Multicylinder Diesel Engine Design for HCCI operation

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Diesel Engine Development

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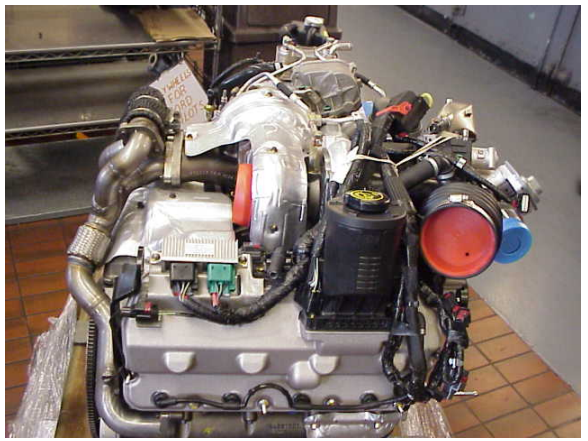


ITEC 6.4L

1. **Objectives of Program**

   Reconfigure ITEC V8 6.4L engine to operate on HCCI throughout the speed and load range.

2. **Engine Development**

   (a) Based on “best” engine hardware, the engine lug curve is defined.

   (b) Optimization tools are applied to FIE, turbocharger, cooling systems.

   (c) Control Strategy and hardware are developed to sustain combustion process based on cylinder pressure feedback.

3. **Next Phase**

   Engine Steady State Testing

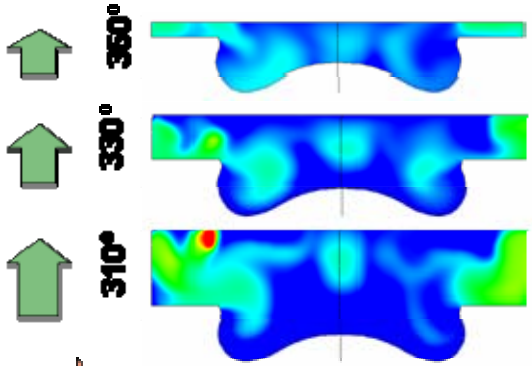
   Transient operation

Key Enabler Technologies

Loss motion valve control

Hardware:

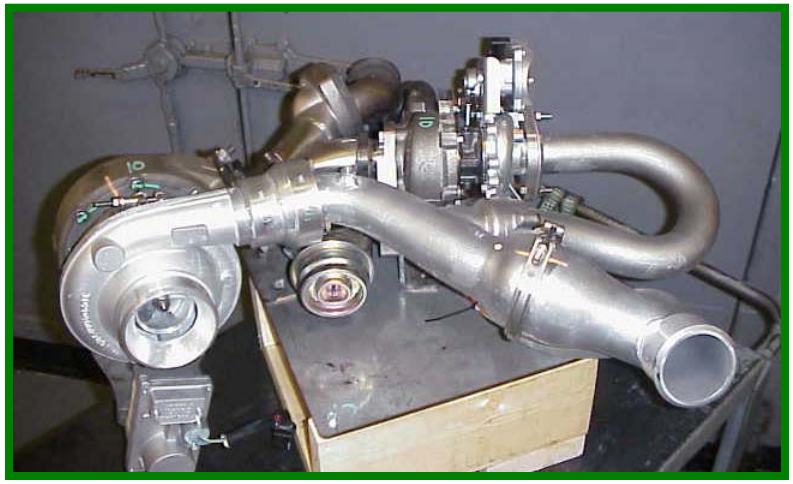
1. Variable valve actuation system
2. Flexible FIE
3. CAC with bypass and heater
4. Cooled EGR
5. Two-stage turbocharger unit



