SuperTurbocharger Presentation
DEER Conference
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OAK RIDGE NATIONAL LABORATORIES

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Introduction to the SuperTurbo

- Alternative approaches
- The SuperTurbocharger
  - Supercharging function
  - Energy recovery function
  - Rapid transient response
- Modeling work
- Experimental results
  - Part load
  - WOT
  - Transient operation
- First round challenges
- Where are we going next

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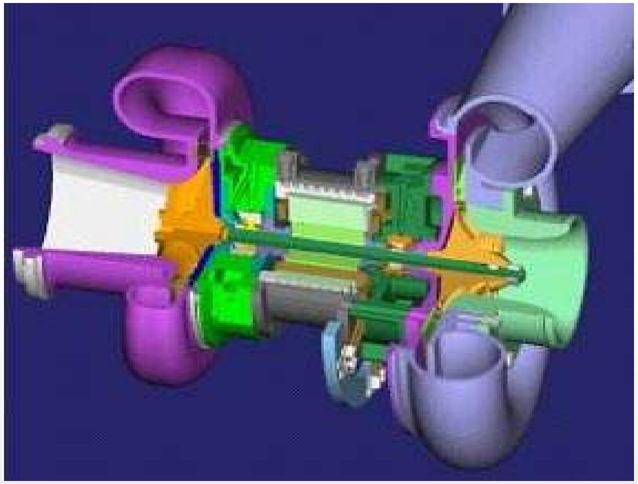
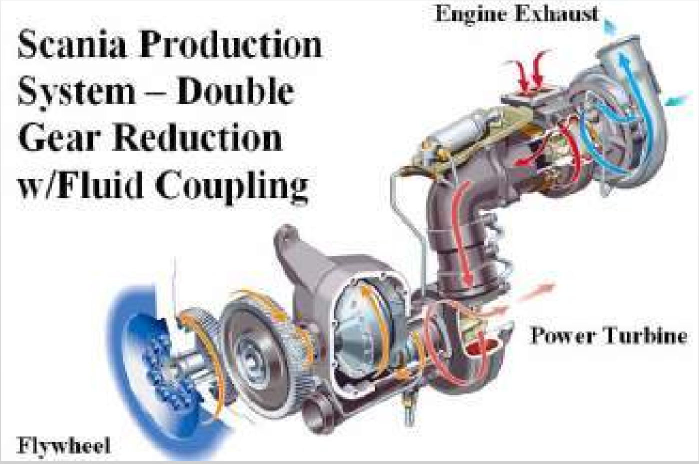
Alternative Approaches

- Electric Turbochargers
  - Attractive features
    - Size
  - Drawbacks
    - Higher inertia
    - Thermal constraints
    - High current and high voltage
- Turbocompounding
  - Attractive features
    - Relatively simple
  - Drawbacks
    - Cost
    - Packaging/weight





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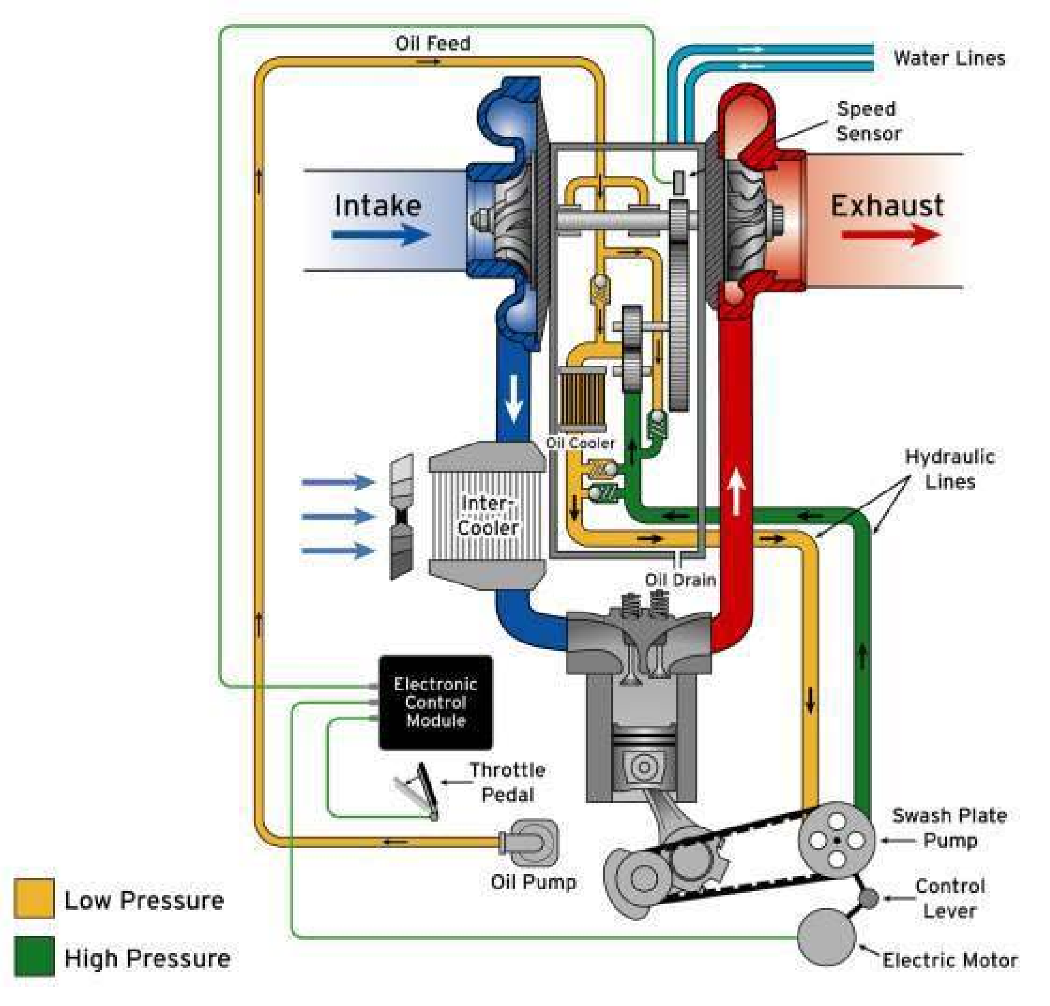
Super Charging Mode

- Acceleration of the engine from low load to high load.
- Hydraulic pressure spools up the turbo.
- Creates a rapid throttle response.
- Compensates for an oversized turbine that would normally create a longer turbo lag time.



