The Importance of High Performance Computing from a Software Vendor's Perspective

P. K. Senecal, Ph.D.
Co-owner and Vice President

CONVERGENT SCIENCE

Presentation Outline

- Motivation

- Company background

- Software background

- Challenges in IC Engine Modeling

- The role of High Performance Computing

- Future Directions

Motivation

As a CFD software vendor, it is our responsibility to provide our customers:
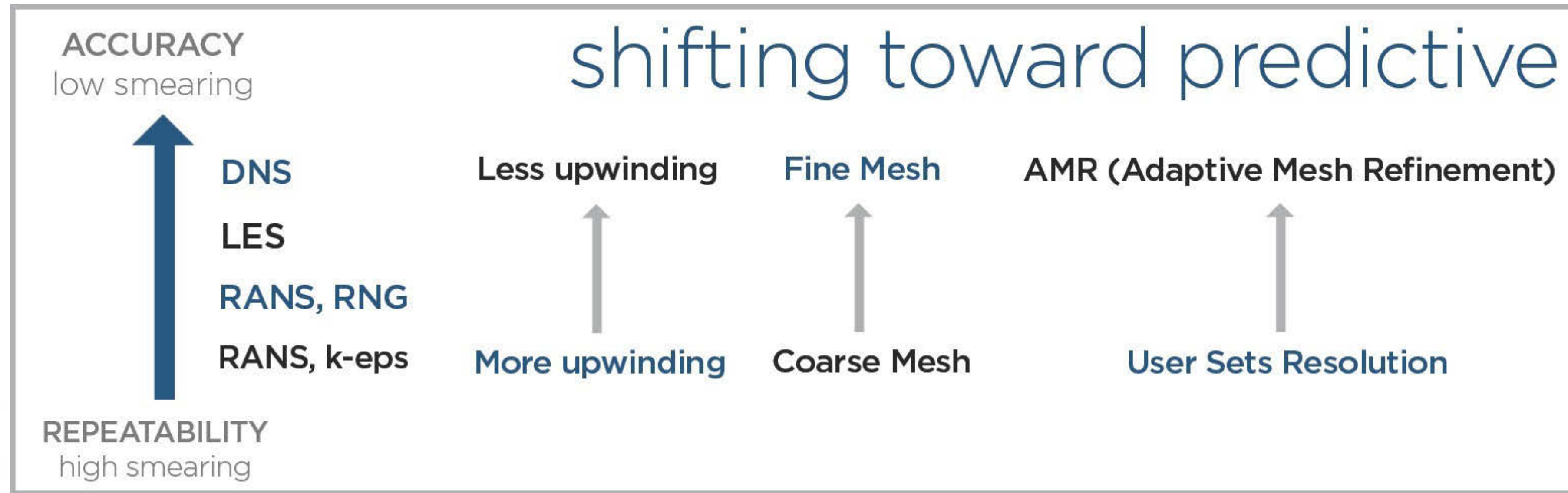
the best possible answers

in the shortest amount of time

How can we improve our software *and our knowledge* when given access to HPC?

- Running very large simulations
- Running a lot of small to medium simulations

The Best Possible Answers…

ACCURACY
low smearing

shifting toward predictive

DNS
LES
RANS, RNG
RANS, k-eps

Less upwinding   Fine Mesh   AMR (Adaptive Mesh Refinement)

More upwinding   Coarse Mesh   User Sets Resolution

REPEATABILITY
high smearing

✳ **More expensive Computationally**

Low Order ➡ **High Order**
Over-Mixing ➡ **Realistic Mixing**
Coarse Mesh ➡ **Grid-Convergence**
Repeatability ➡ **Accuracy**
Ensemble Avg. ➡ **Unsteady**

The Best Possible Answers…

More is Better!