Spray modeling

Simulation

1. Spray CFD analysis
2. Chemical Kinetics
3. 1-D Engine Performance



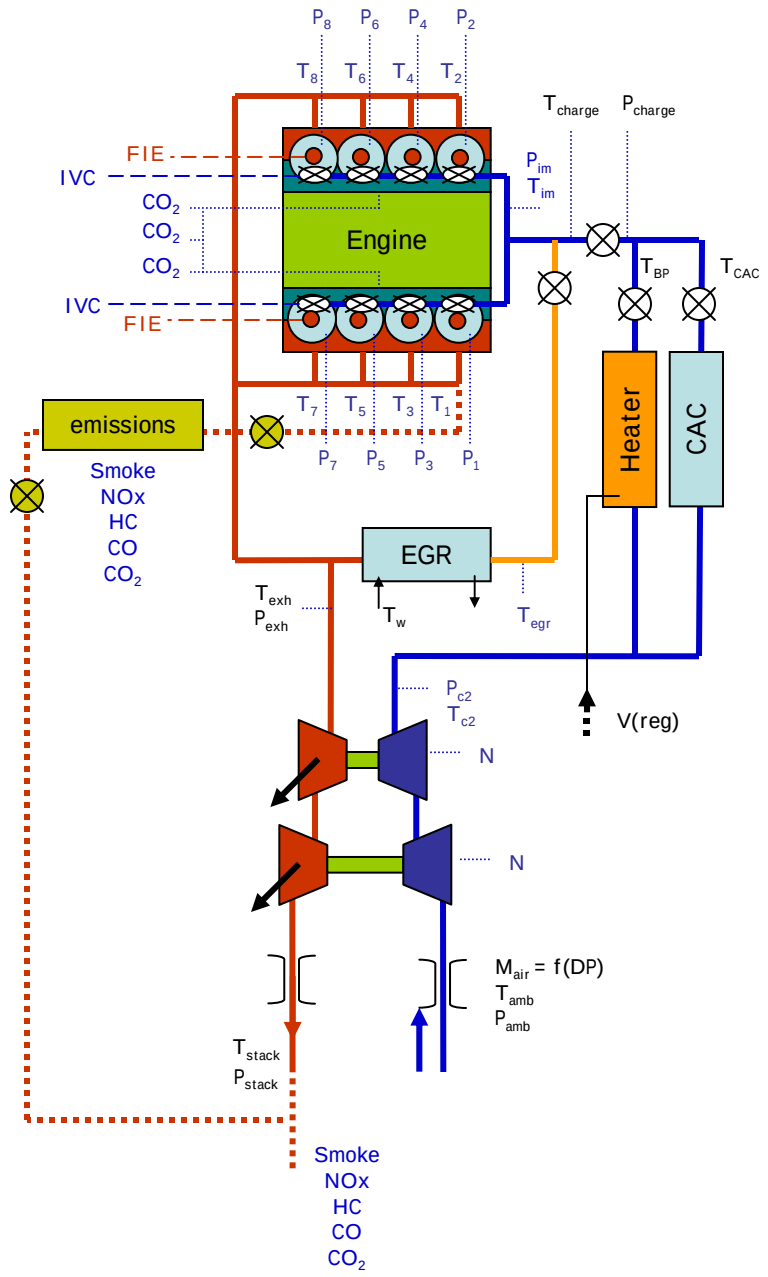
Two-stage turbocharger technology

Control System

Engine Layout

Laboratory Set-up:

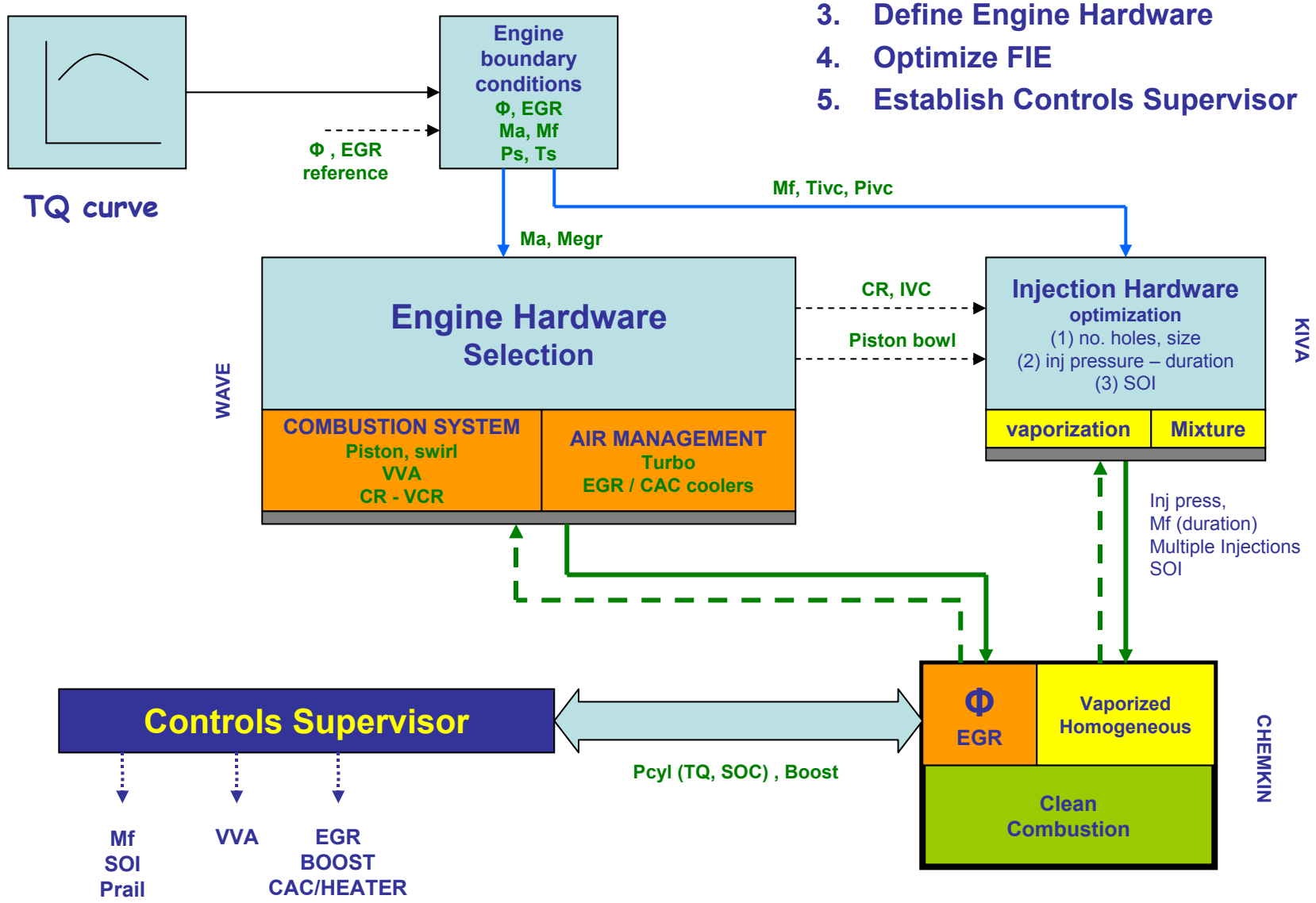
1. Establish overall manifold temperature, boost control:
   a. Boost regulation
   b. CAC / heater control
   c. EGR control
2. Commence control over single cylinder to later expand to multi-cylinder operation.
   a. Validate single cylinder emission probe
   b. Validate control diagnostics and algorithms
3. Implement injection system
4. Implement turbocharger
5. Implement cylinder head
6. Implement VVA system



Design Procedure

Goal:

1. Define LTC conditions
2. Define Engine Torque and Performance
3. Define Engine Hardware
4. Optimize FIE
5. Establish Controls Supervisor