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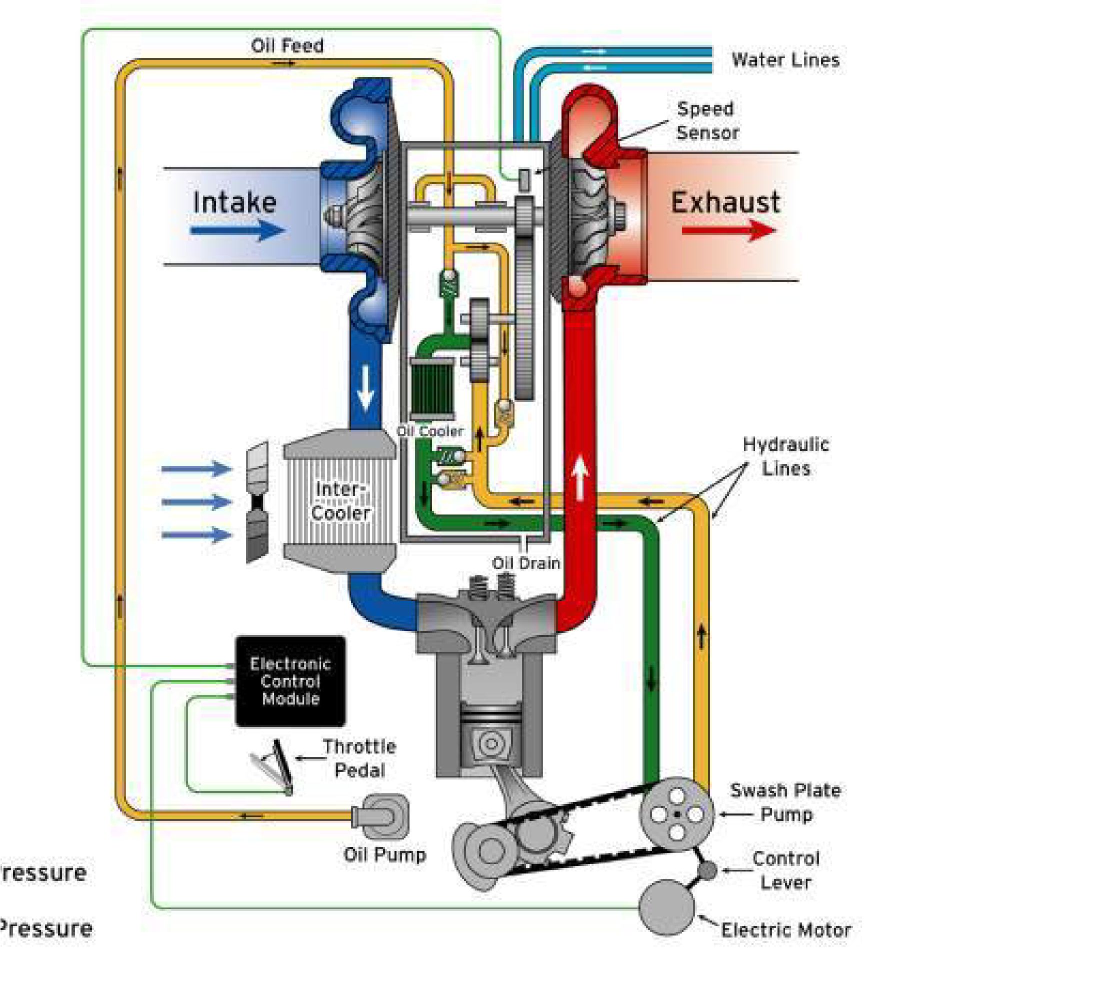
Energy Recovery Mode



- Without a waste gate the turbine energy exceeds the power needed by compressor.
- The high pressure switches to the other side of the Hydraulics.
- Up to 6% of engine power is added to the crankshaft at full throttle.
- Fuel efficiency is improved up to 5.6%.

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SuperTurbo Benefits

- Supercharging
  - Improves load acceptance
  - Reduces soot emissions
- Turbo Compounding
  - Improves fuel economy
  - Controls backpressure
- Engine Down-sizing
  - 30% more low end torque available
  - Lower engine mass

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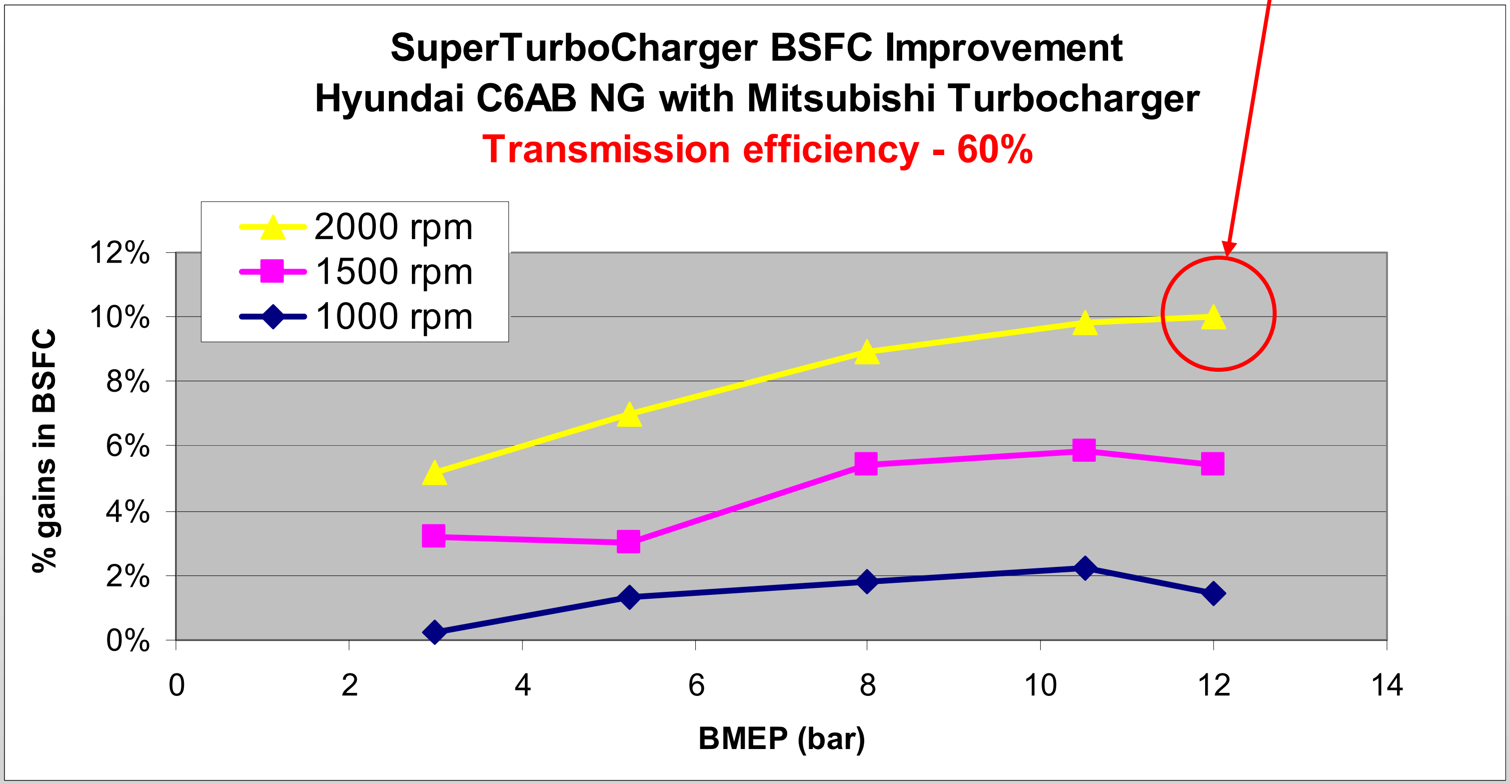
Modeling Follow-up