- More mesh
- More chemistry
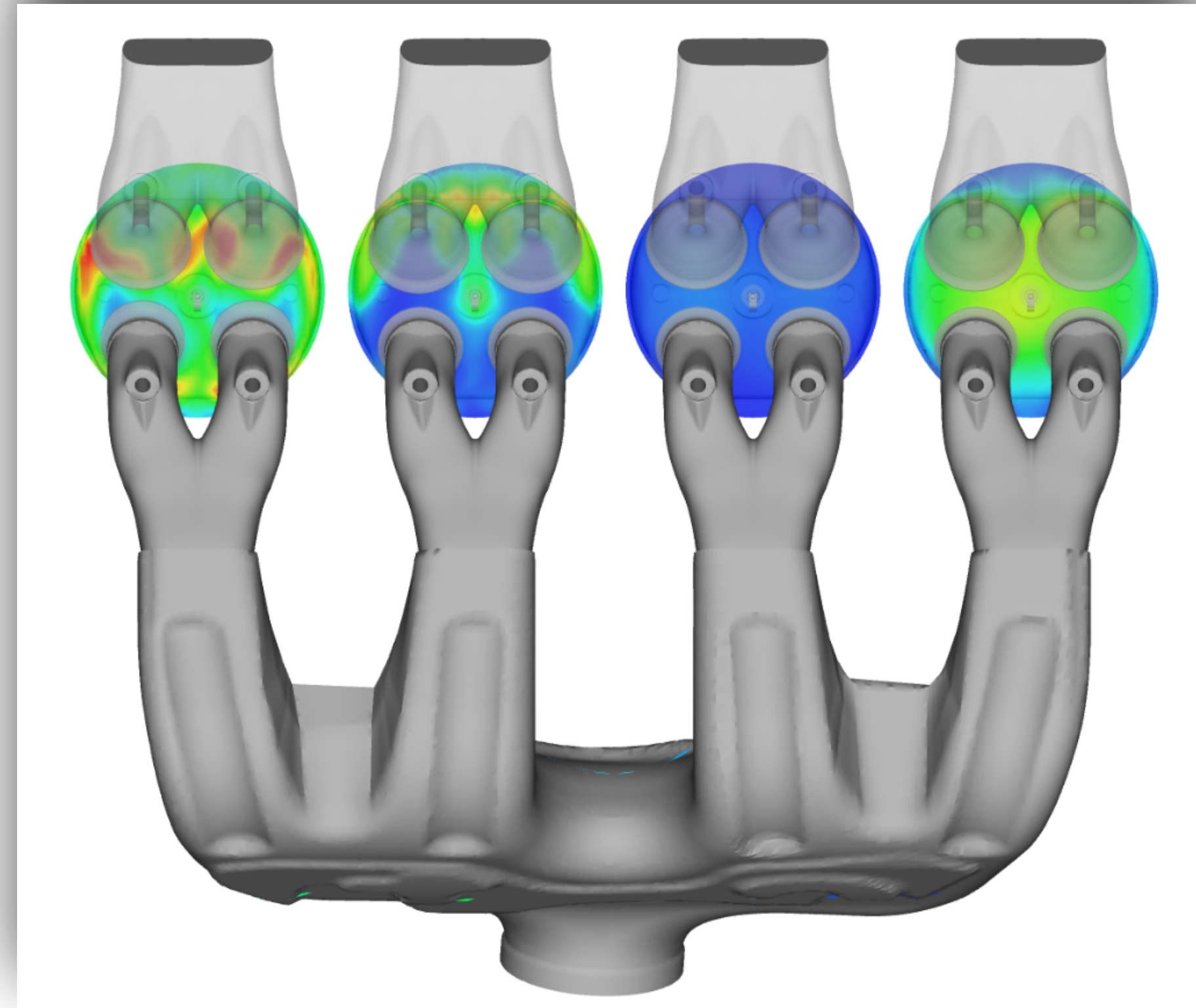- More resolved scales
- More cycles
- More geometry

Image Courtesy of Chrysler Group LLC

…In the Shortest Amount of Time

HPC Enables

- Use of high-spatial and temporal resolution
- High-fidelity turbulence models (LES)
- Use of detailed chemistry based combustion models
- Solving "one-of-a-kind" problems

Benefits

- Unprecedented insights into the combustion process
- Grid-convergent results
- Increased predictive capability
- Modify "best practices" in industry