Boundary Conditions

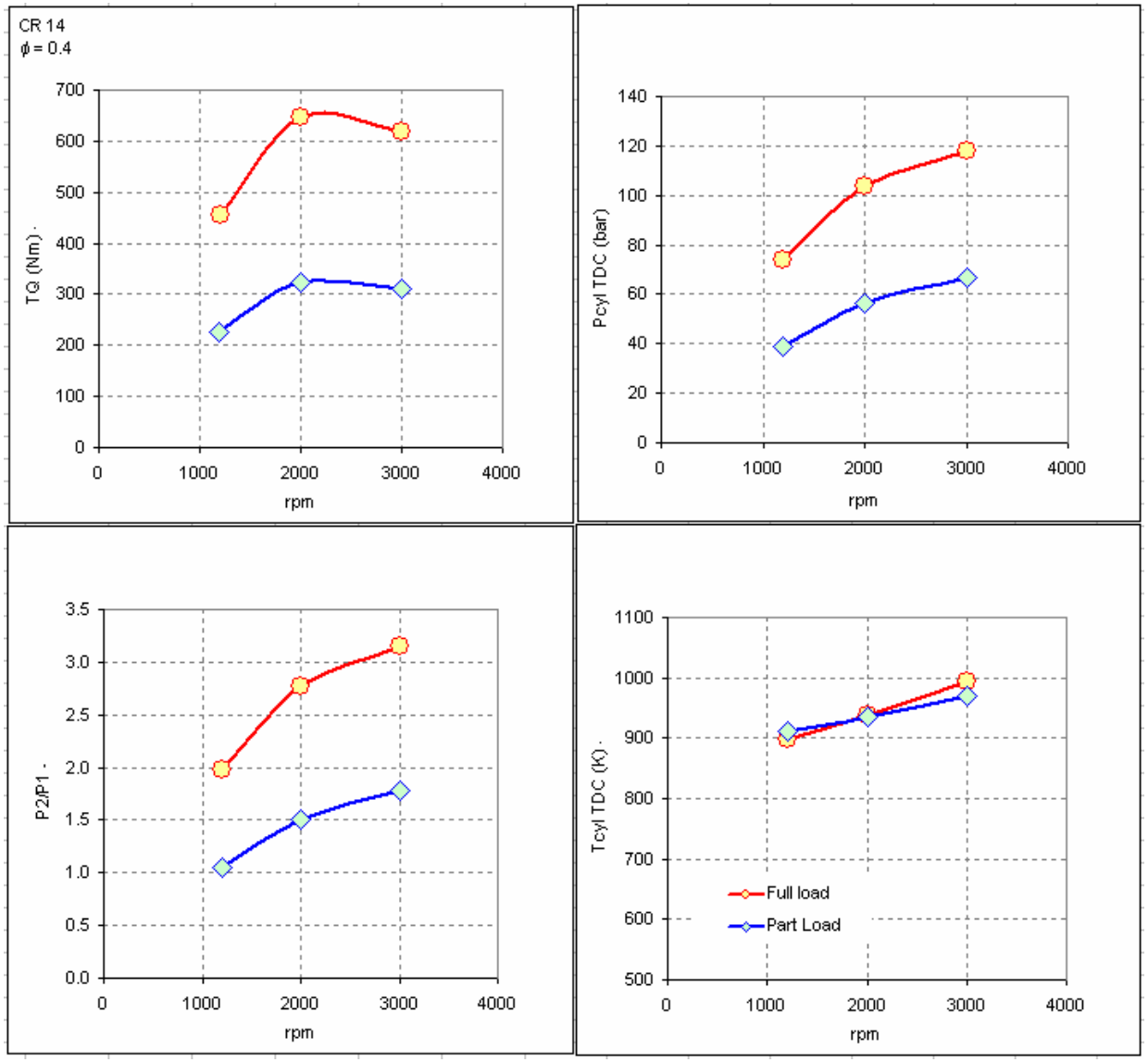
BCs are established based on:

- Torque line
- EGR and CAC specs
- CR=14
- Φ = 0.4
- EGR rates 40-50%

With hardware requirements to yield:

Max in-cylinder temperatures *to sustain auto-ignition control (compression max temperatures of 900K)*

Capable turbocharger output



Effects of IVC

Illustrated for rated condition

Capabilities of IVC:

- **Lower in-cylinder temperatures, *pressures***

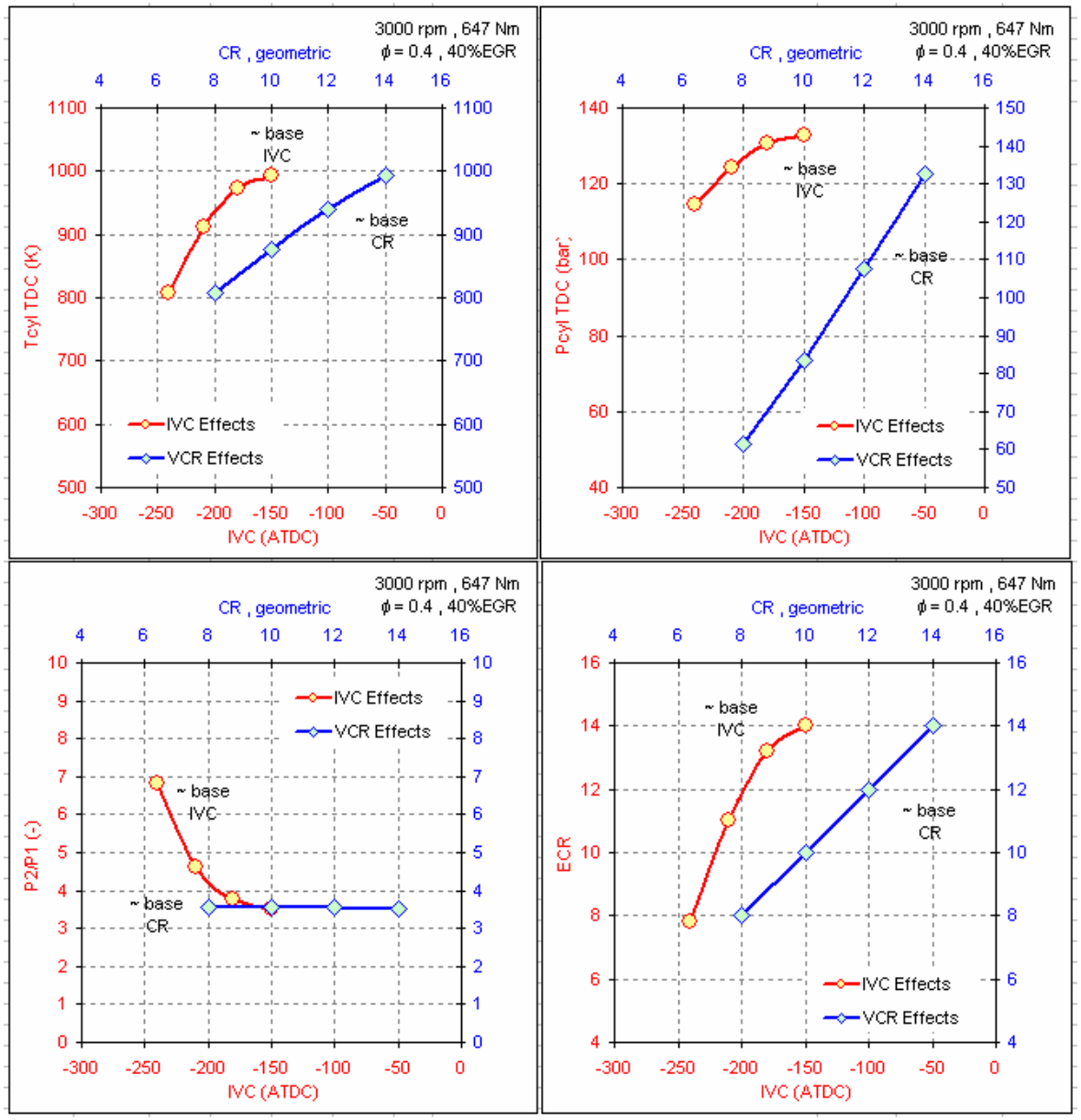
Penalties associated with IVC:

