VanDyne
SuperTurbo, Inc.

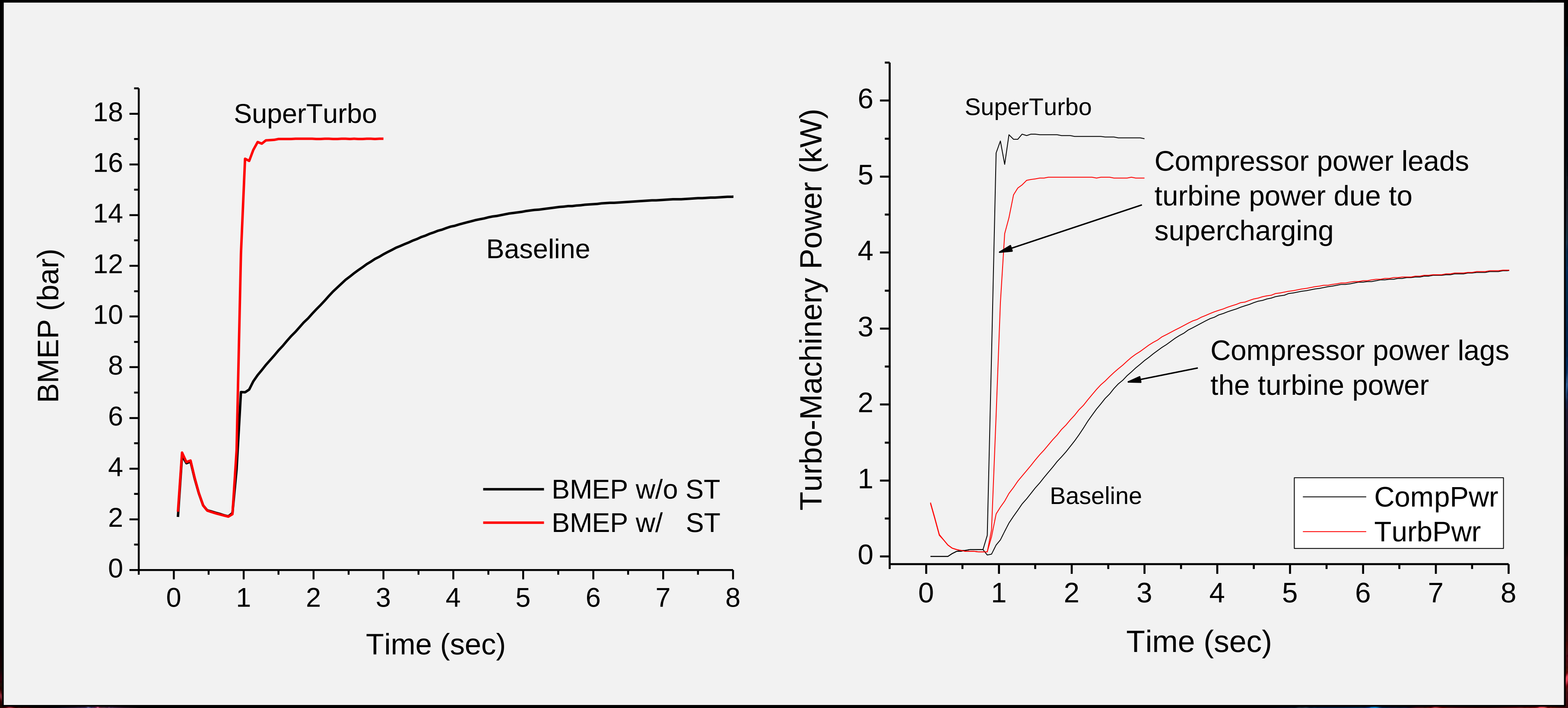
SuperTurbo™ for Engine Downsizing and Formula 1

