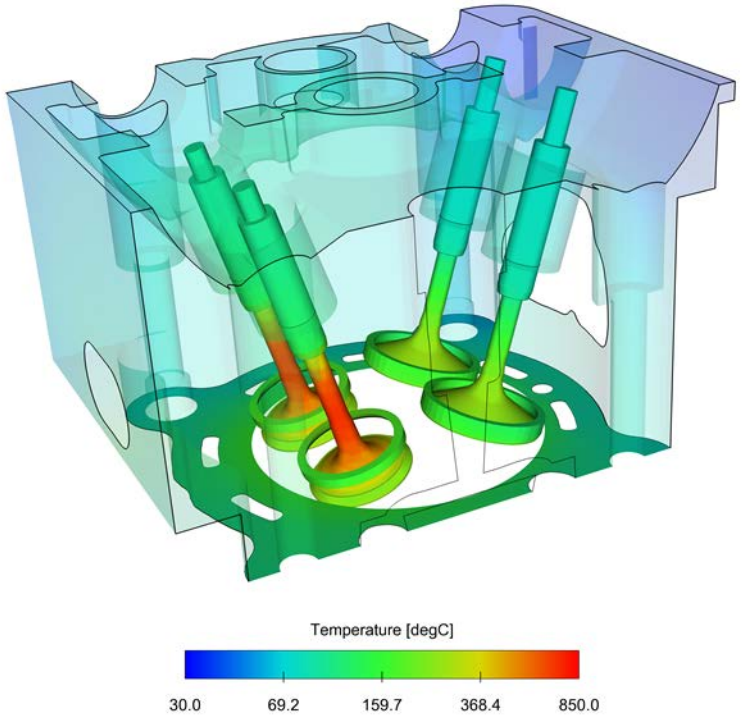
Black H_2O_2 iso-surface

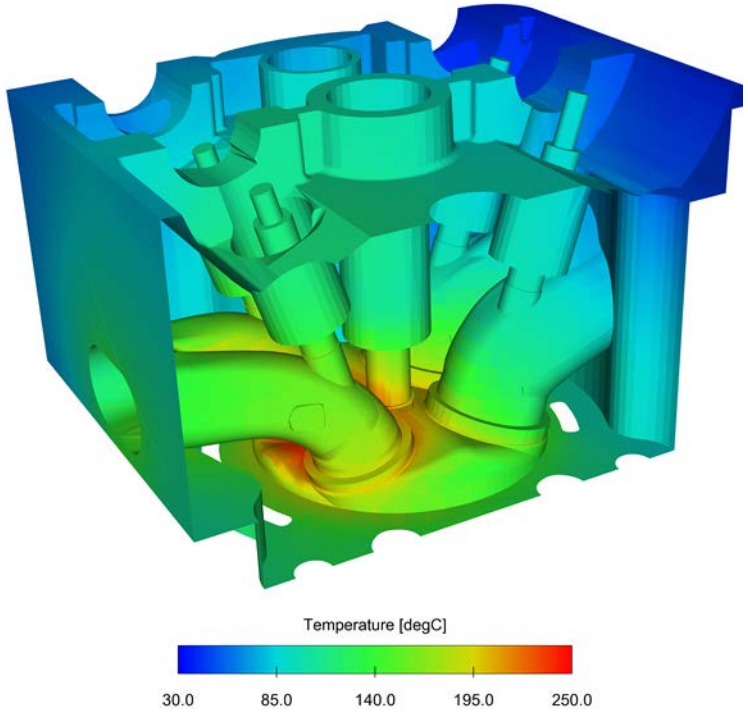
while end gas auto-ignition is shown using the

Authors' affiliation: Prometheus Applied Technologies

Why CONVERGE for IC Engine Modeling?

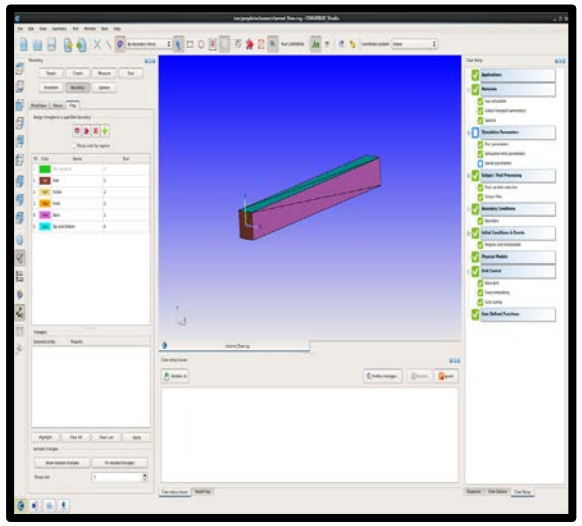
- Metal Thermal Analysis using CHT





What is the CONVERGE workflow?