- Simulated improvements in BSFC

We'll come back to this point later



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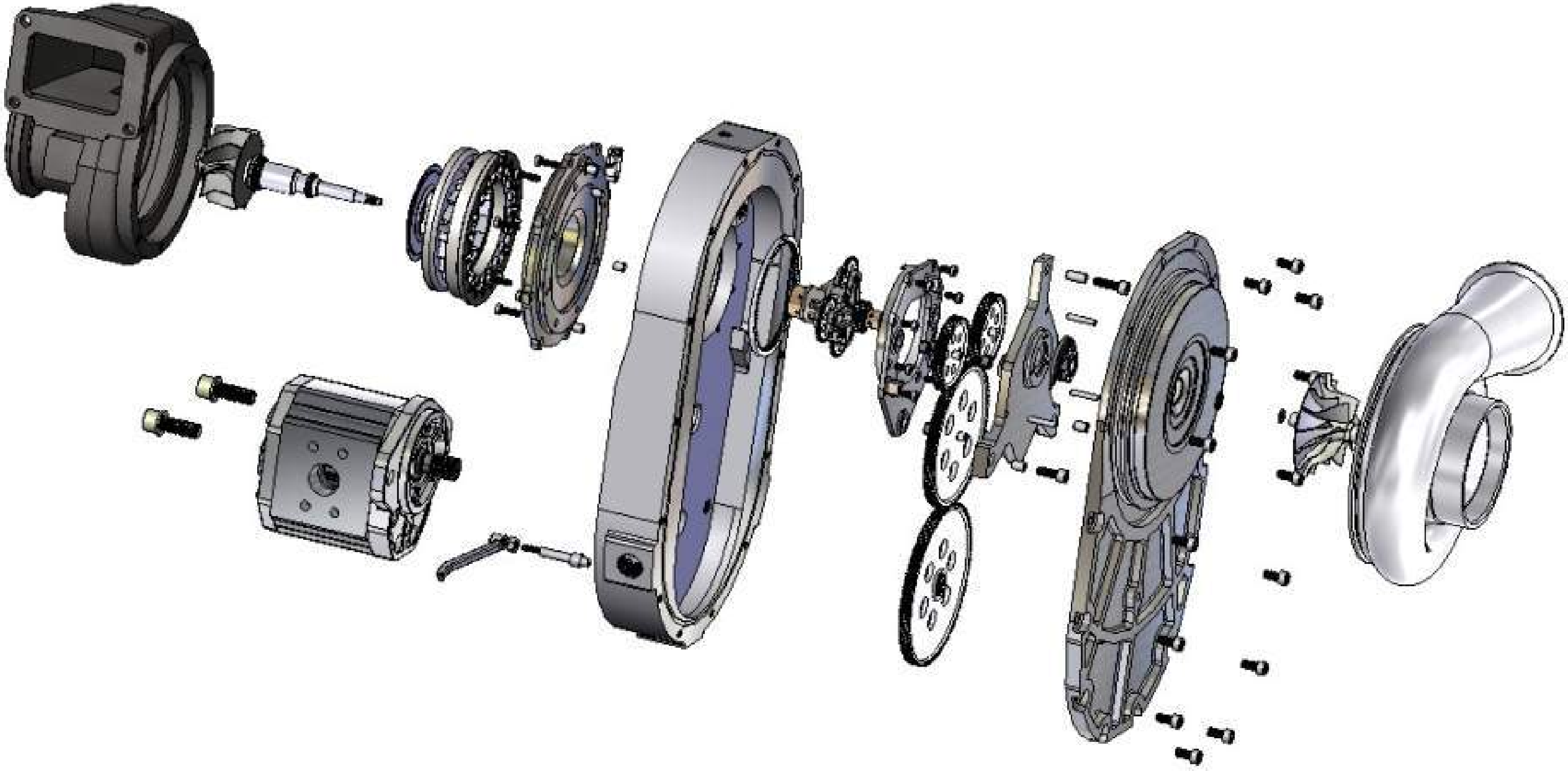
Assembly Drawing



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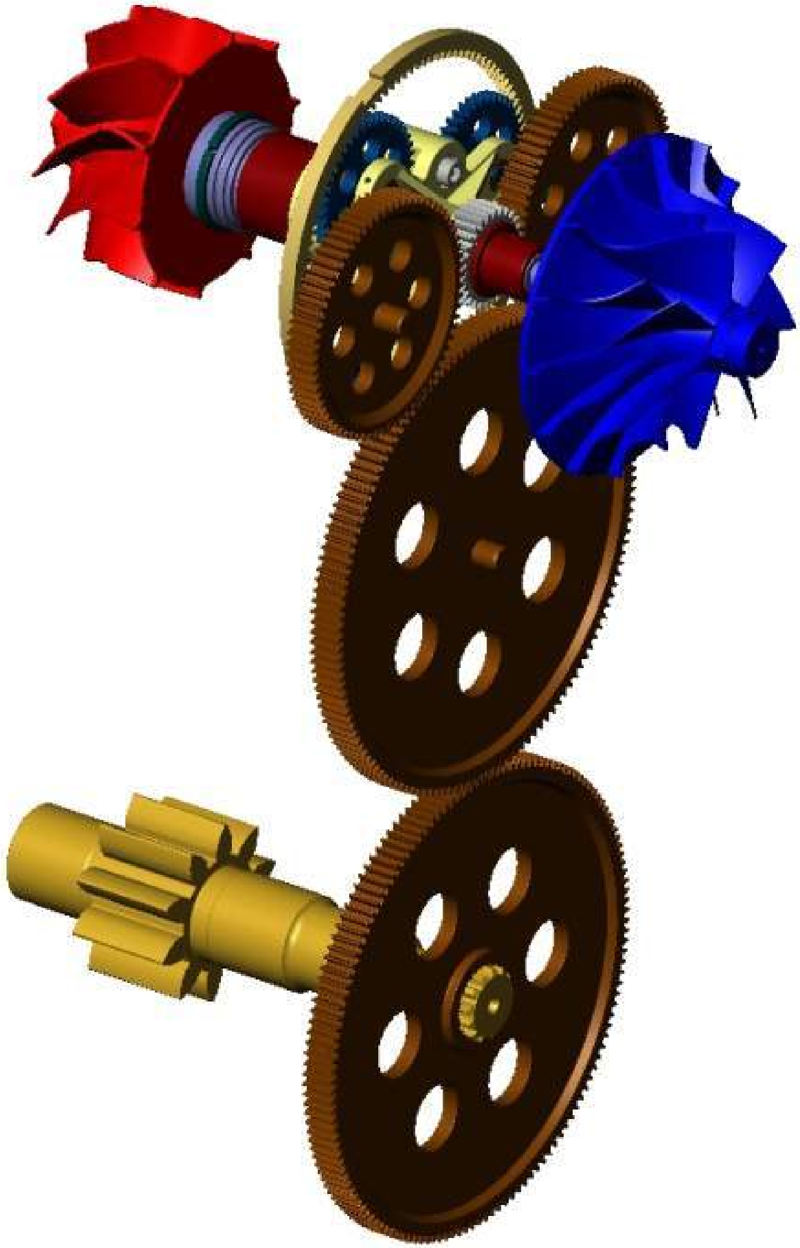