Engine Expo Conference

October 2011

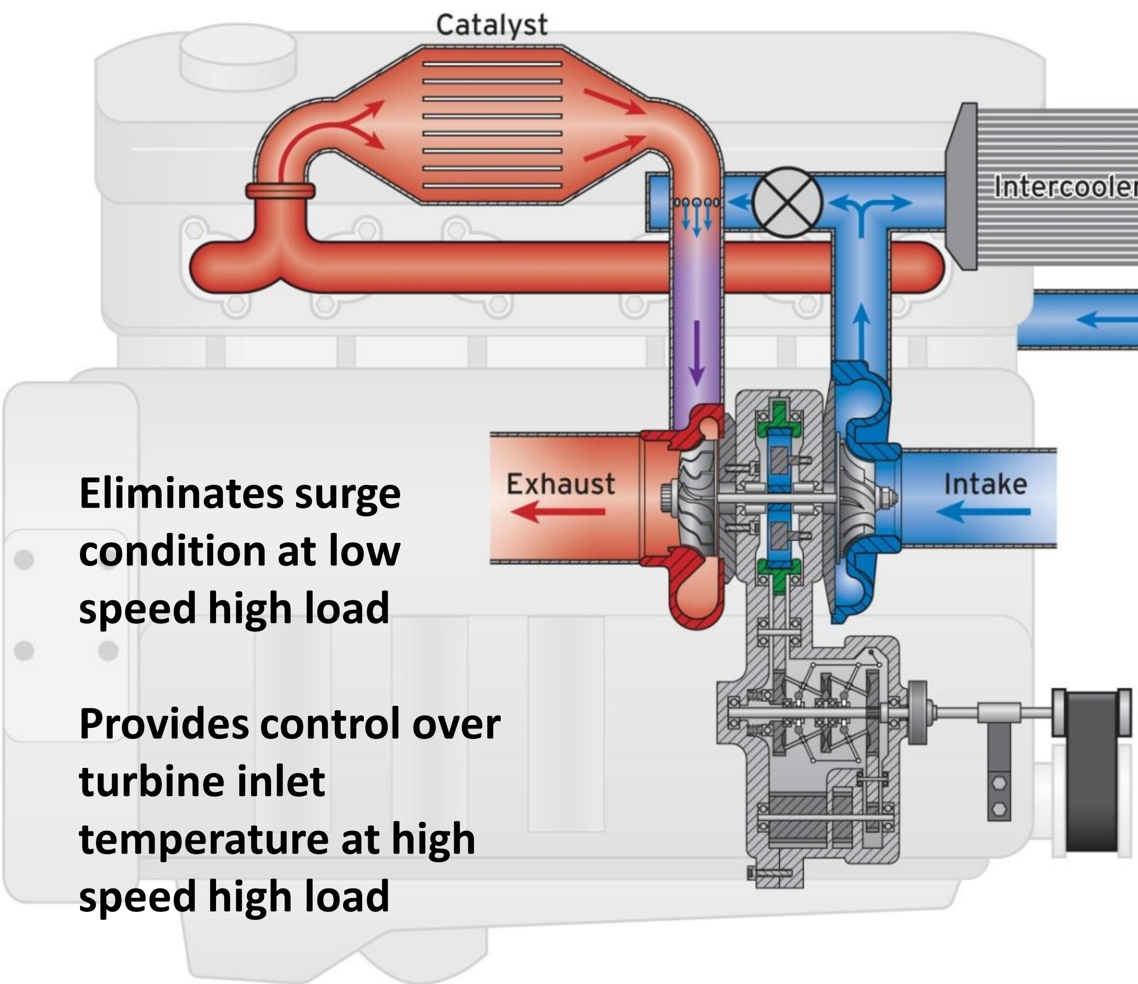
SuperTurbo Movie

Transient Supercharging



250,000 rpm/second

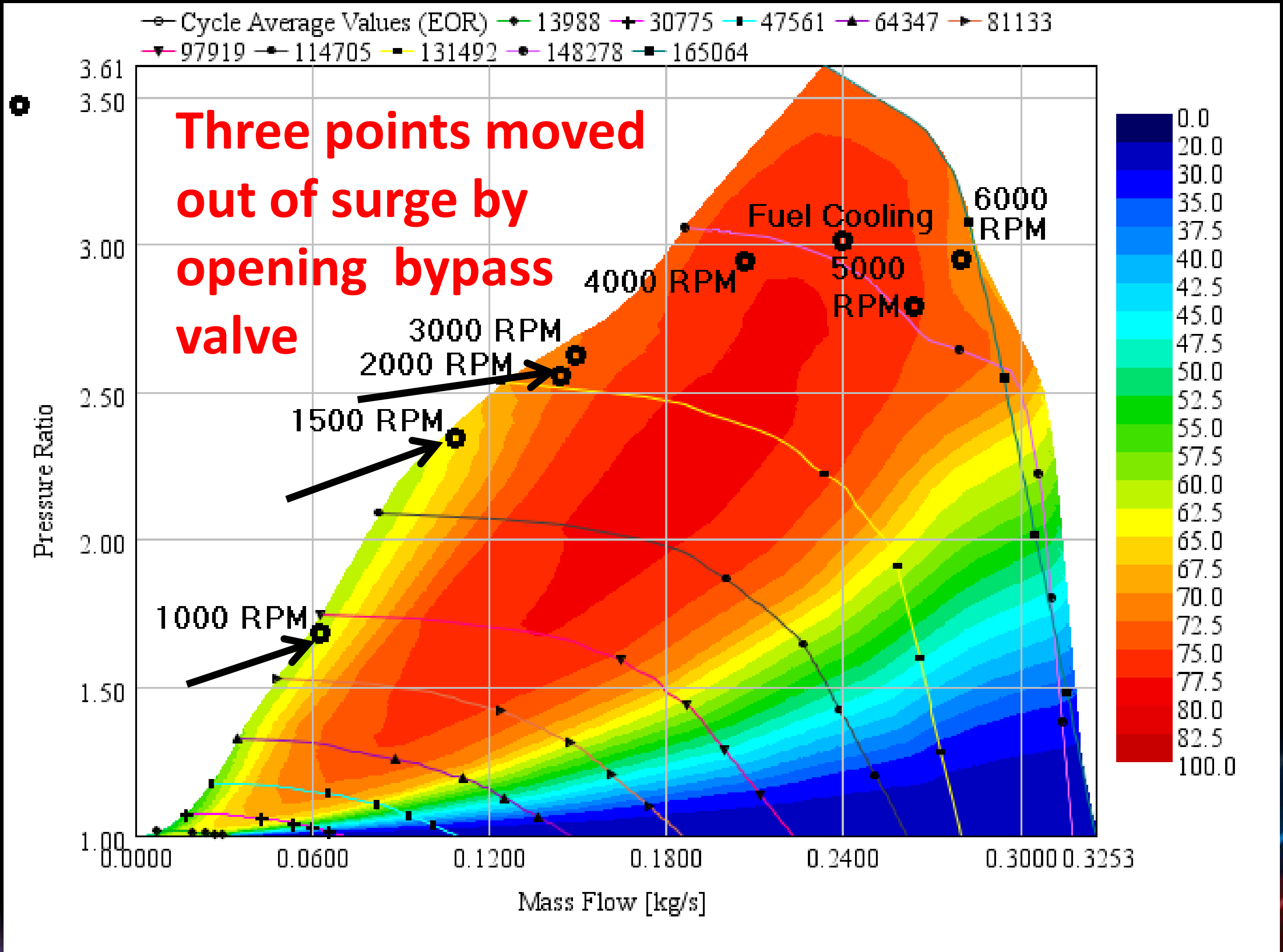
What can be Done Differently



Eliminates surge condition at low speed high load