- **Extra boost required from compressor**

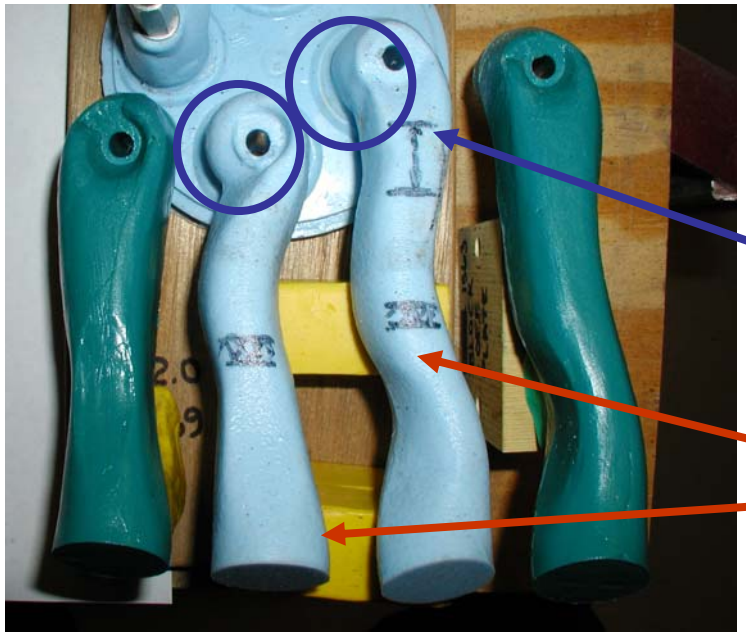
Added Notes:

Same effects obtained with varying the geometric compression ratio without the associated penalties