Convergent Science Background

- Founded in 1997 as graduate students of the University of Wisconsin-Madison
- Started developing CONVERGE in 2001 to address CFD bottlenecks
- Started selling CONVERGE licenses in 2008
- Have been experiencing rapid growth since 2008, growing from 5 to over 50 employees
- Work closely with OEM's, National Laboratories, and Universities
- Europe and Japan are following the adoption trends seen in the US
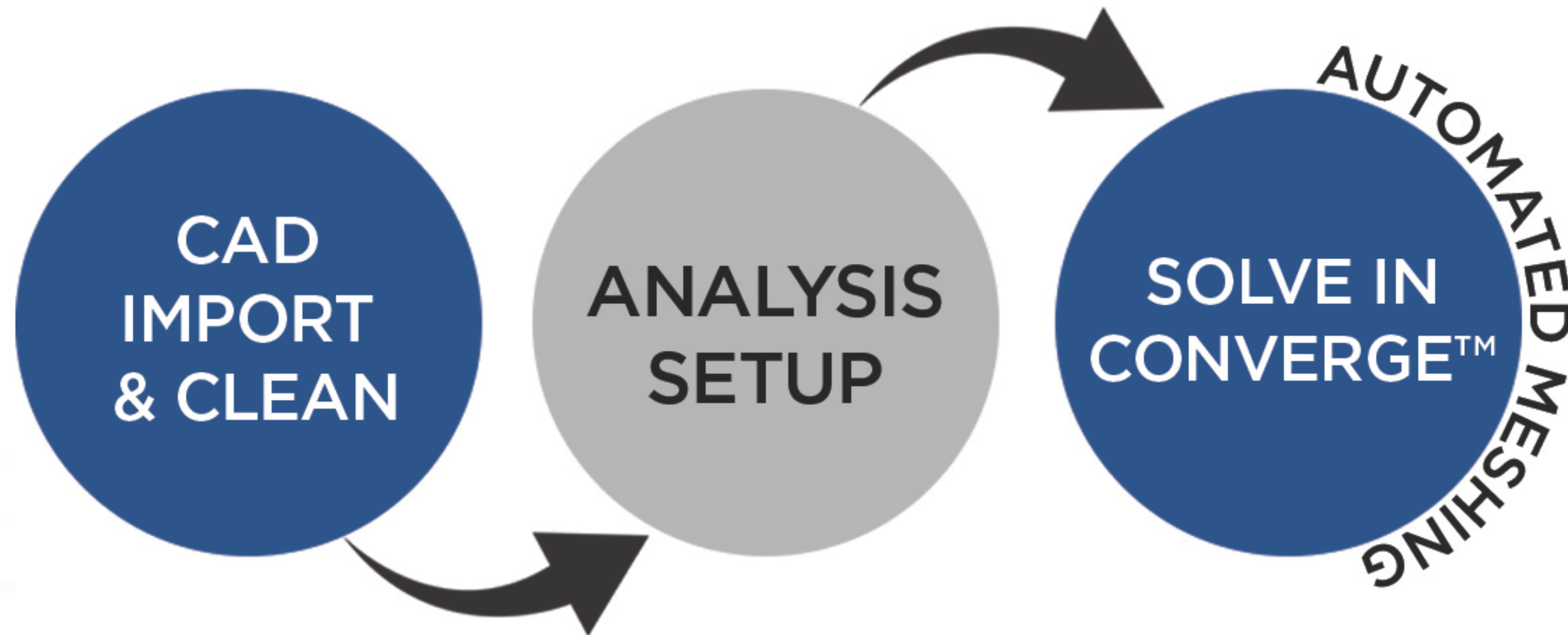