Provides control over turbine inlet temperature at high speed high load

Compressor Map



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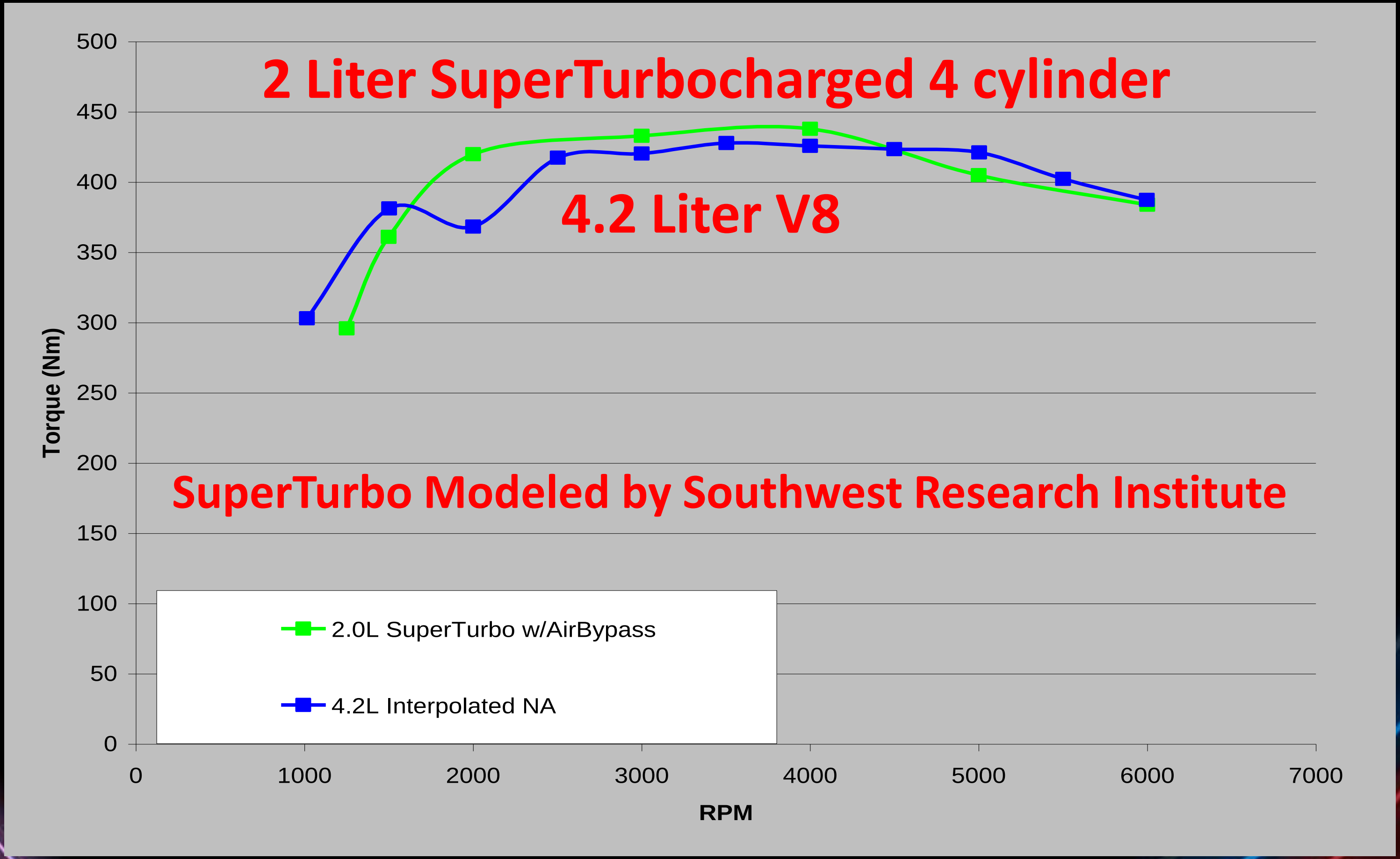
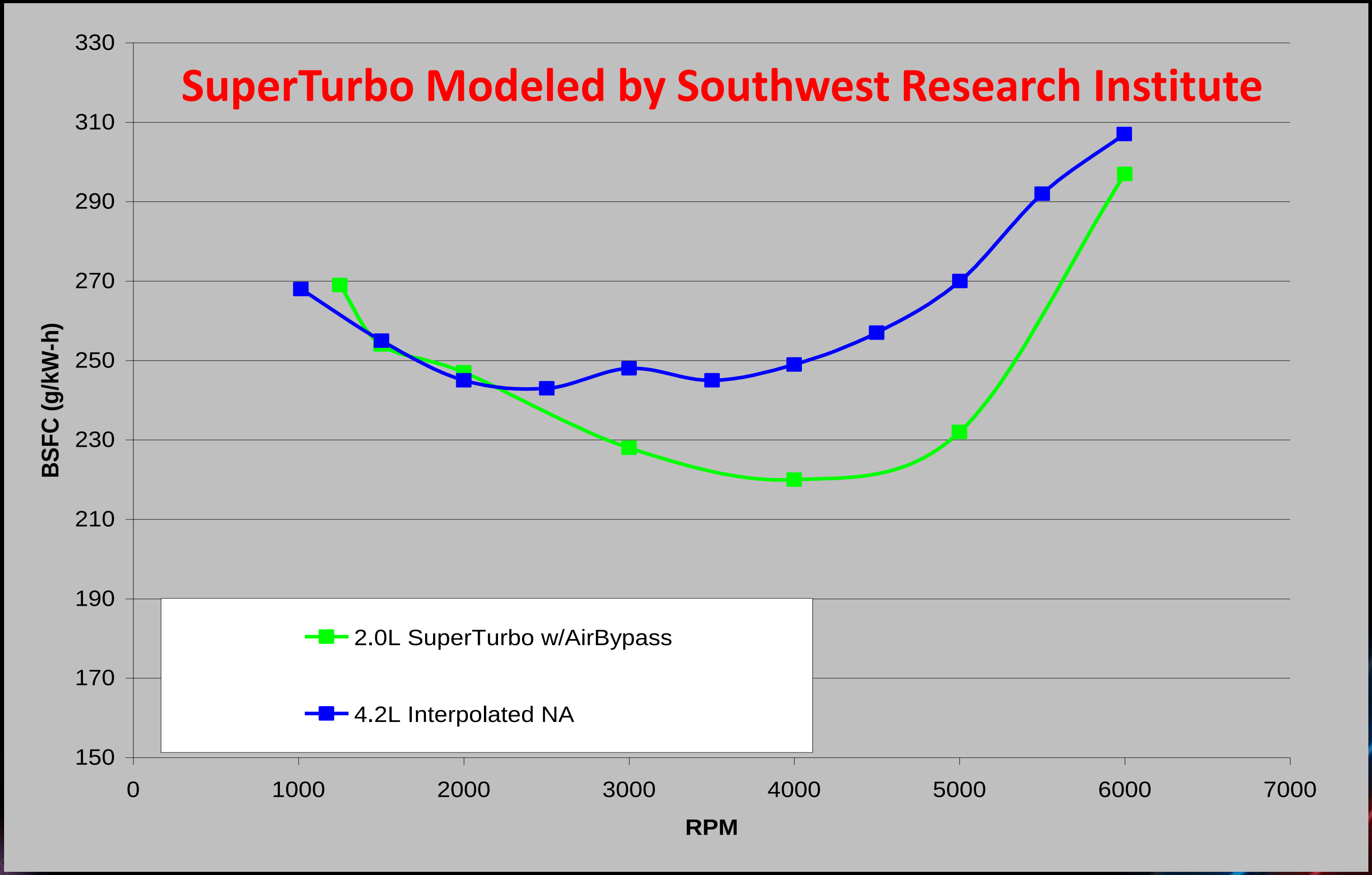
DOUBLE the TORQUE or HALF the ENGINE