IVC gives the capability for cylinder-to-cylinder trimming

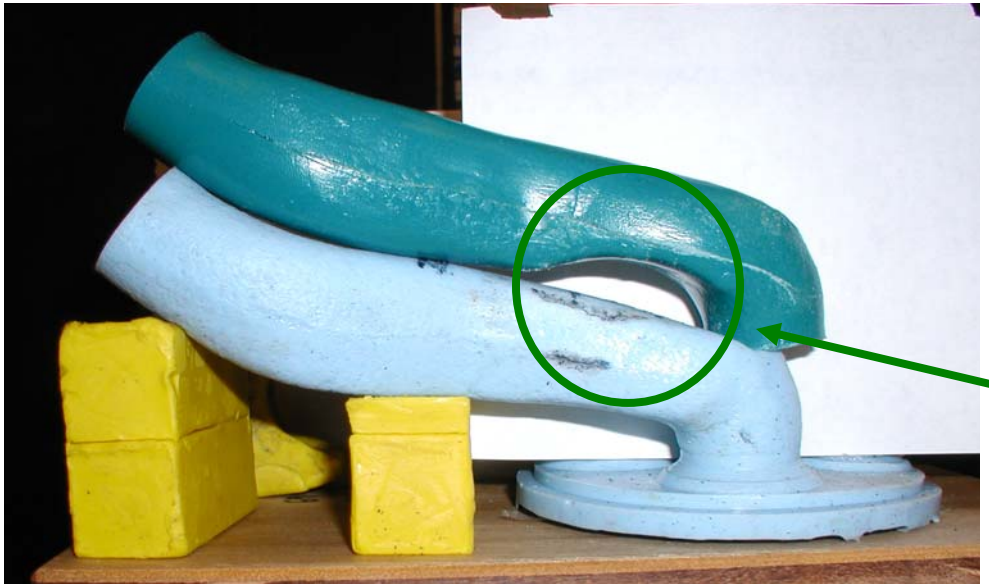


Cylinder Head Optimization



Helical features removed

Port straightened and widened



Short side radius modified

Performance at 30% flow over baseline cylinder head

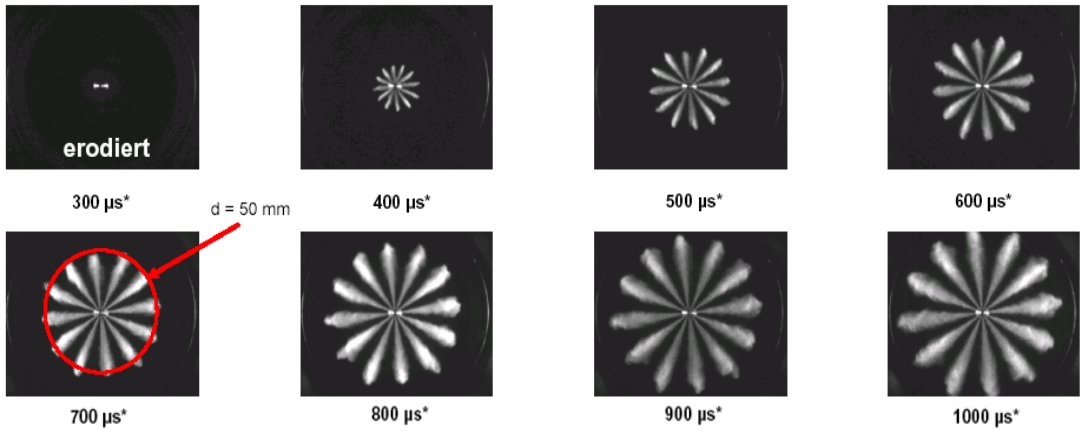
1. The middle light blue sticks show the original ports and the darker sticks are from the developed flow box
2. These sticks will be digitized and imported to CAD to update the cylinder head drawing.
3. The cylinder head will be recast and used in the HCCI engine testing.

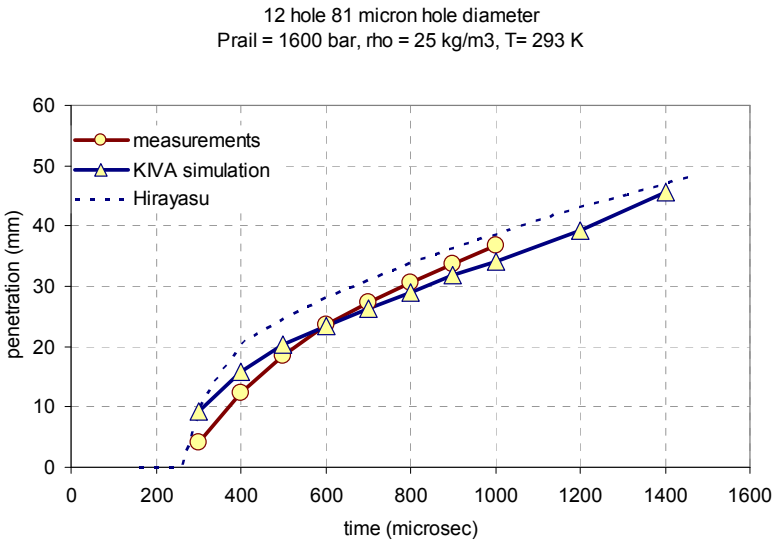
Bench Marking Simulation Code

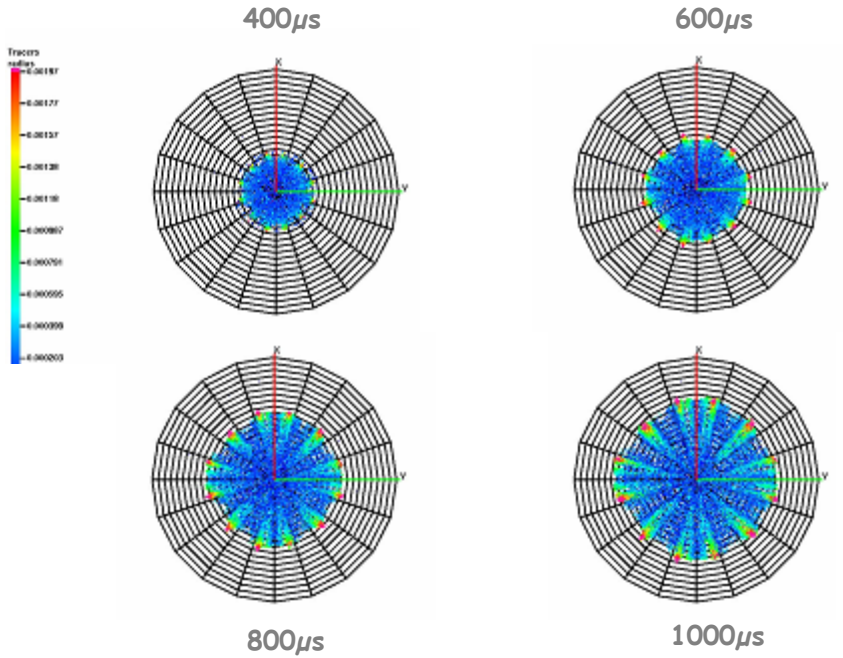
1. High speed Photography (top) is compared with KIVA modeling (below)