Design Features:

Only a 20% increase to the inertia of the base turbocharger

Only a 50% increase in the length of the turbine shaft

Results

- Comparison between baseline engine with stock turbo and the SuperTurbocharger
  - Transient response
  - WOT performance
  - Fuel economy

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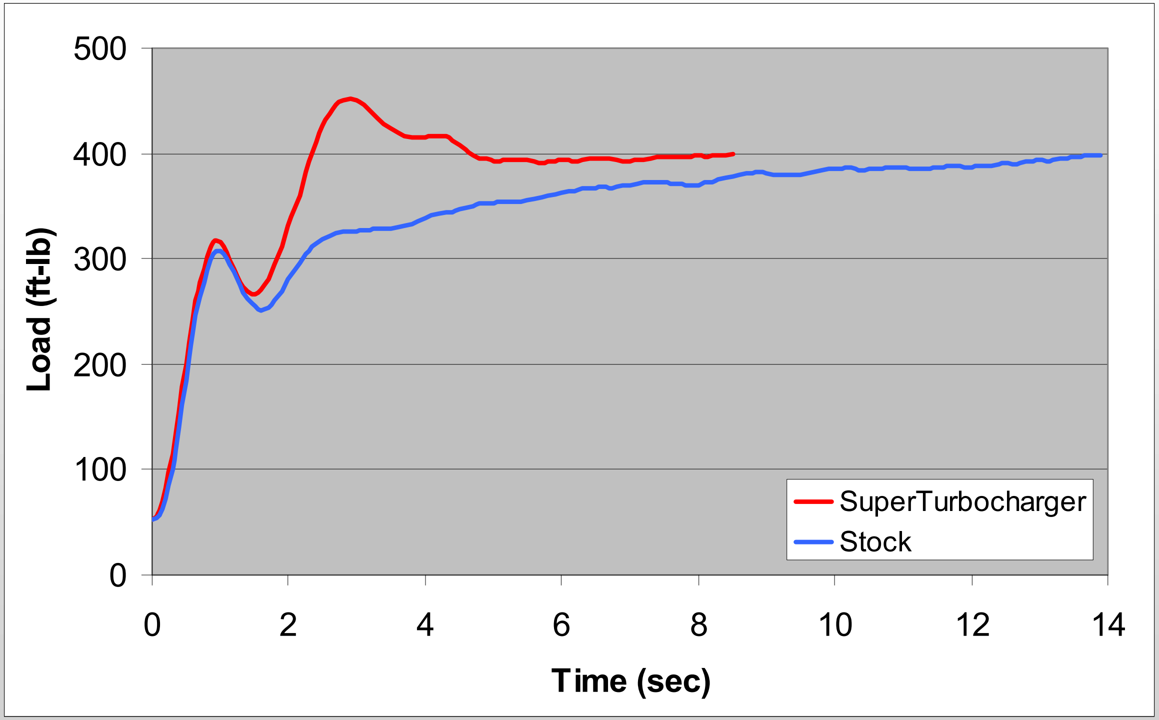
Super Charging Results

Up Transient Performance

- Step change at 1600 rpm from 50 ft-lb to 400 ft-lb
- Dramatic reduction where turbo performance counts



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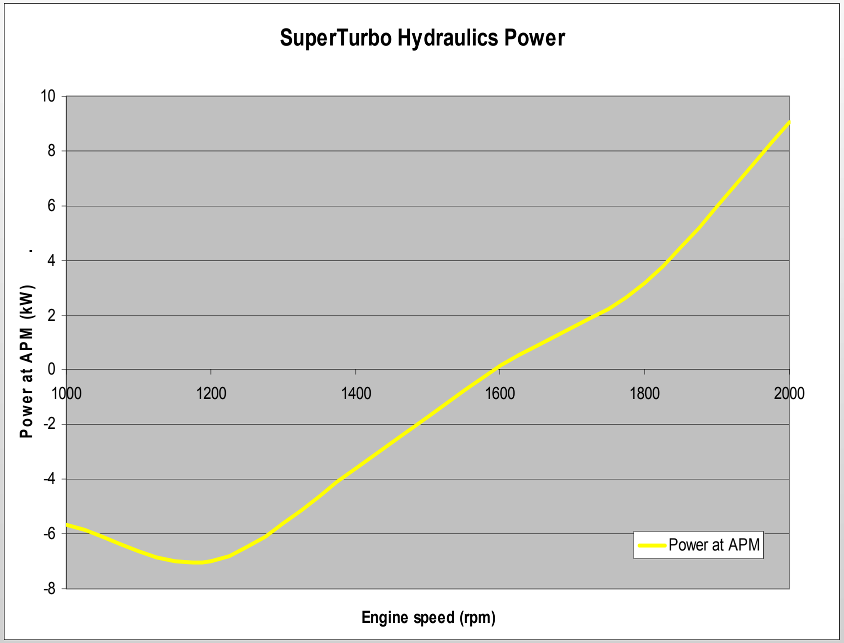
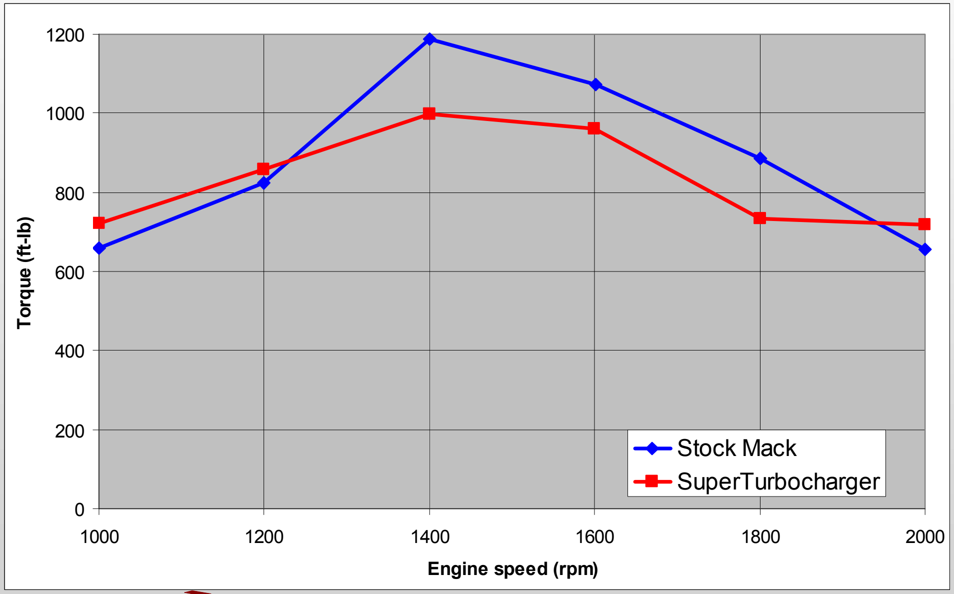
Power Test Results