Based on 26 Bar BMEP in the 2 L Engine

Efficiency at Full Power

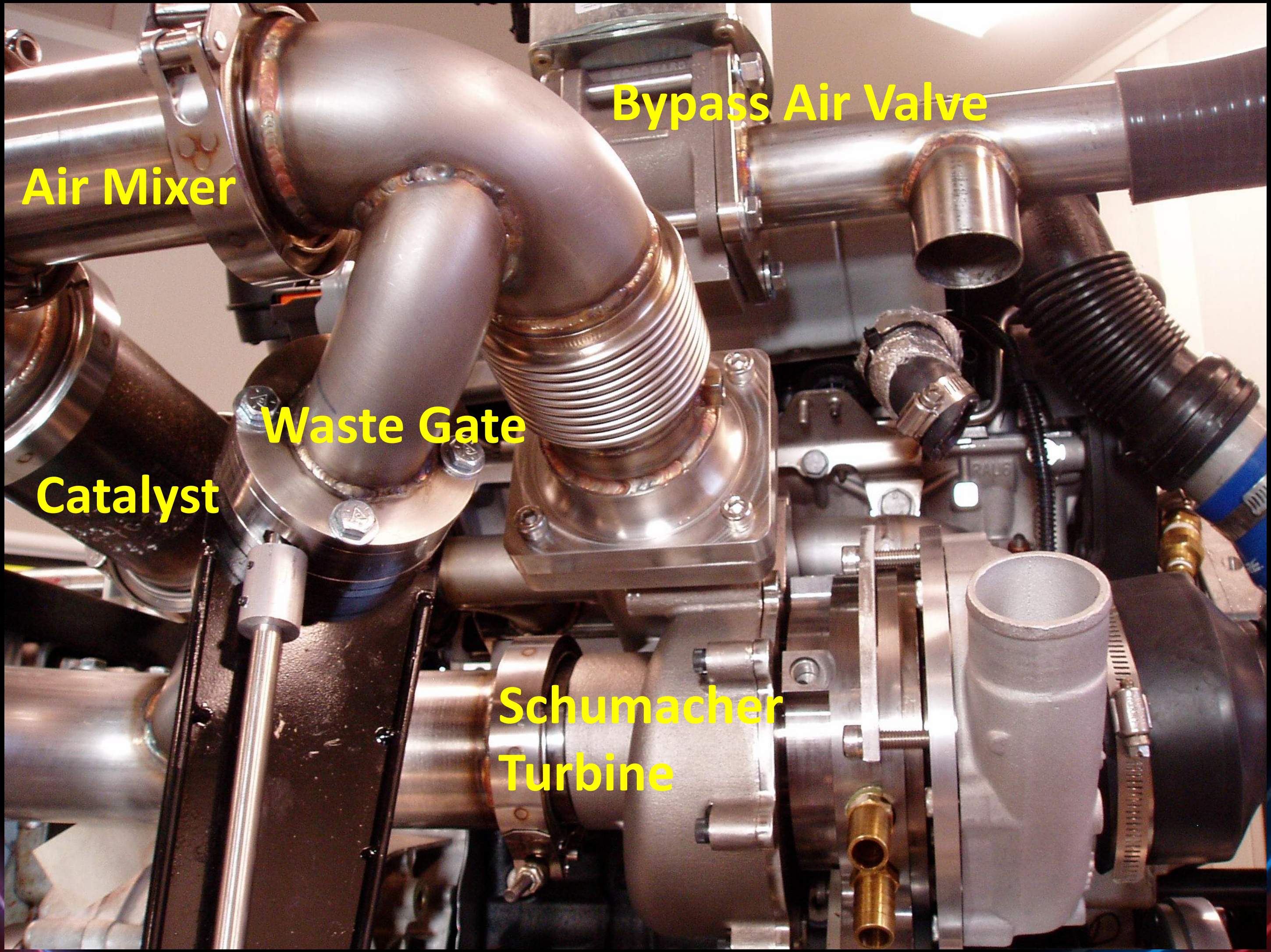


Estimated efficiency gain of 36% in EPA test

Bypass Benefits

- With a bypass more low rpm torque is possible with one big compressor
- When you bypass to the turbine for surge control the high efficiency of the supercharging is maintained
- Using the bypass valve to control turbine inlet temperature eliminates fuel cooling
- More air mass flow of 950°C air creates more power on the turbine

NSF Project Set-up



Road Car SuperTurbo Benefits

- Turbo machinery has higher efficiency
- Low turbo lag (less than 1 second)
- Highest efficiency supercharging
- Smaller lower cost catalyst because of higher density before turbine
- Lower engine backpressure
- Better mileage from a ½ size engine
- Lambda 1 to full power
- Lower cold start emissions