HQ in Madison, WI

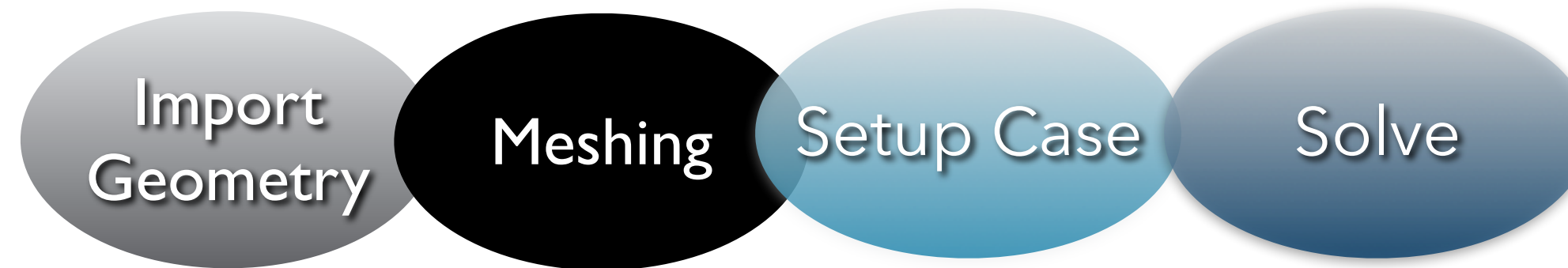# Convergent Science Background

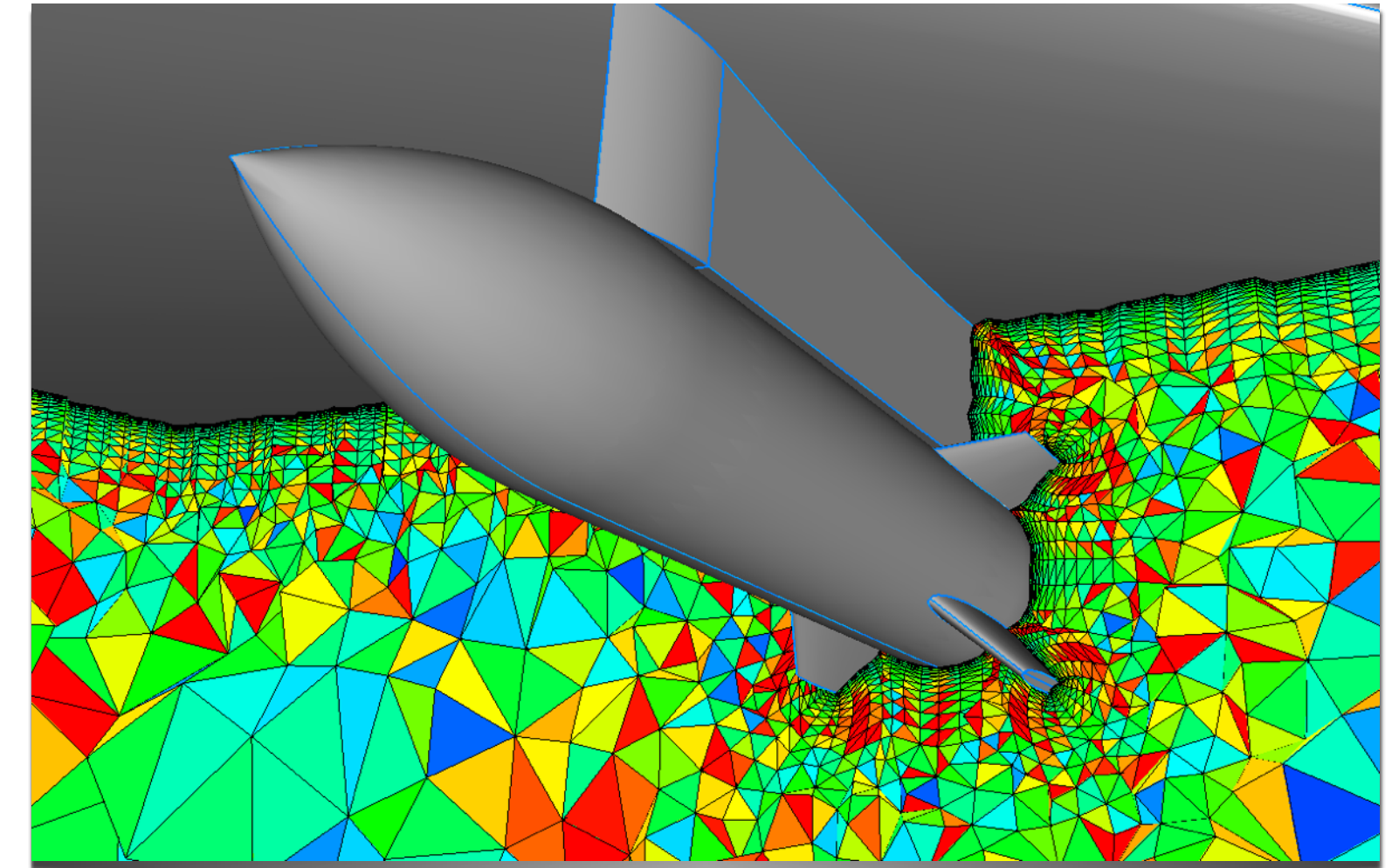# CONVERGE CFD Software

CONVERGE CFD Software

The Mesh Generation Bottleneck

- **Traditional Approach**

  Import Geometry → Meshing → Setup Case → Solve

  - Long meshing times
  - Meshing by guessing
  - Skewed cells
  - Grid convergence?