Wide Open Throttle Performance

- SuperTurbocharger as supercharger
  - Up to 1400 rpm acted as supercharger
- SuperTurbocharger recovered power
  - From 1600 to 2000 rpm power was returned to the crank





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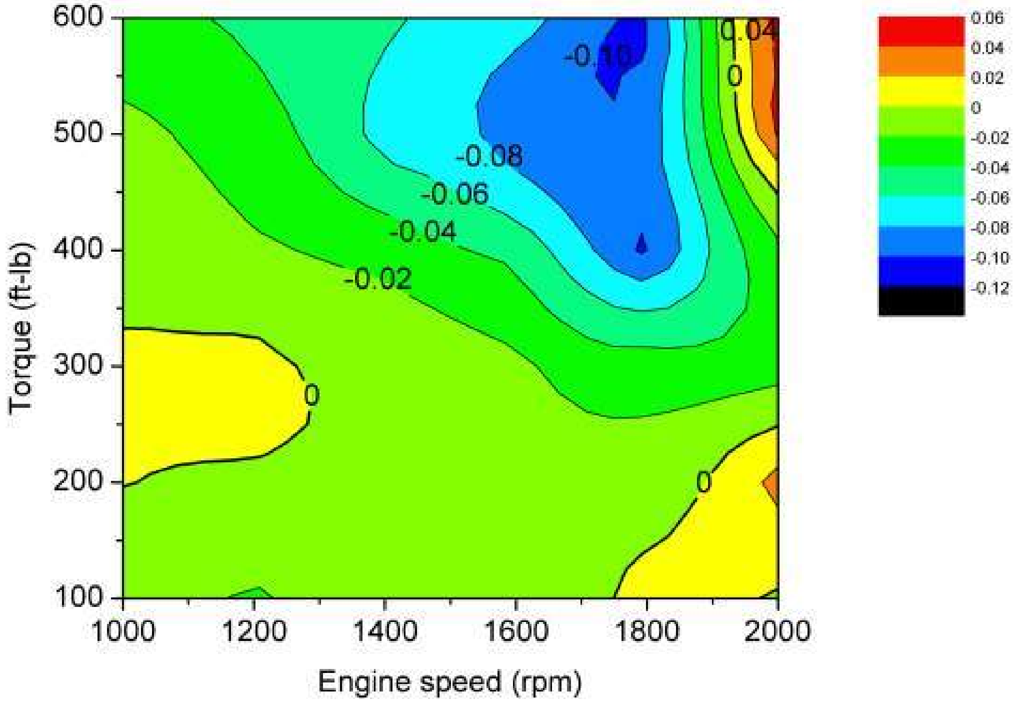
Efficiency Test Results

Part-load Fuel Economy

- Ran from 1000 to 2000 rpm
  - Min engine speed ~650 rpm, max engine speed ~2000 rpm
- Torque levels tested from 100 to 600 ft-lb



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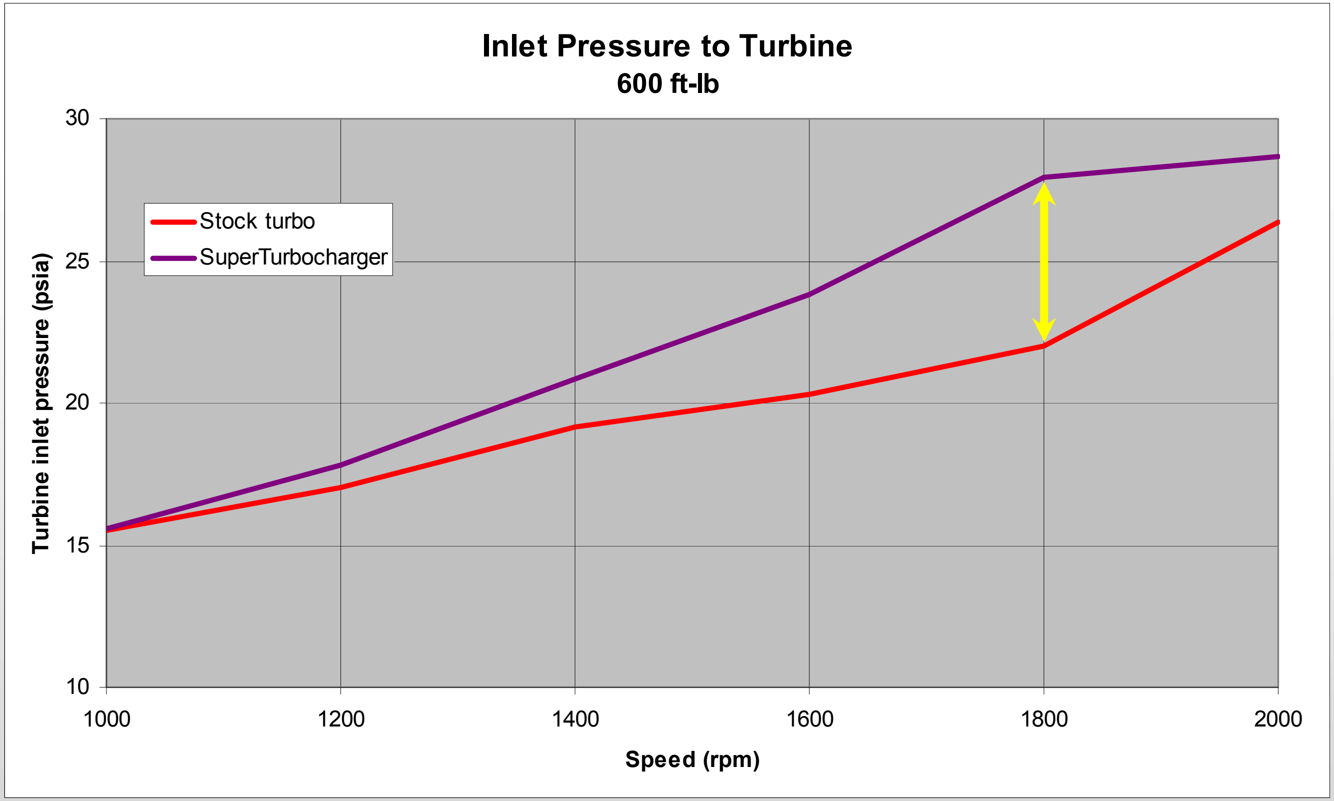
Exhaust System Changes

Turbine Backpressure Difference



Inlet pressure to the turbine at 1800 rpm represents more pumping work lost with SuperTurbo