CONVERGE Studio

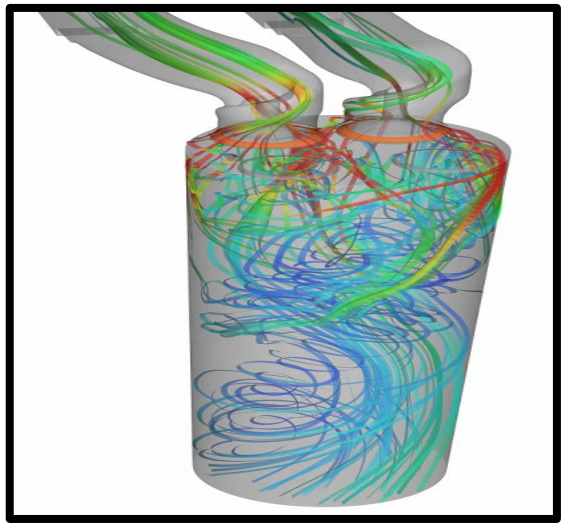


- Prepare geometry
- Set up input files
- Export surface and input files

CONVERGE solver

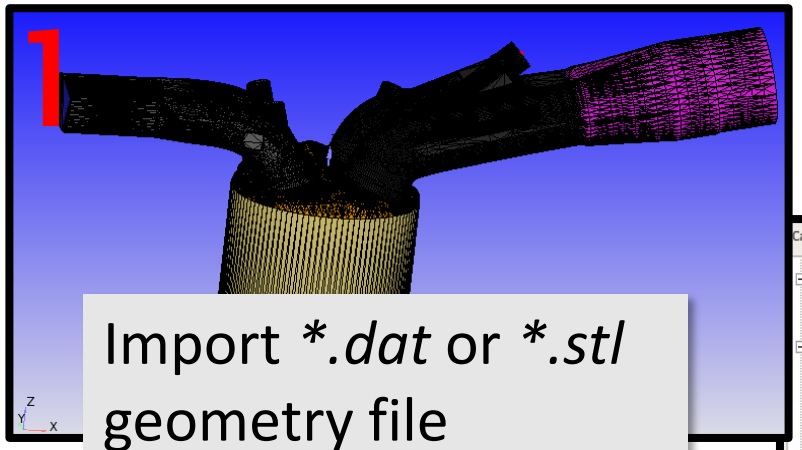
- Execute simulation in serial or parallel using local cluster or cloud computing

CONVERGE Studio



- Visualize 2D results
- Run *Post Convert* tool
- Launch Ensight

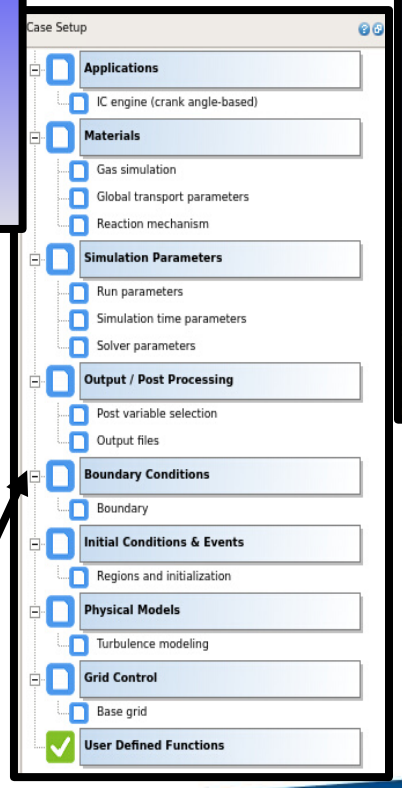
How do I set up a case in CONVERGE Studio?