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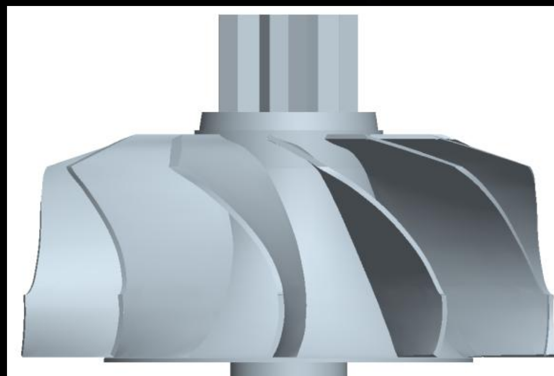
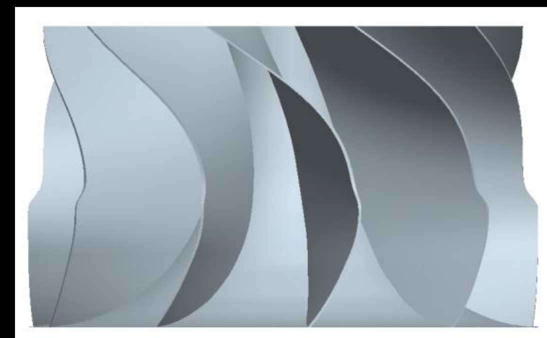
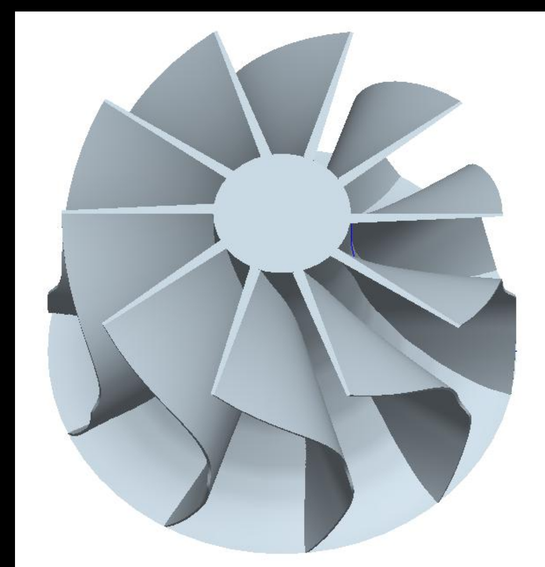
Turbine Comparison