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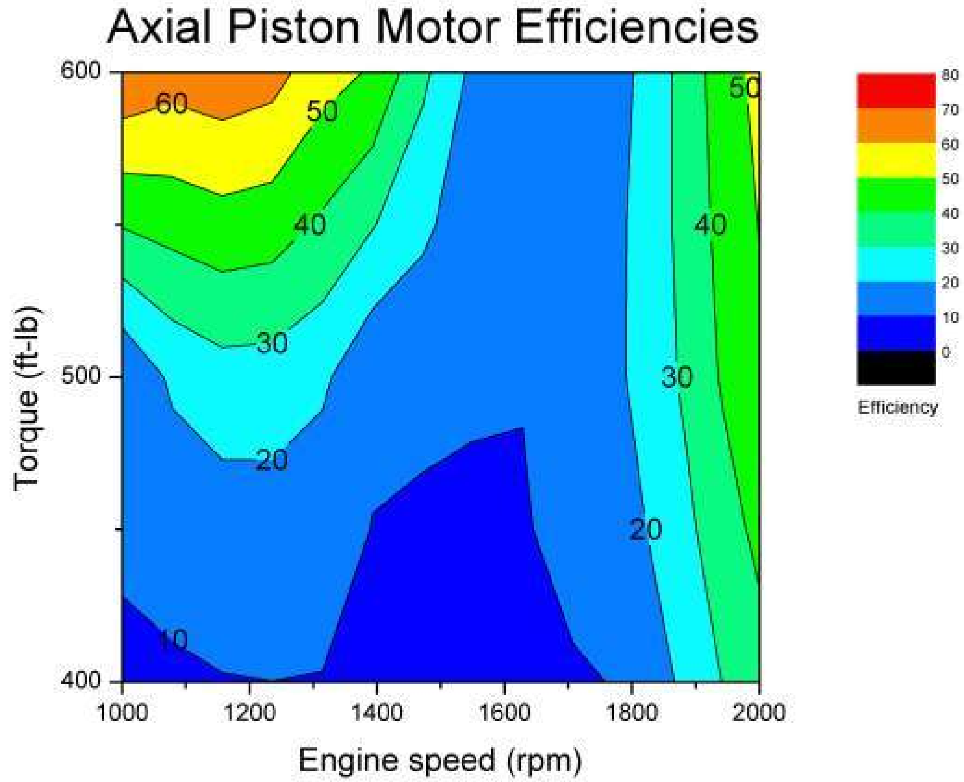
Transmission Challenges

Swash plate pumps are attractive until …



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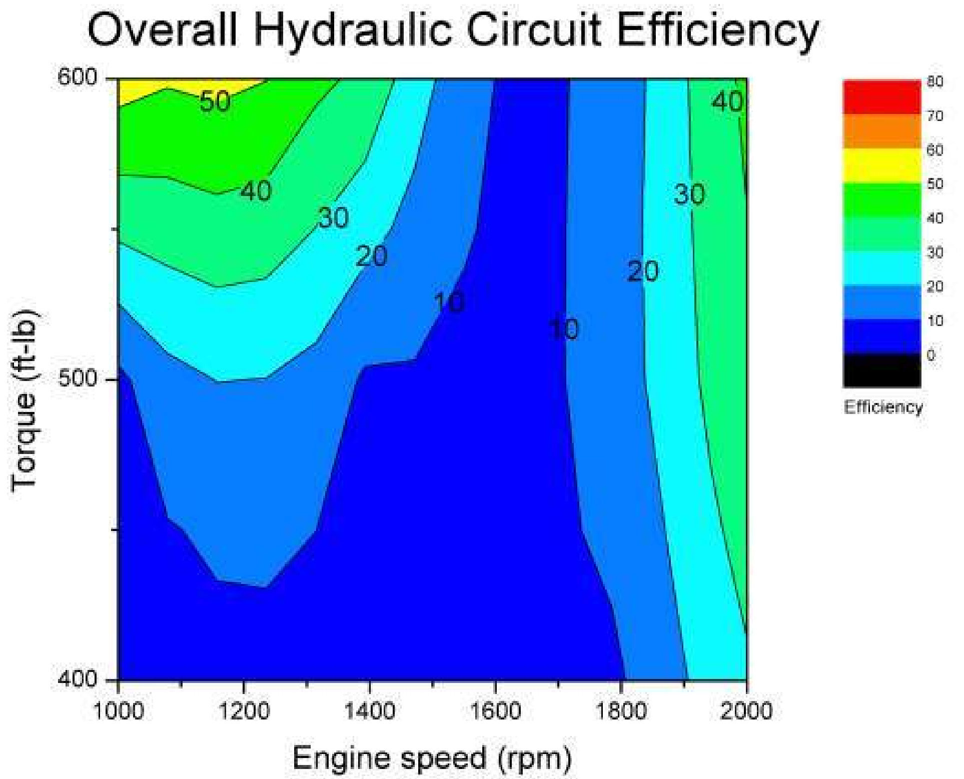
Transmission Challenges

Now add in the efficiency of the gear pump …



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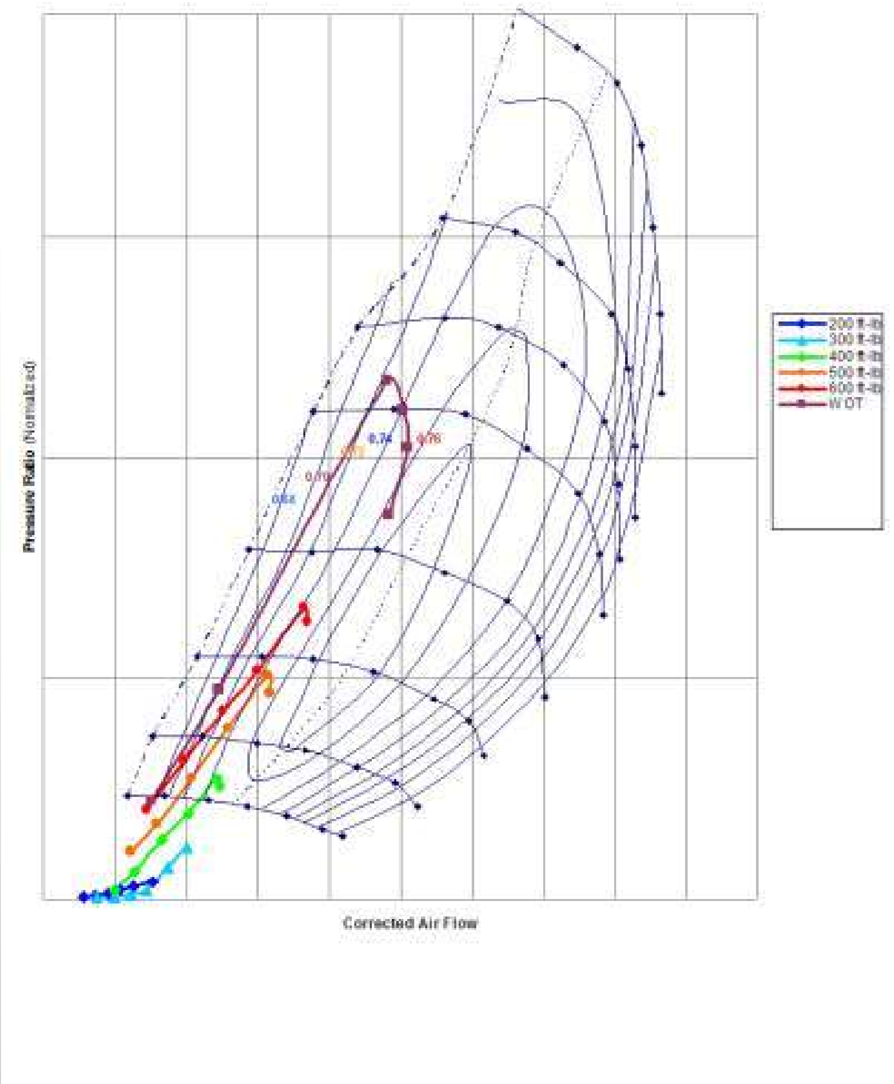
Turbomachinery Selection