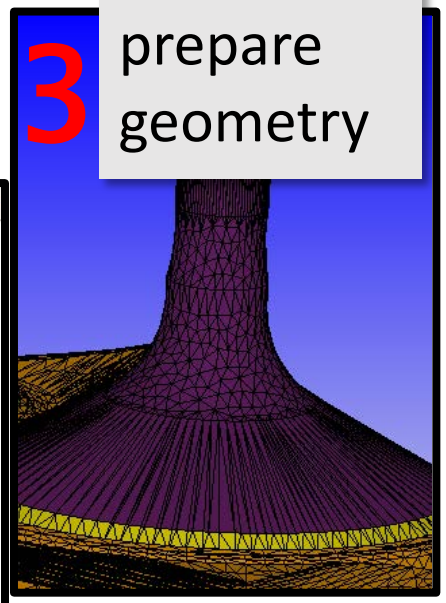


Import **.dat* or **.stl* geometry file

2 Import input (**.in*) and data (**.dat*) files if available

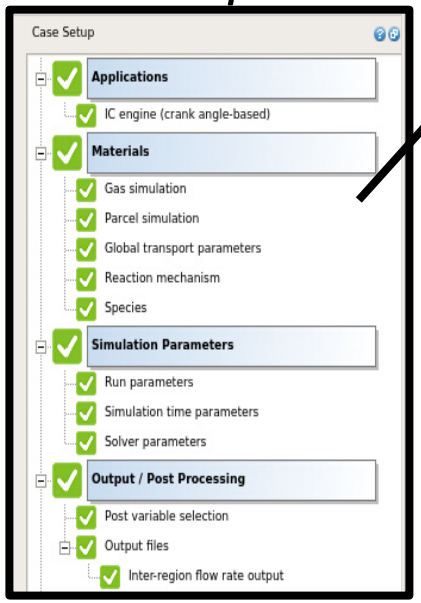
```
amr.in          initialize.in
boundary.in     inputs.in
combust.in      liquid.dat
events.in       post.in
embedded.in     species.in
gas.dat         turbulence.in
```





Repair and prepare geometry

4 Configure input files in *Case Setup*



5 Export input and data files

```
amr.in          initialize.in
boundary.in     inputs.in
combust.in      liquid.dat
engine.in       post.in
events.in       species.in
embedded.in     surface.dat
gas.dat         turbulence.in
```