2. KIVA penetration estimates correlates well with "quiescent" conditions for conditions below.

3. Both compare well with estimates of Hirayasu.







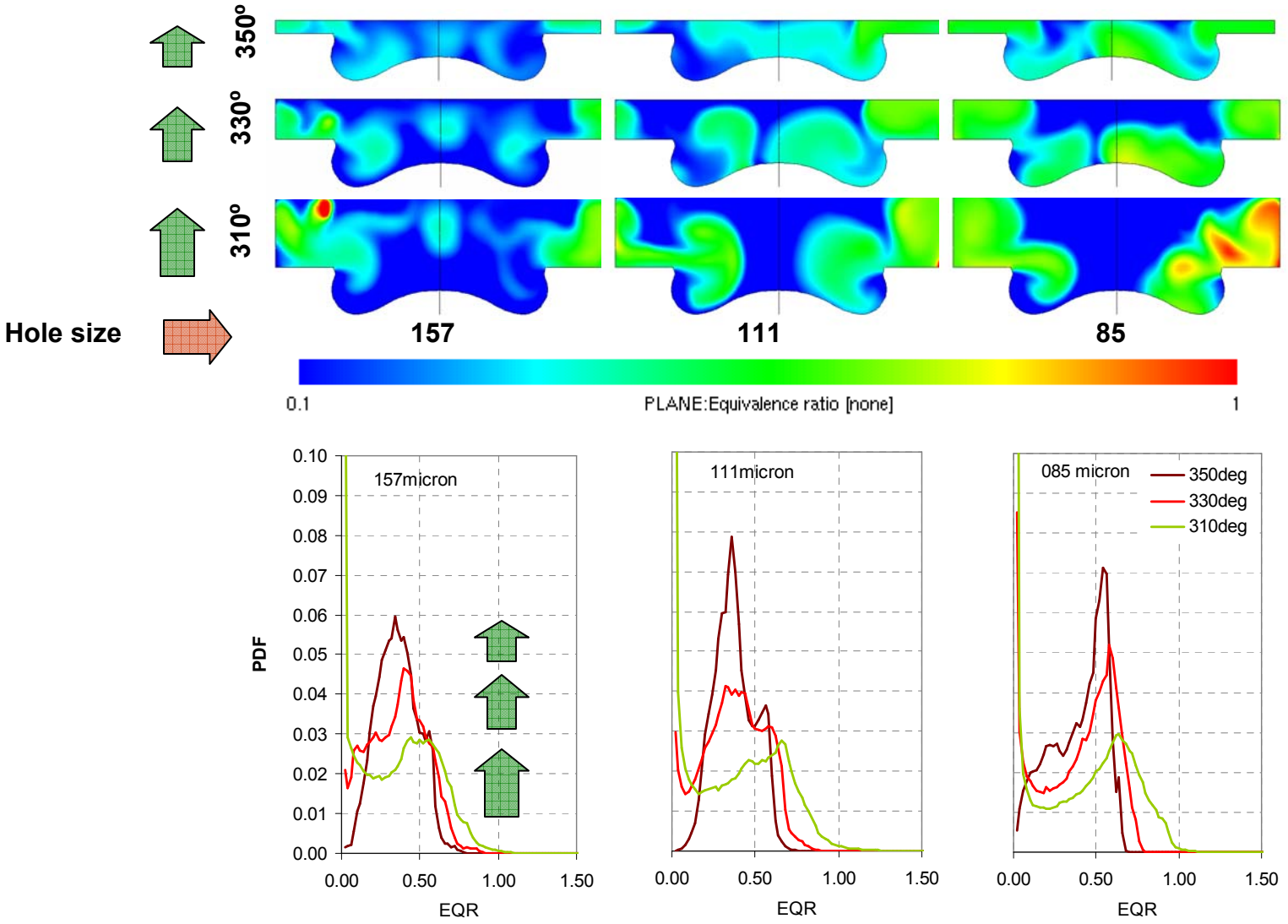
Spray Data: Optimizing Mixture

rated condition (3000 rpm, 12.4 bar)
SOI = 120 BTDC

Hole size affects homogeneity of mixture

Histograms of Φ help determine the mixture formation

Middle hole size (111μm) shows tighter histogram around average Φ



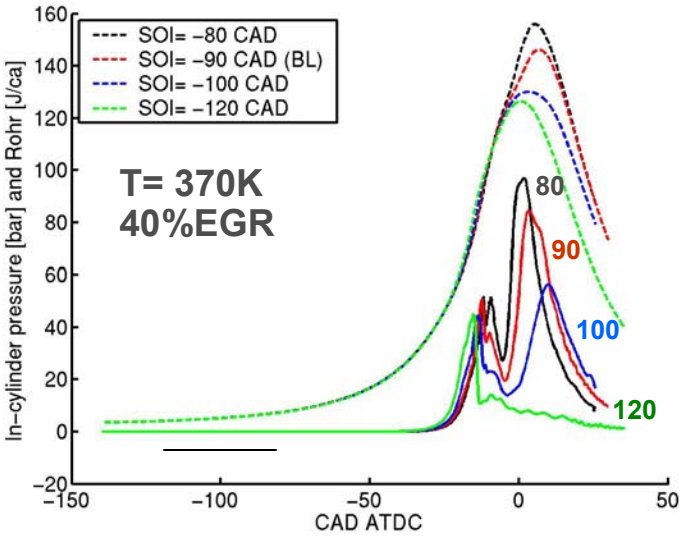