- **Our Approach**

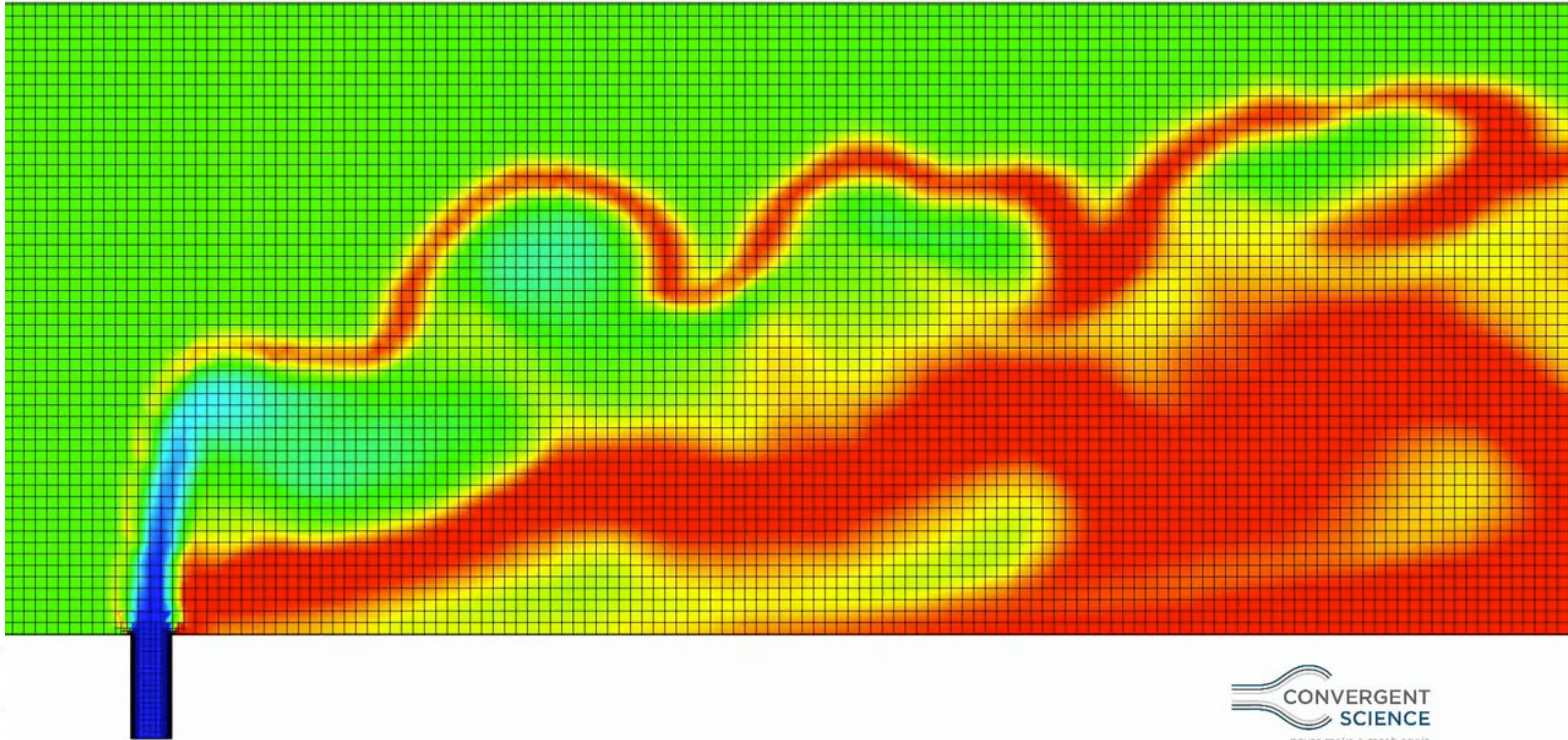 Import Geometry → Setup Case → Solve

  - Automated meshing (no meshing time)
  - Adaptive Mesh Refinement (AMR) – no more guessing
  - Orthogonal cells
  - Easy to perform grid convergence studies
