

# The Importance of Analysis in the Cummins Engine Development Process



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# Brief History of Analysis at Cummins

- Through the early 90's, analysis was component based and more reactive than proactive
- Several factors energized an initiative called "Analysis Led Design" (ALD) whose underpinning is Technical Productivity
  - Down turn in 2001-2002
  - Expanding global products
  - Achievements in the combustion arena
  - Challenging criteria pollutant regulations as well as efficiency
  - Engineering Standard Work
- Traditional Areas that leverage High Performance Computing
  - Structural and Dynamic Analysis
  - Combustion System Design
  - 3-D CFD (broadly)



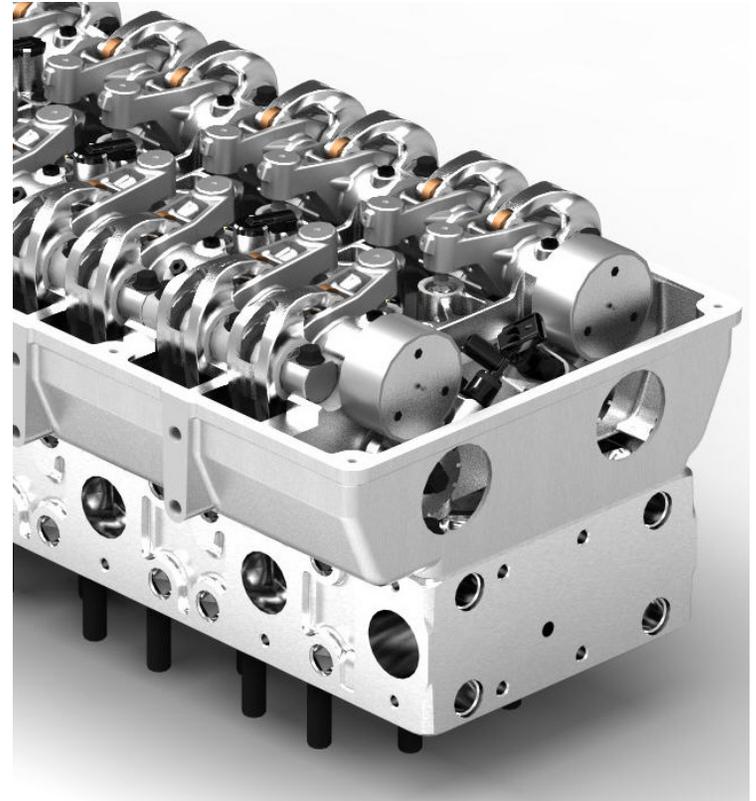
# Structural & Dynamic Analysis

## ■ Key Advances

- Fluid Structural Interaction
- Conjugate Heat Transfer
- System-level modeling-non-linear
- Improved geometry manipulation and meshing capability

## ■ Key Gaps

- Thorough set of fatigue data
- Data management-data transfer is slow
- Fast/low cost data storage
- Robust non-linear analysis
- Predictive noise analysis
- True multi-physics tools
- Available RAM