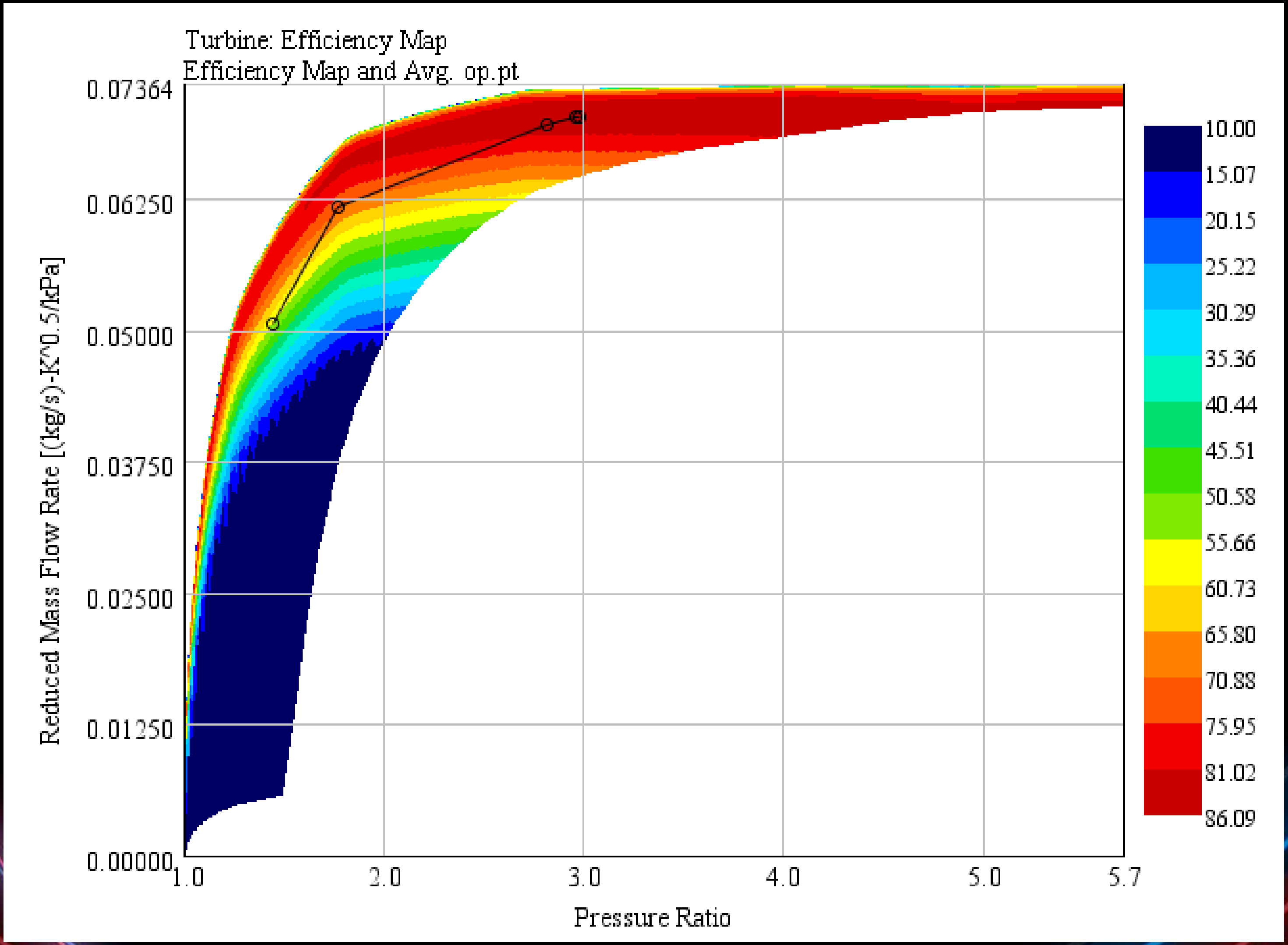




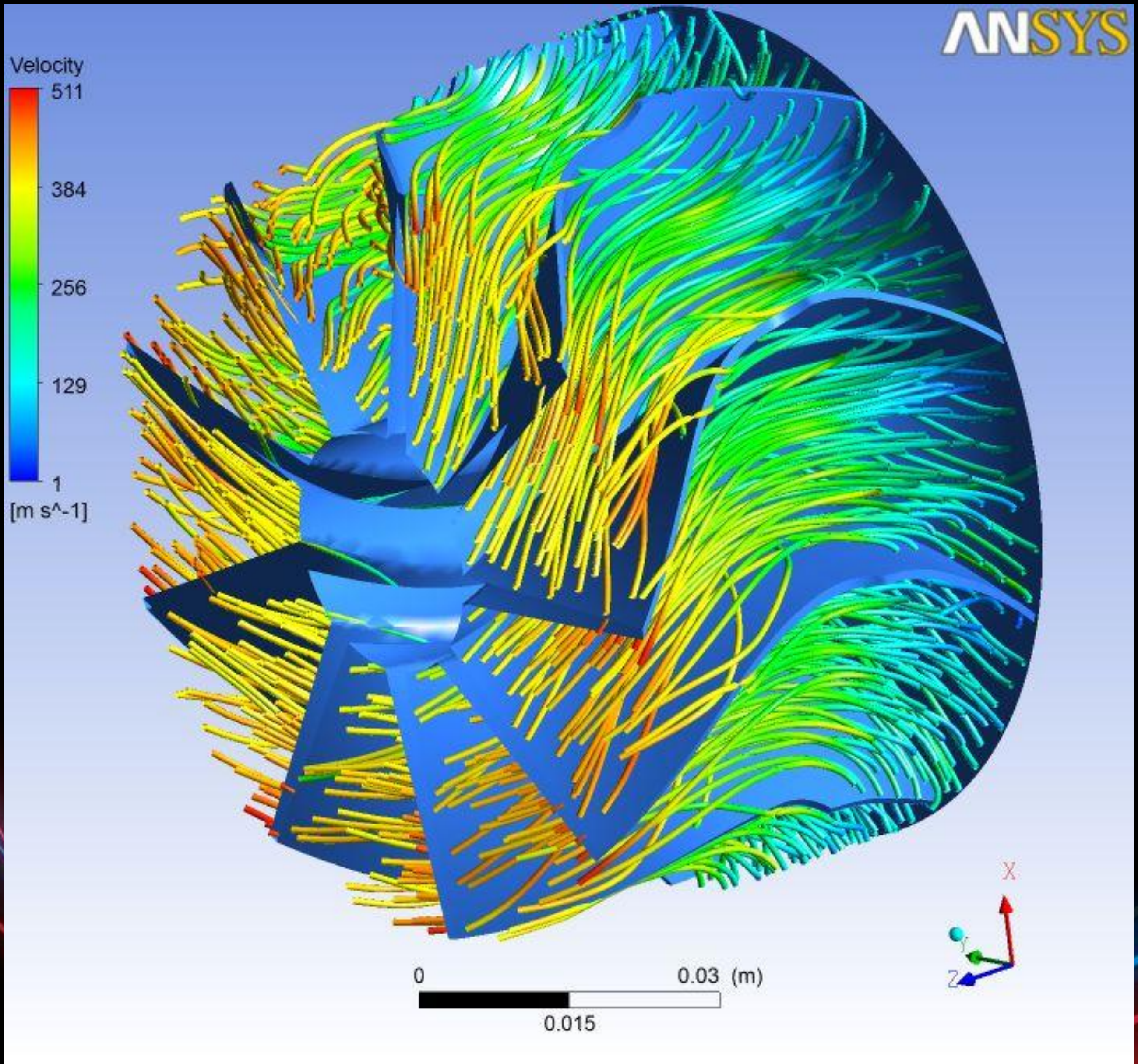
Stock Turbine

Schumacher

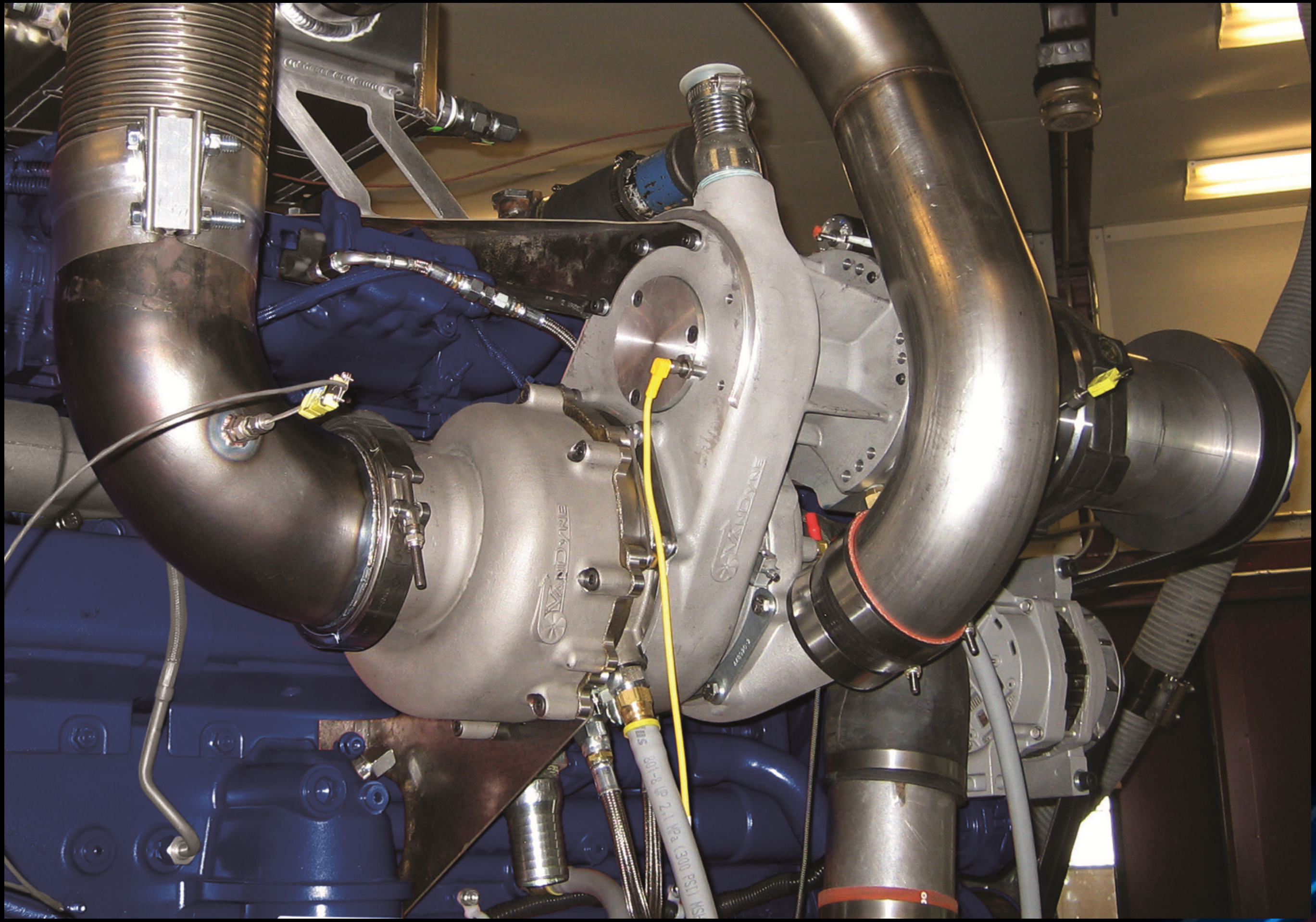
Schumacher Turbine Map



Velocity in Meters per Second



Big Diesel SuperTurbo



Making 1.7kW at 1200 rpm 75kW load

2014 Formula 1 Modeling

- GT Power® modeling software was used
- 1.6L, V6 cylinder engine modeled at 8000, 10,000, 12,000 13,500 and 15,000RPM
- Estimated cylinder dimensions and valve profiles based on max piston speed
- Gross IMEP was limited to 29 bar