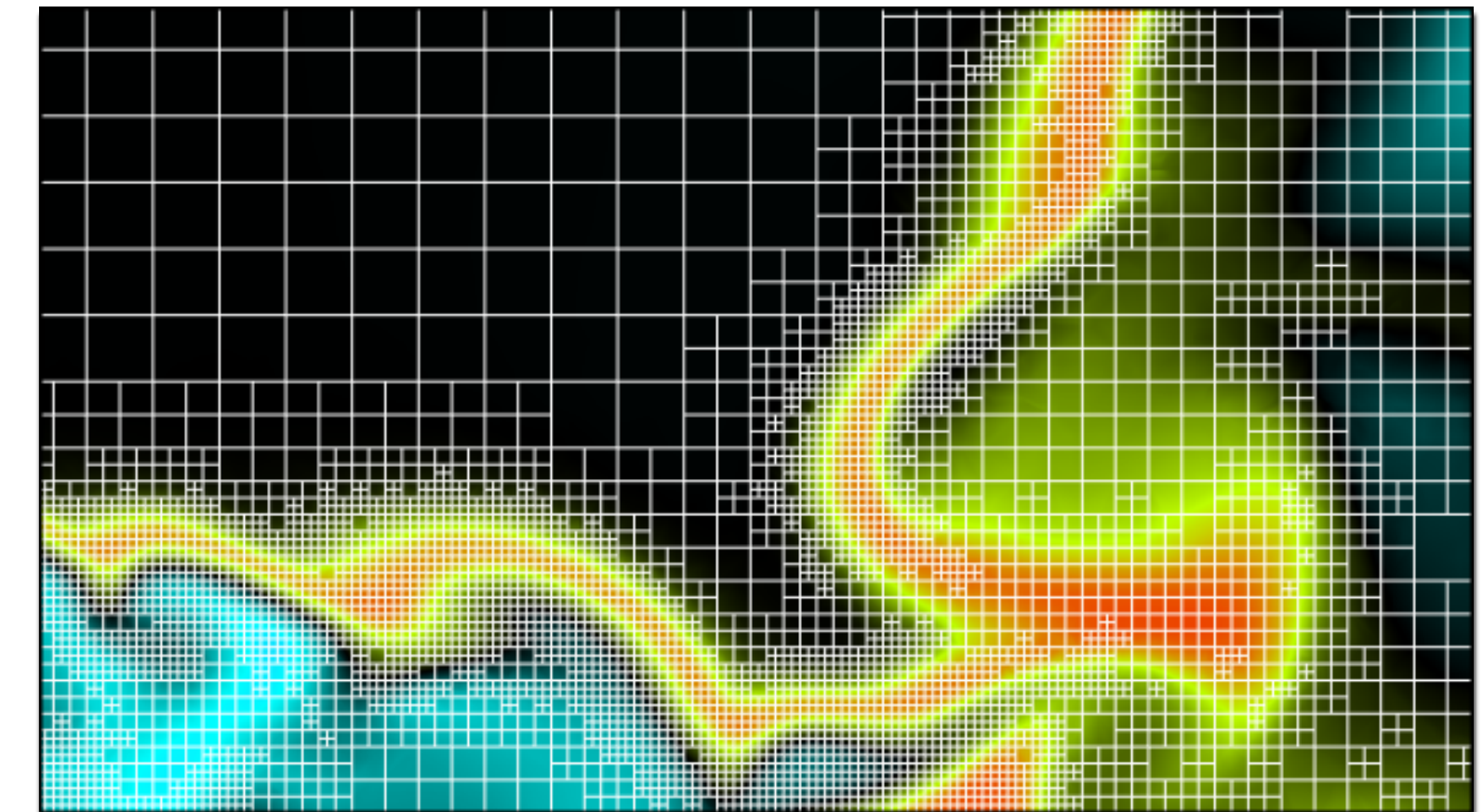
The Mesh Generation Bottleneck

Challenges in IC Engine Modeling

As engine CFD becomes more tightly integrated into the design process, it must be faster and more accurate than it has been traditionally.