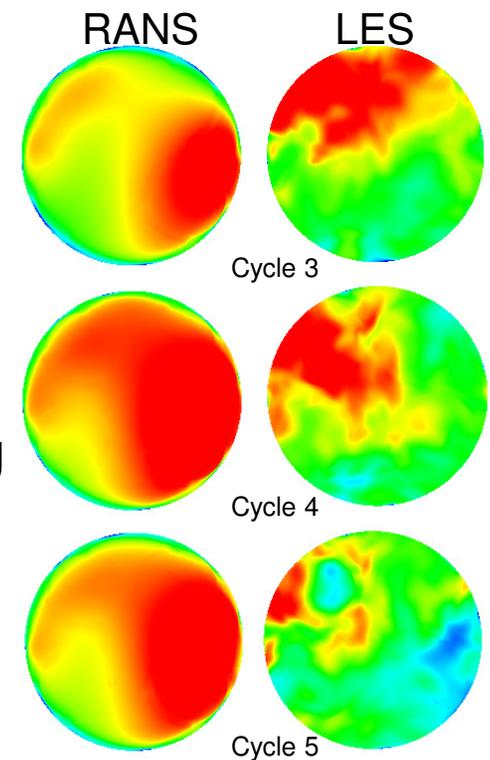
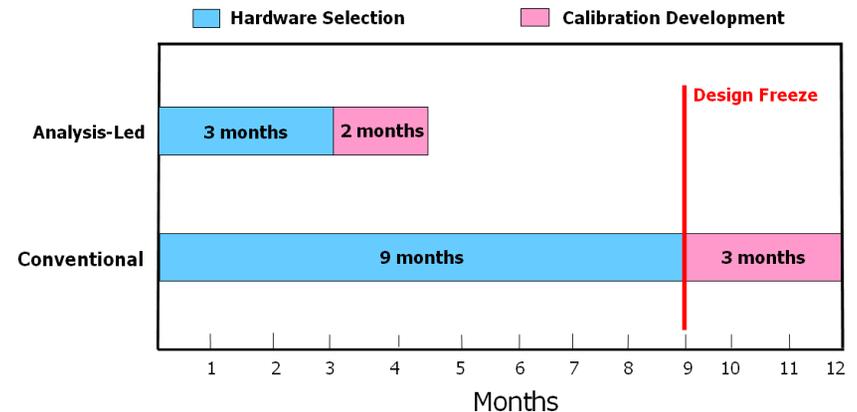
# Combustion Design

## ■ Key Advances

- Analysis Led Combustion Design for all engine programs
- Prediction of low emissions
- Development of alternative fuel reduced kinetics
- Use of LES to study cycle to cycle variation

## ■ Key Gaps

- Fully-Coupled Large Eddy Simulation (LES) with Sprays and Chemistry
- Improved Combustion and Emissions Models
- Injector Internal Flow and Spray Routine Coupling
- Computation time
  - Use of GPU Technology
  - Communication between nodes



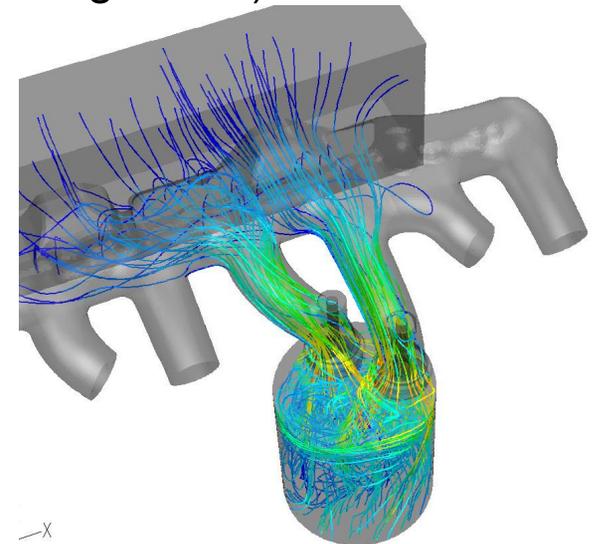
# 3-D CFD

## ■ Key Advances

- Routine use of steady state CFD
- Unsteady CFD combined with engine simulation
  - Computation time reduced from 1-3 weeks to 1-3 days
- Time to create grids
- Combines engine cycle simulation, in-cylinder combustion modeling, fluid flow and heat transfer modeling
  - computational time for modeling of the cylinder head (including intake and exhaust port flow, coolant flow and conduction through solid) has been reduced from 1 -2 days to 1-2 hours
- Prediction of piston temperatures
- Prediction of boiling

## ■ Key Gaps

- Cost effective parallelization



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# Summary

- Analysis Led Design was a necessity
- High performance computing continues to improve productivity
- Required use of ALD in the development processes accelerates its implementation
- Engineers must be devoted to developing and improving tools and processes
- Measures reviewed by senior leadership
- Computation time and model accuracy are limitations
- Current expansion into controls modeling and catalyst modeling offering significant opportunity