- Compressor matching could have been better
- This is real test data over laid on the map
- Turbocharger choice was too big for this engine



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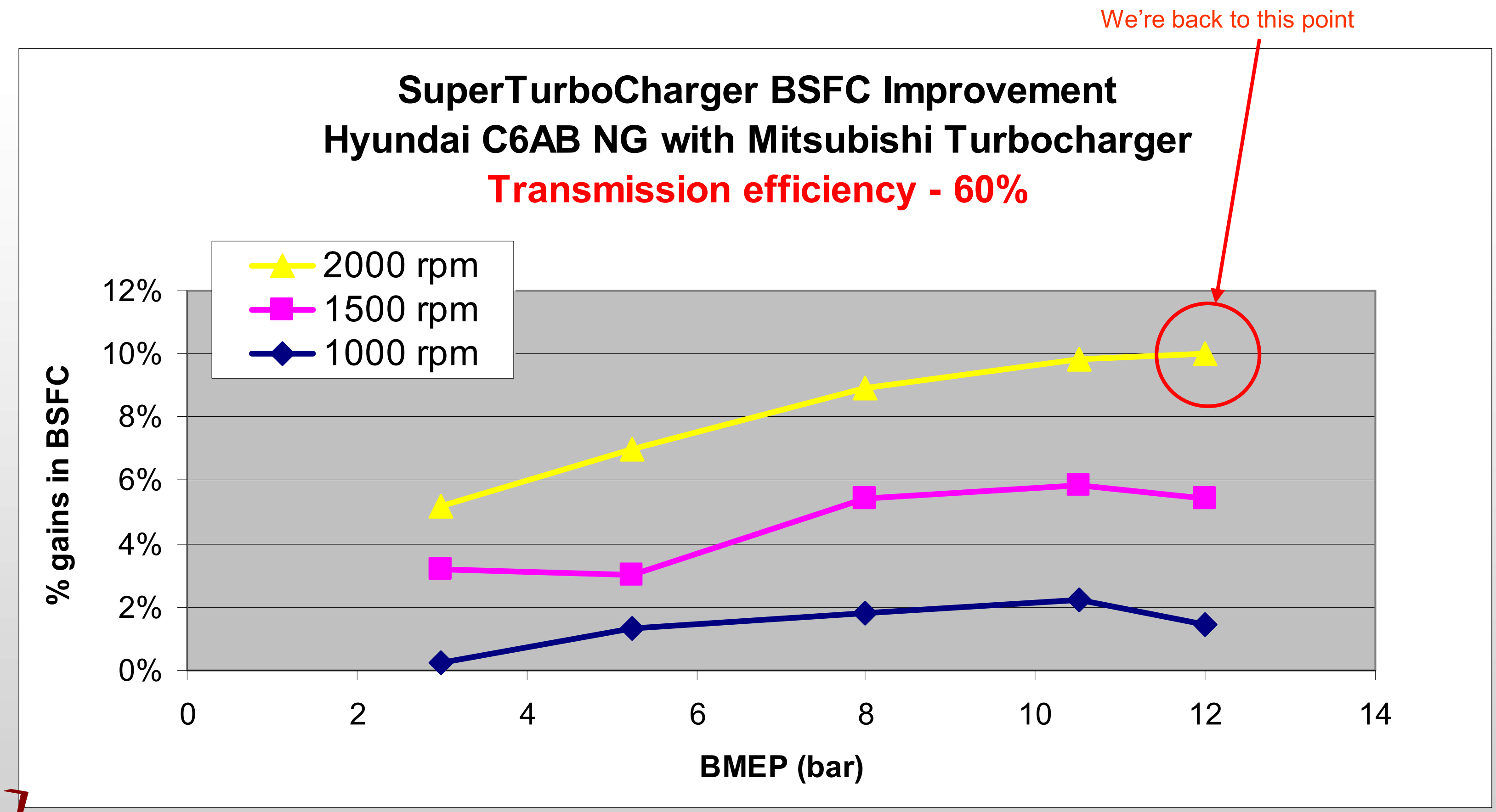
Modeling Follow-up

Simulated Improvements in BSFC



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Conclusion

- Dramatic improvement in transient response
  - Possible high level natural gas load acceptance
  - Reduced Soot spike on a diesel engine
- Fuel economy improvement encouraging
  - Parallel between modeling and experiment with appropriate transmission efficiency
  - Results hurt by poor performance of hydraulic transmission and the higher back pressure
- WOT results are encouraging
- New transmission alternatives under review
- Better turbo matching will improve performance
  - Requires better turbo matching to the engine than we have achieved in this first prototype

Future of Energy Recovery

- Elimination of waste gate losses.
- Reduction of throttling losses
- More efficient turbine design (narrow rpm)
- More efficient compressor design (narrow rpm)
- Optimize backpressure to improve EGR loop
- Lower speed to achieve greater efficiency
- Optimum speed for the boost condition can be controlled for maximum compressor and turbine efficiency

Diesel Engine Potential

- With a high pressure loop EGR system, the higher back pressure across the turbine can be recovered for better efficiency
- The supercharging benefit can lower the up transient Soot emissions
- The efficiency gains on a diesel will not be as big as on natural gas or gasoline engine because of the lower exhaust enthalpy
- The CO_2 reduction potential is substantial for the world, based on the much greater fuel use per year for trucks vs. cars