- **Speed.** Design timescales are significantly shorter than in research—results are needed in days, not weeks or months. Areas of improvement in speed include:
  - Improved scalability
  - Processing power
  - Chemistry improvements
  - Optimization

- **Accuracy.** The results must be reliable, or good decisions cannot be made. Areas of improvement in accuracy include:
  - Meshing
  - Models
  - Physical inputs

Challenges in IC Engine Modeling

Many benefits of increased accuracy

- Realistic mixing predictions
- Grid convergence
- Unsteady phenomena (misfire, knocking)
- Cyclic variability
- Improved emissions predictions
- CHT - reliable temperature predictions

High accuracy is needed for predictions of unsteady phenomena, cyclic variability and emissions
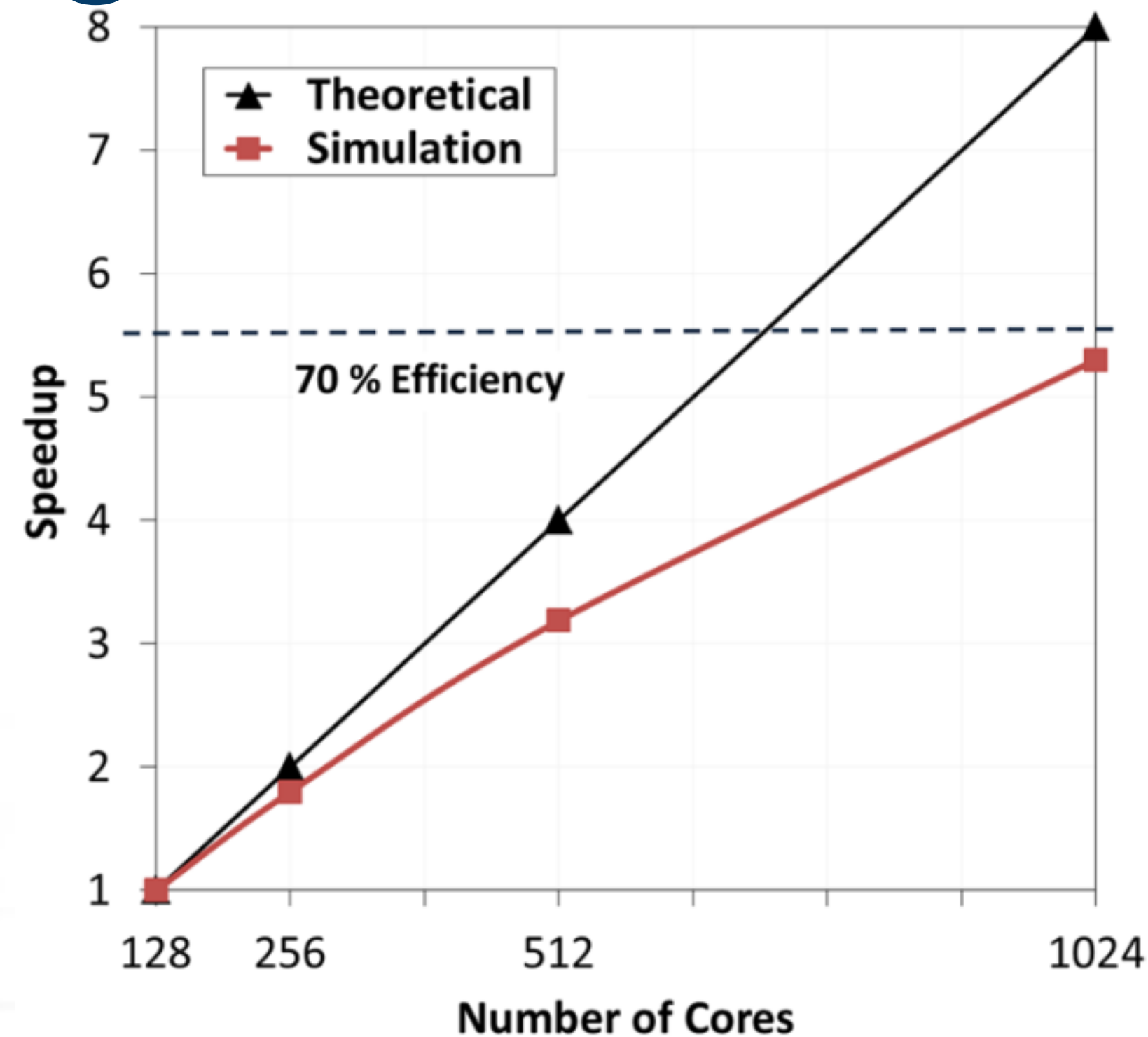
But comes at a cost of longer runtimes

Industry needs fast turnaround times in order to help make design decisions!