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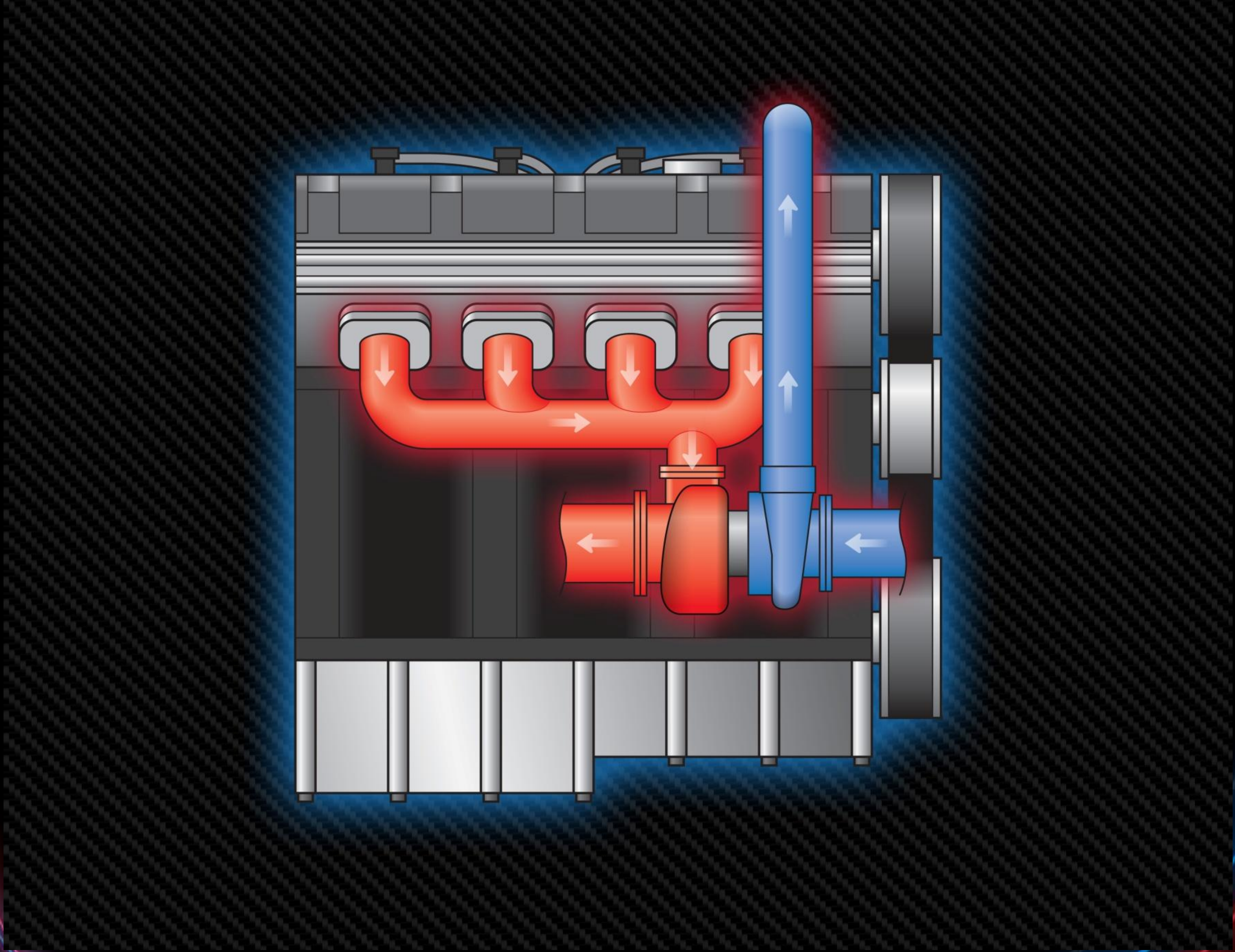
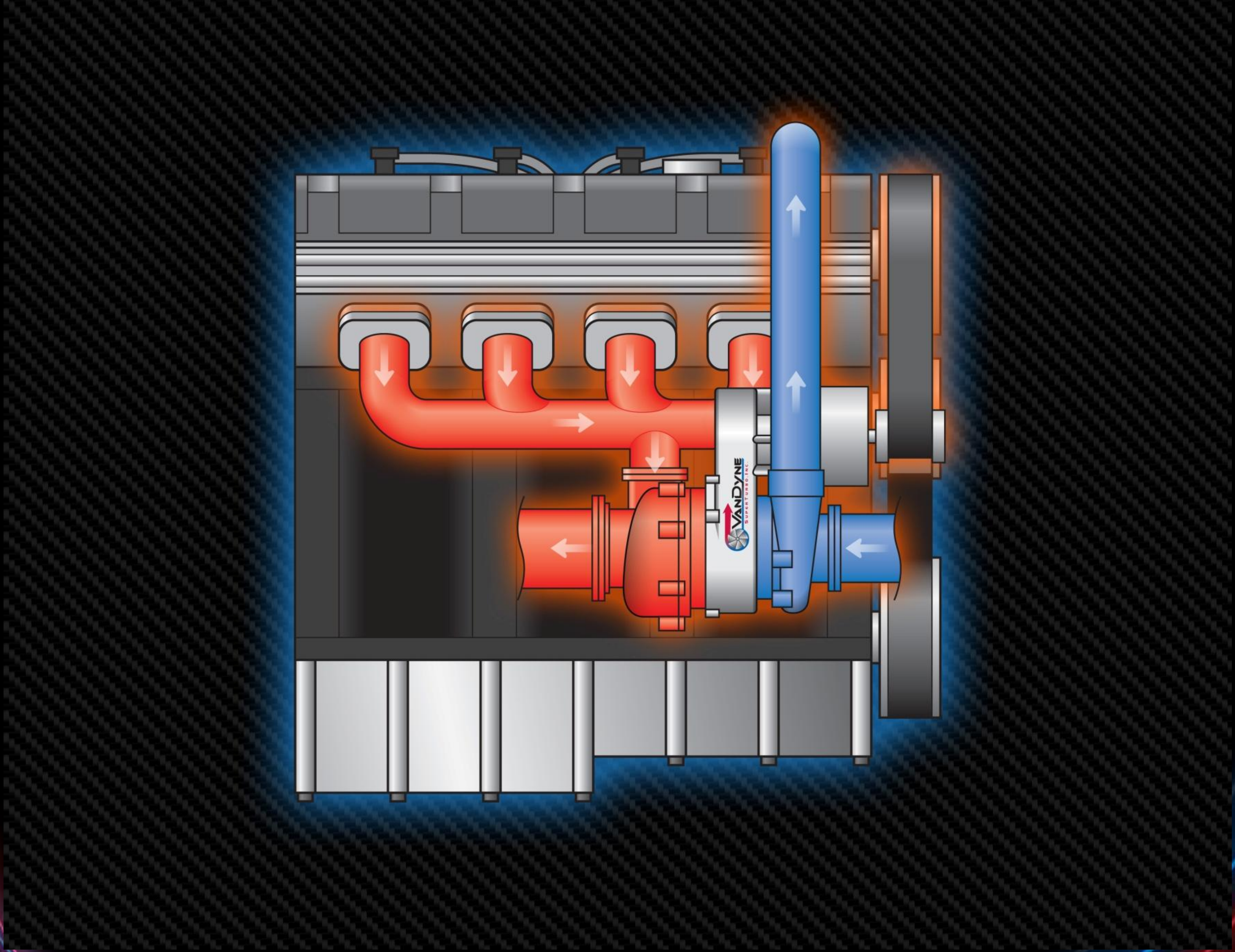
- Stock turbo is modeled to be free-spinning with a waste-gate
- SuperTurbo assumes an 80% efficient CVT transmission to enable turbo-compounding
- SuperTurbo with Bypass includes a post compressor intake air bypass into the pre-turbine exhaust, upstream of a catalyst to enable excess fuel in exhaust from rich in-cylinder conditions to burn and produce more turbine work for turbo-compounding