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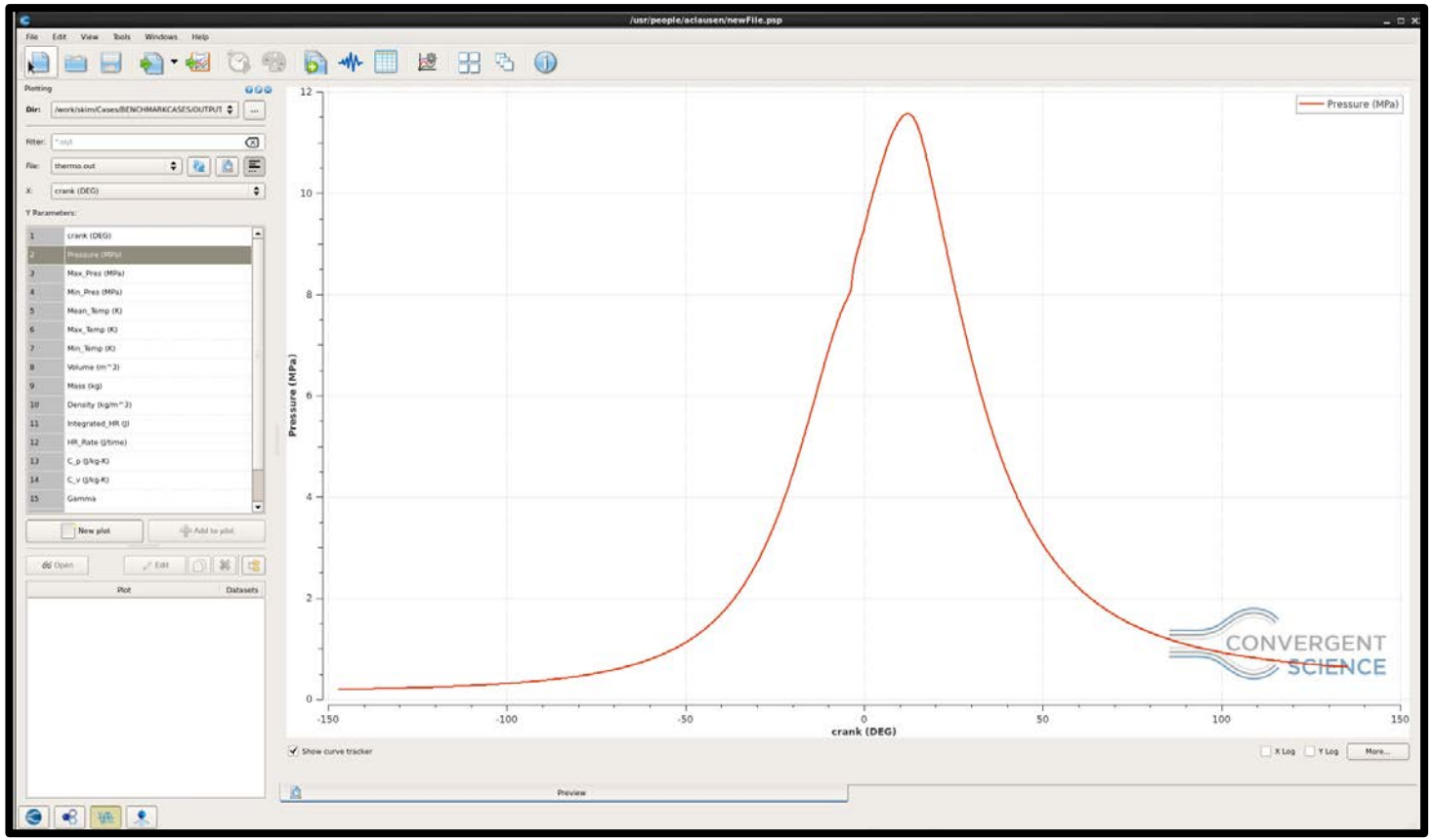
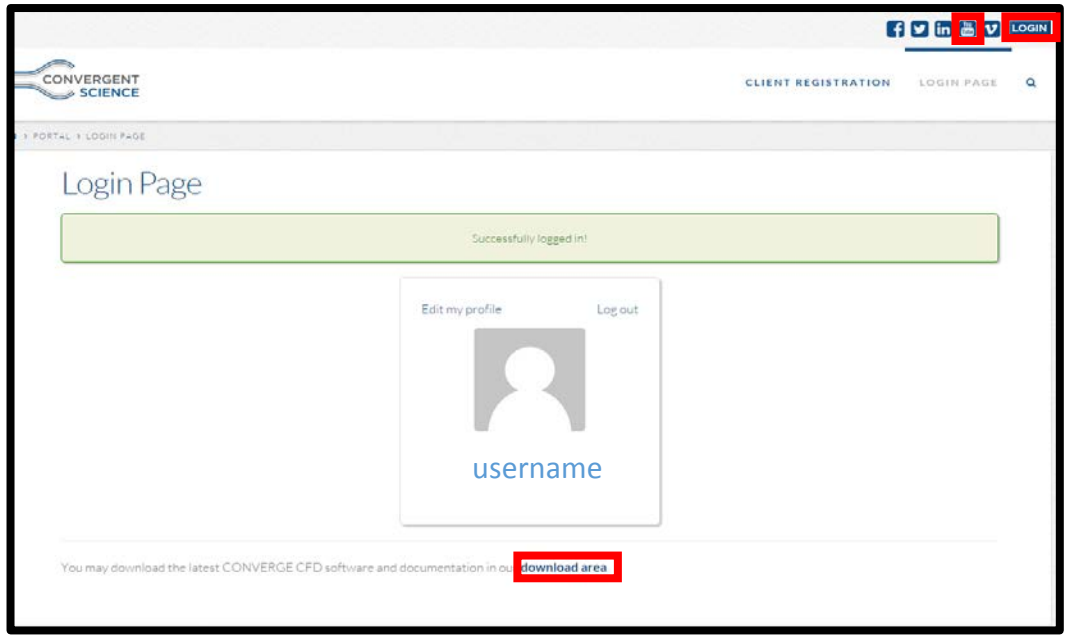
What post-processing tasks can I do in CONVERGE Studio?

- Create and export 2D plots
- Calculate values such as apparent heat release and engine work
- Post-convert data for 3D visualization
- Launch EnSight for 3D visualization



Do you have questions about CONVERGE?

- Contact the Support Team at **support@convergecfd.com**
- Download documentation at **convergecfd.com**
  - Getting Started Guide
  - CONVERGE Manual + Release Notes
  - CONVERGE Studio Manual + Release Notes
  - CONVERGE UDF Manual
  - Quick Setup Guides
    - PDF + set(s) of input and data files
- Watch videos at **convergecfd.com**
  - Complete cases (channel flow, port fuel injected engine) from pre- to post-processing
  - Miscellaneous videos



CONVERGE CFD SOFTWARE

Advanced Training Topics

Scheduled on request

- Sealing: 2-stroke or rotary engines
- Heat transfer mapping
- UDF
- GA optimization
- GT-SUITE coupling
- Radiation modeling
- FSI
- Advanced combustion modeling
- CHT
- Engine aftertreatment
- Advanced pre- and post-processing
- Gas turbine combustion

THANK YOU!

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