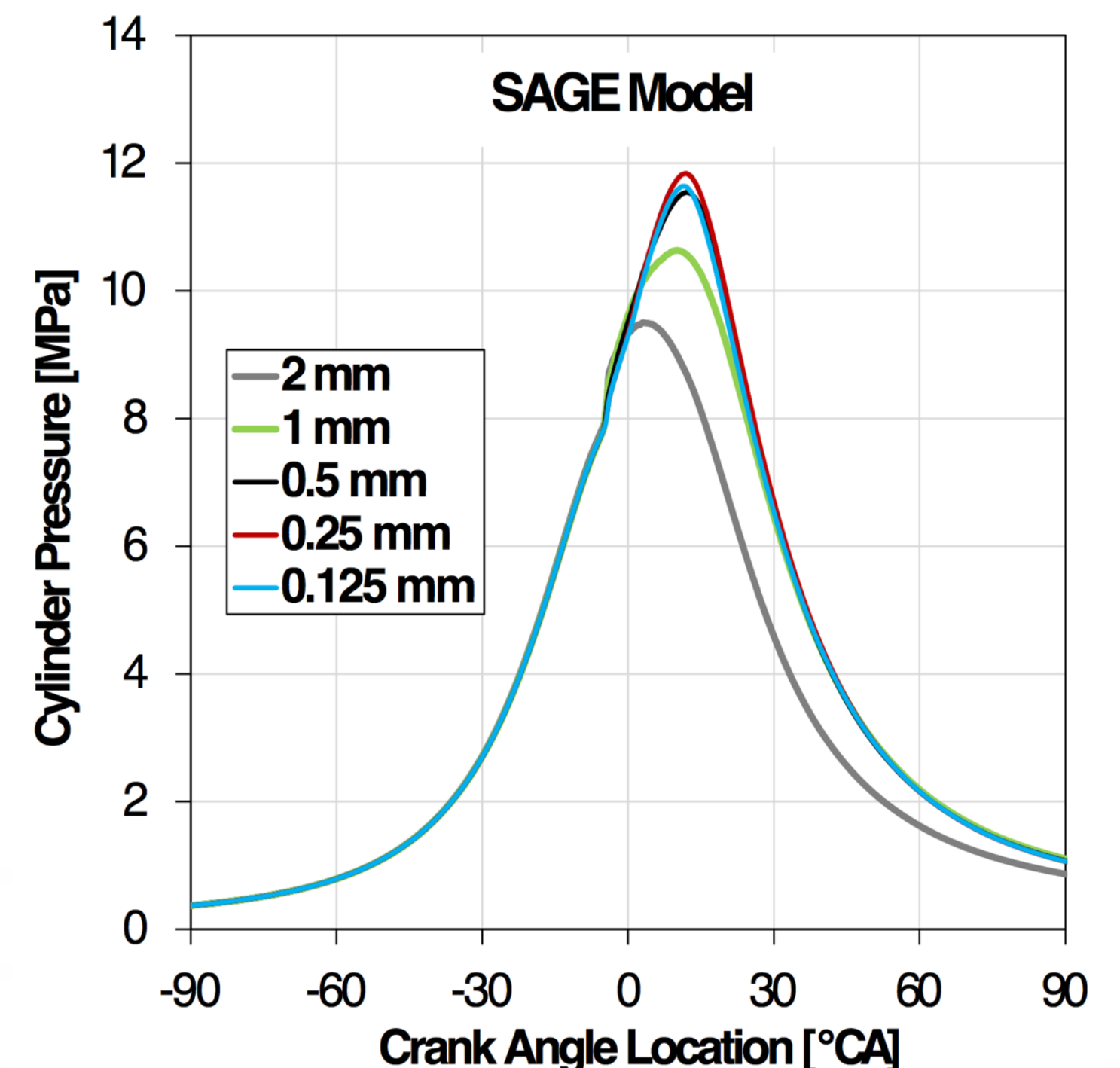The major obstacle is that predictability and quick turnaround are at odds

High Performance Computing

- Improved load balancing in CONVERGE
- Engine simulations have been run in a scalable fashion on 2048 processors at the leadership computing facility (LCF) at Argonne
  - ★ Scalable => At least 70% efficiency
- Full engine simulations with up to 34 million cells, run on 256 cores for 13 days

- Further enhance scalability by improving I/O issues
- Use HPC to perform high-fidelity multi-cylinder open-cycle simulations

*Som et al. SAE 2013