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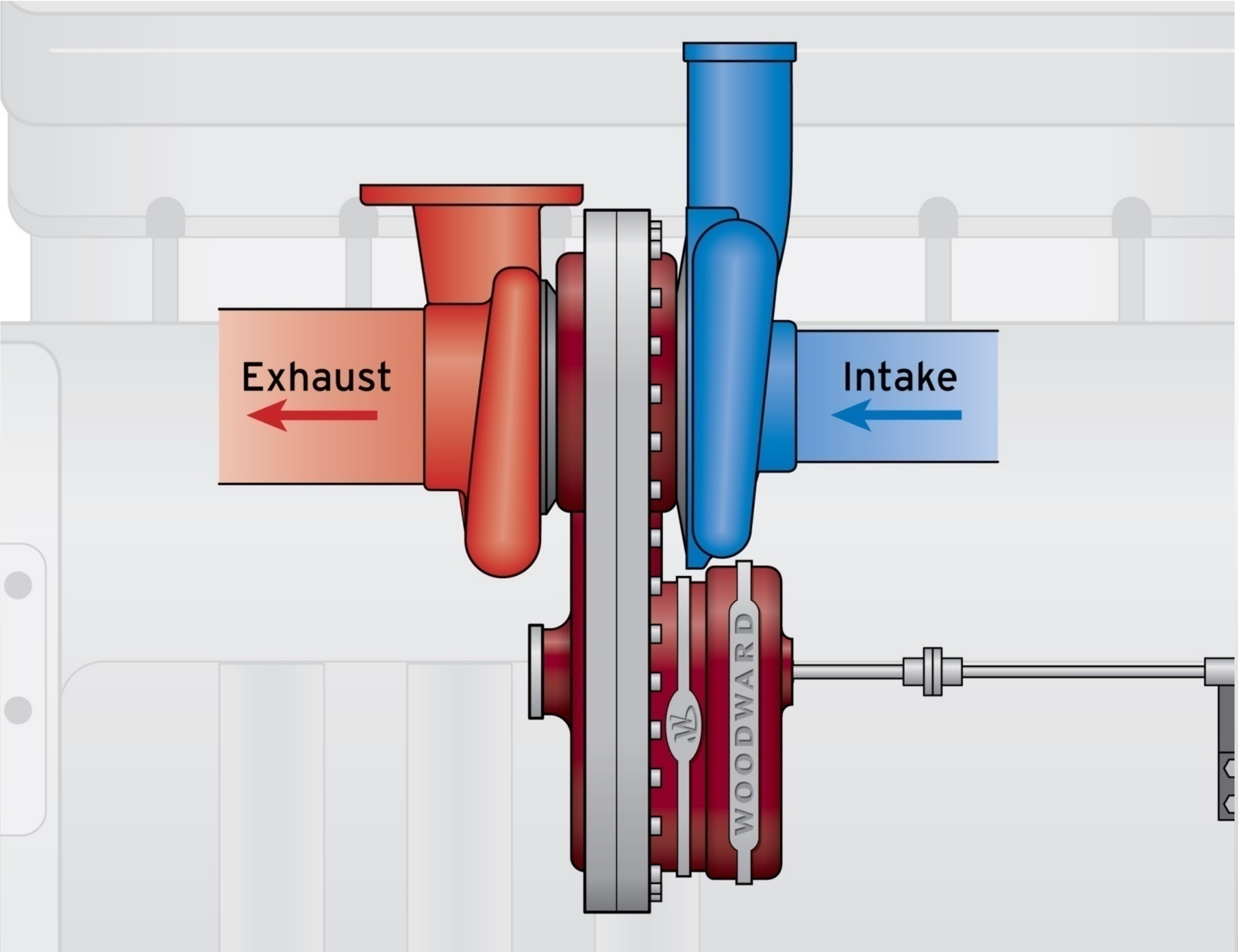
Next Generation Design



Thank you for your attention!

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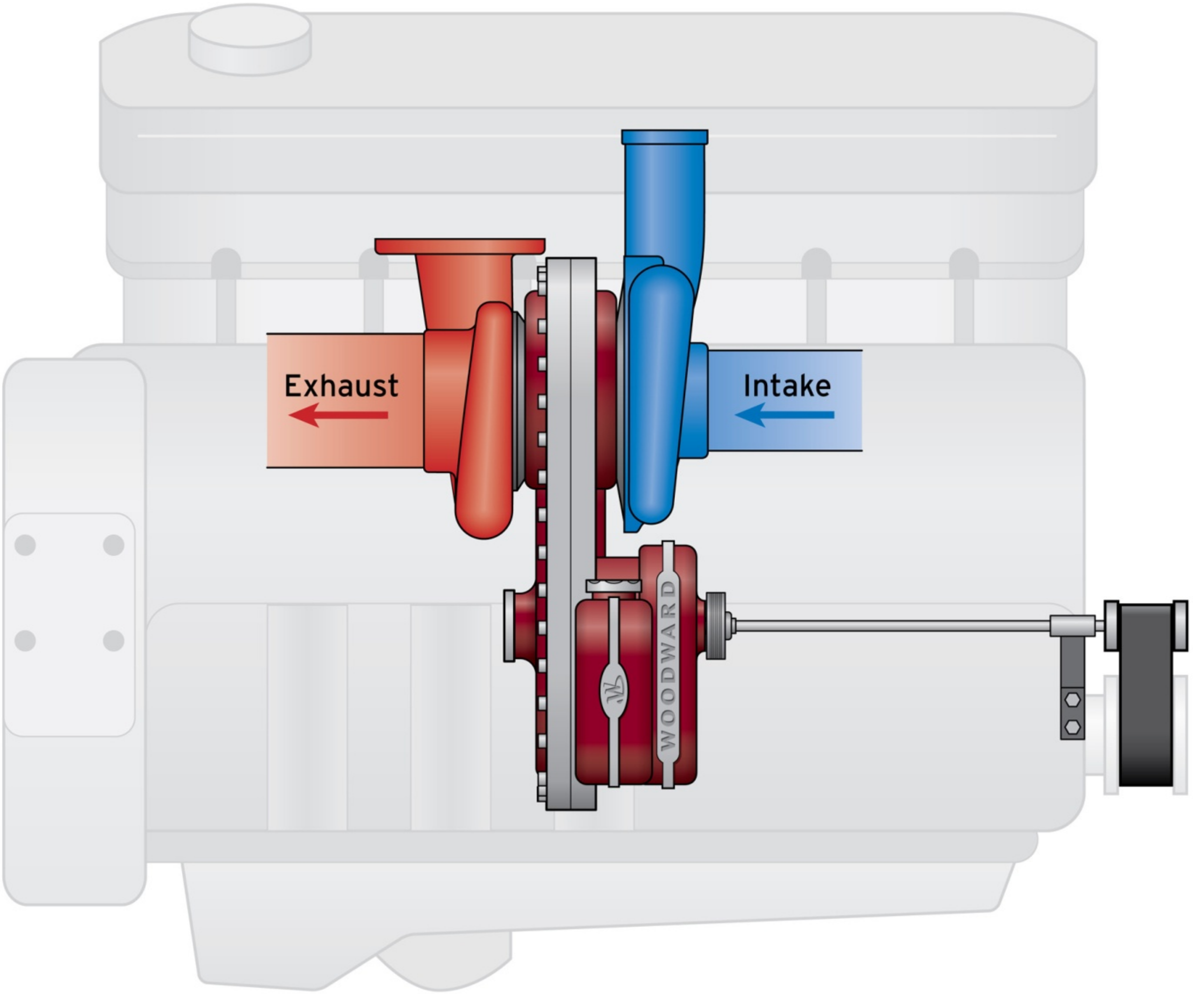
Questions???



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