Combustion – 3000 rpm Full Load

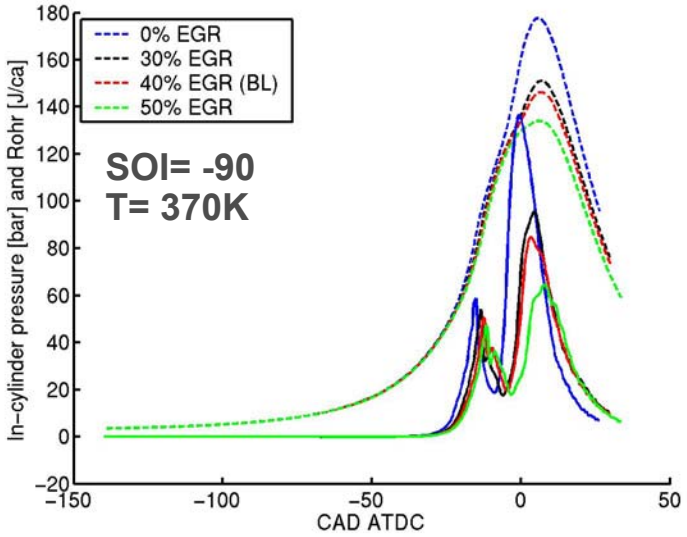
Effect of SOI, Tin, EGR, other

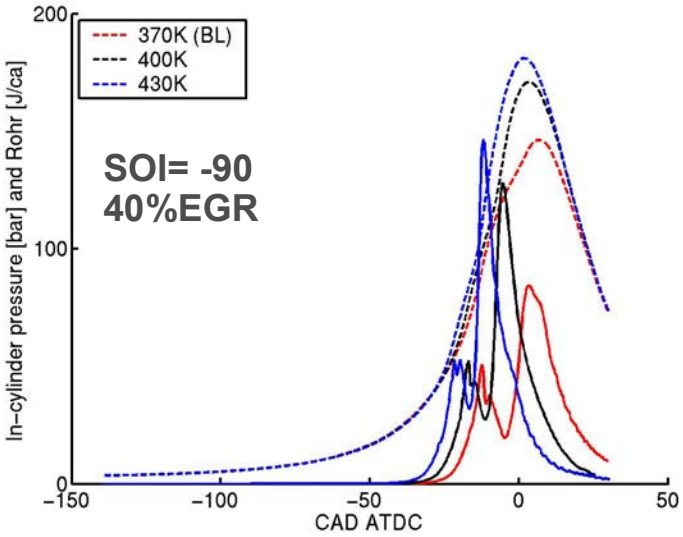
Goal:

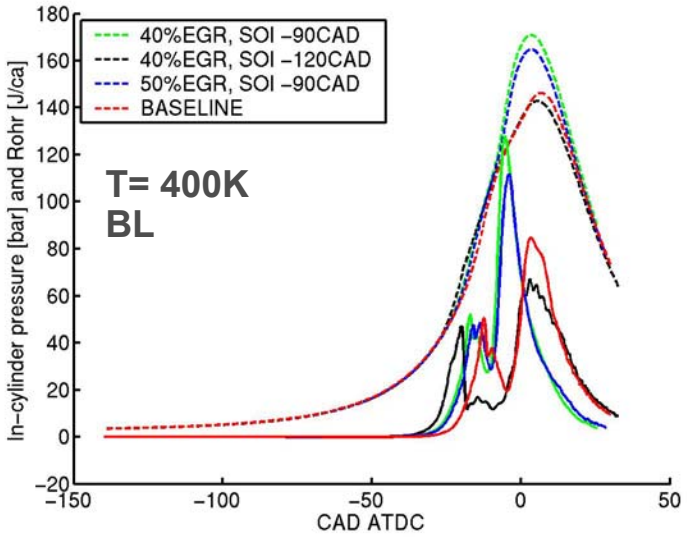
Optimize the heat release curves to maximize power output and keep peak in-cylinder temperatures below NOx generation.

Here, the effects of SOI, EGR and Temperature are pronounced. The insight is positive in regards to the capability to control each of these quantities.



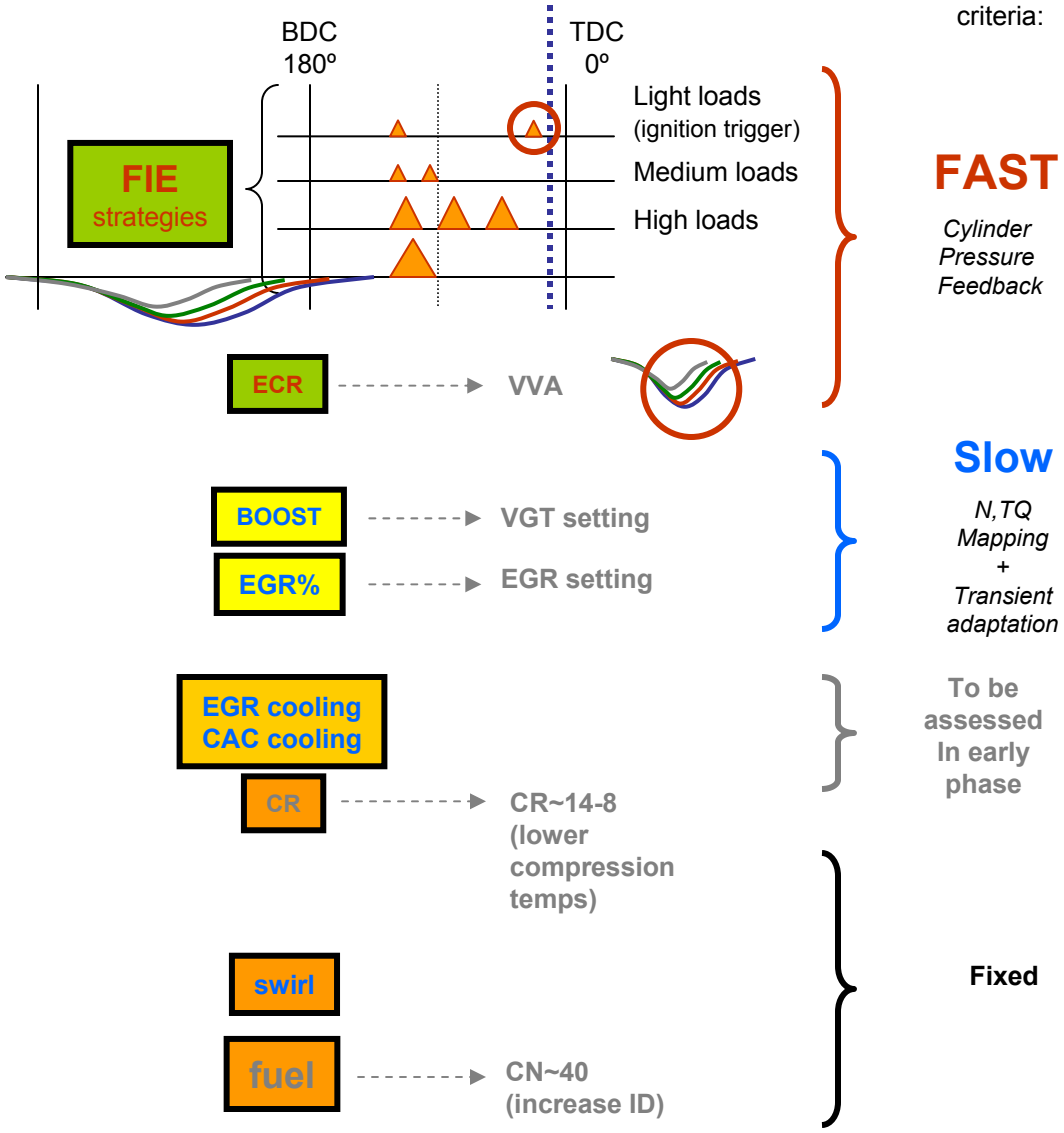




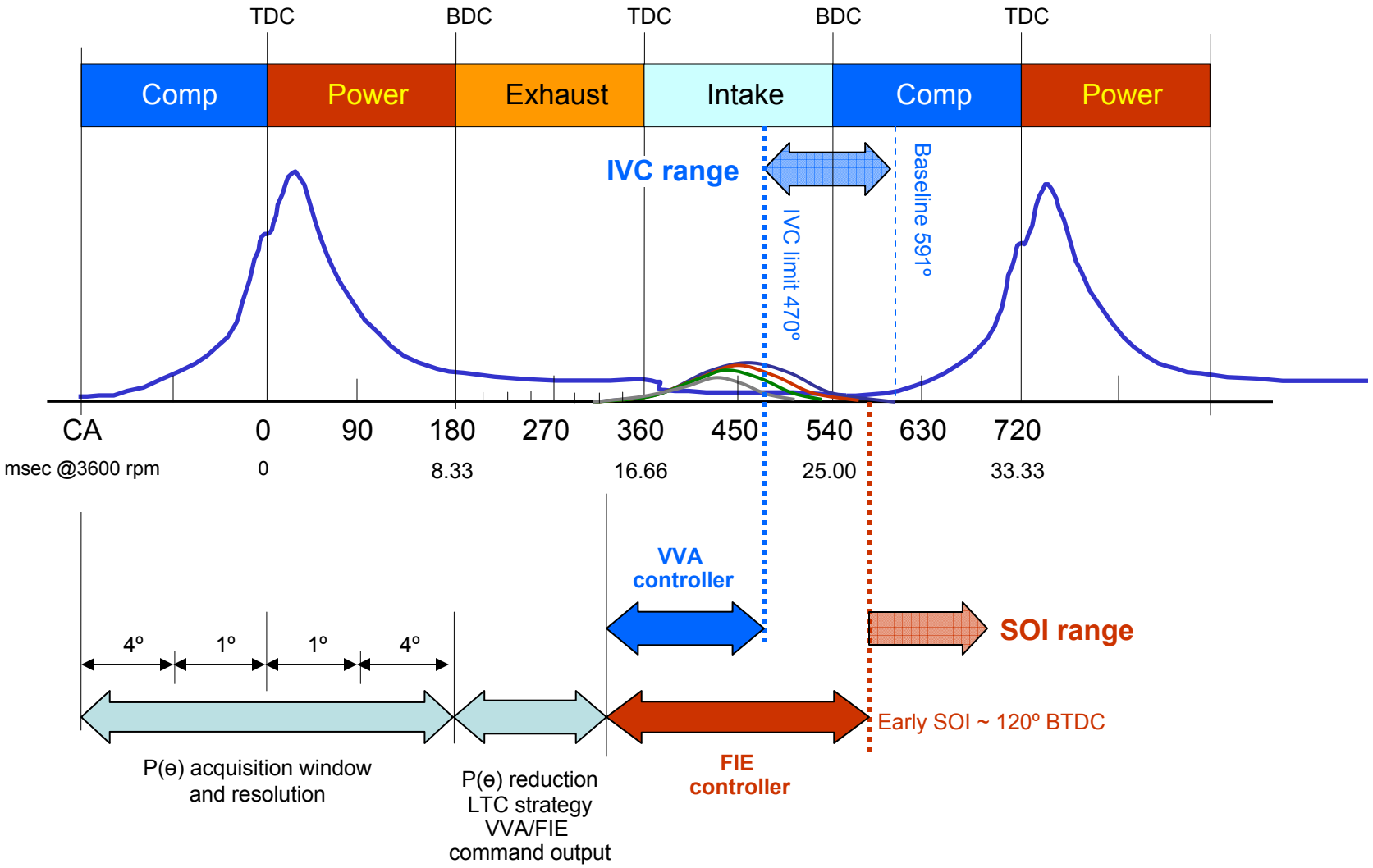


Control Strategy

1. The engine under development will rely on a supervisor controller to adjust the FIE and VVA systems on a cycle-to-cycle or angle base.
2. The controller will also be able to adjust boost and EGR levels on a periodic base.
3. The controller is to demonstrate it is capable to run at maximum speed (target 3600 rpm) with capability to:
   a. Process combustion parameters (SOC, 50% burn, etc)
   b. Interface with auxiliary systems on a cycle-to-cycle base.



Cylinder Timing Sequence



Summary

1. **DESIGN AND PERFORMANCE: specifications were outlined for a production engine to operate with a low temperature combustion mode. Specifically:**
   a. **Target peak torque was set at 670 Nm at 2000 rpm (12.6 bar BMEP), rated set to 620 Nm at 3000 rpm, maximum engine speed set to 3600 rpm. The power output is within the target range proposed.**
   b. **Equivalence ratio targets are from 0.3 - 0.4 with EGR levels of 40 -50%.**

2. **HARDWARE DEFINITION:**
   a. **Compression ratio was set at 14.**
   b. **VVA concept was selected with flexible IVC, capable to control valves independently at each cylinder and cycle-to-cycle.**
   c. **A two-stage series turbocharger system with VGT turbines at each stage.**
   d. **FEI hardware was identified to yield optimum vaporization of fuel and adequate mixing.**
   e. **The base engine cylinder head was modified to improve the flow capacity into the engine. Improvements of 30% were attained with a final swirl of 0.5.**
3. **COMBUSTION SIMULATION provided heat release profiles, in-cylinder maps of temperature, equivalence ratio, soot, NOx.**
4. **CYLINDER PRESSURE BASED ALGORITHM execution is being benchmarked.**