Stock Turbo



SuperTurbo™

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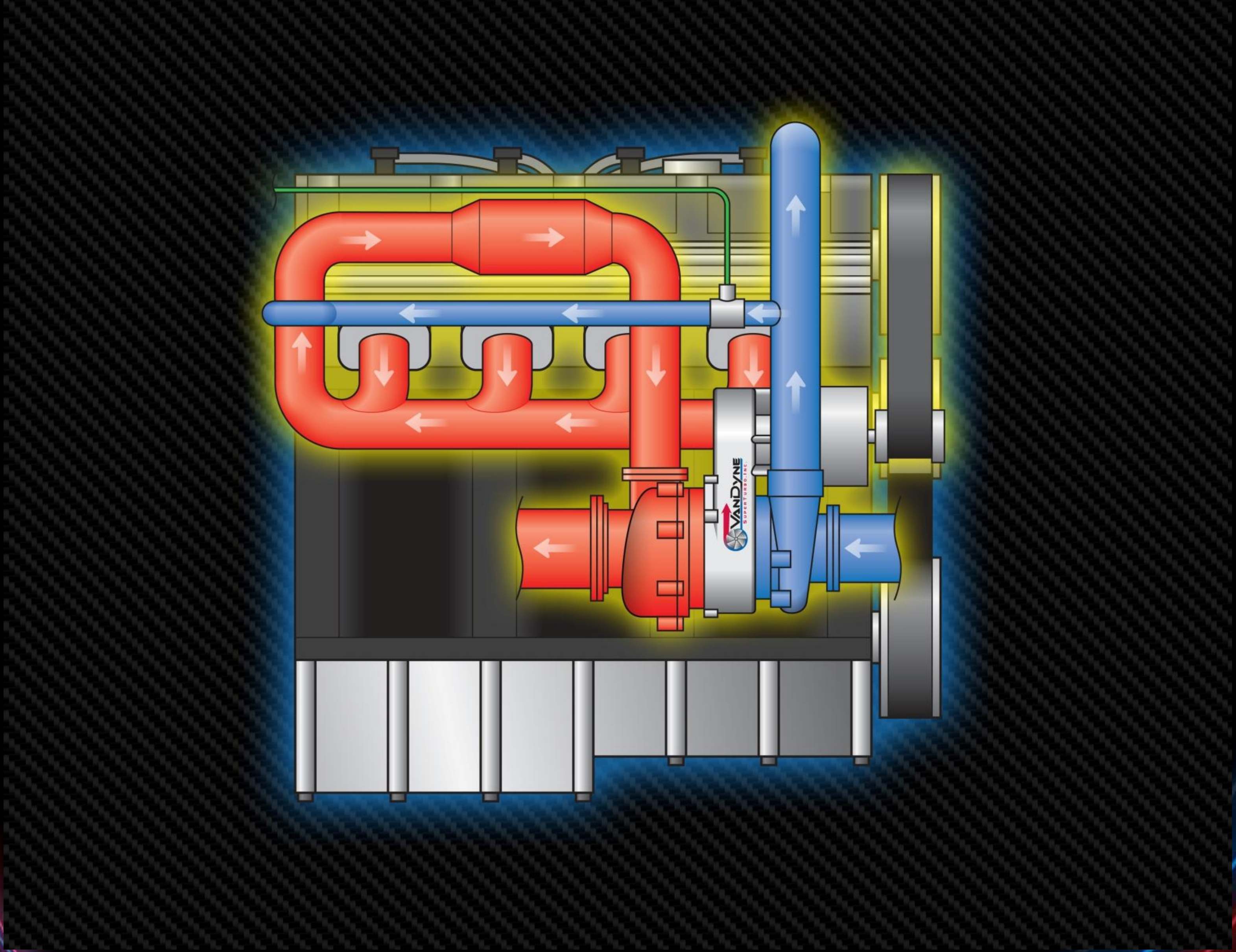
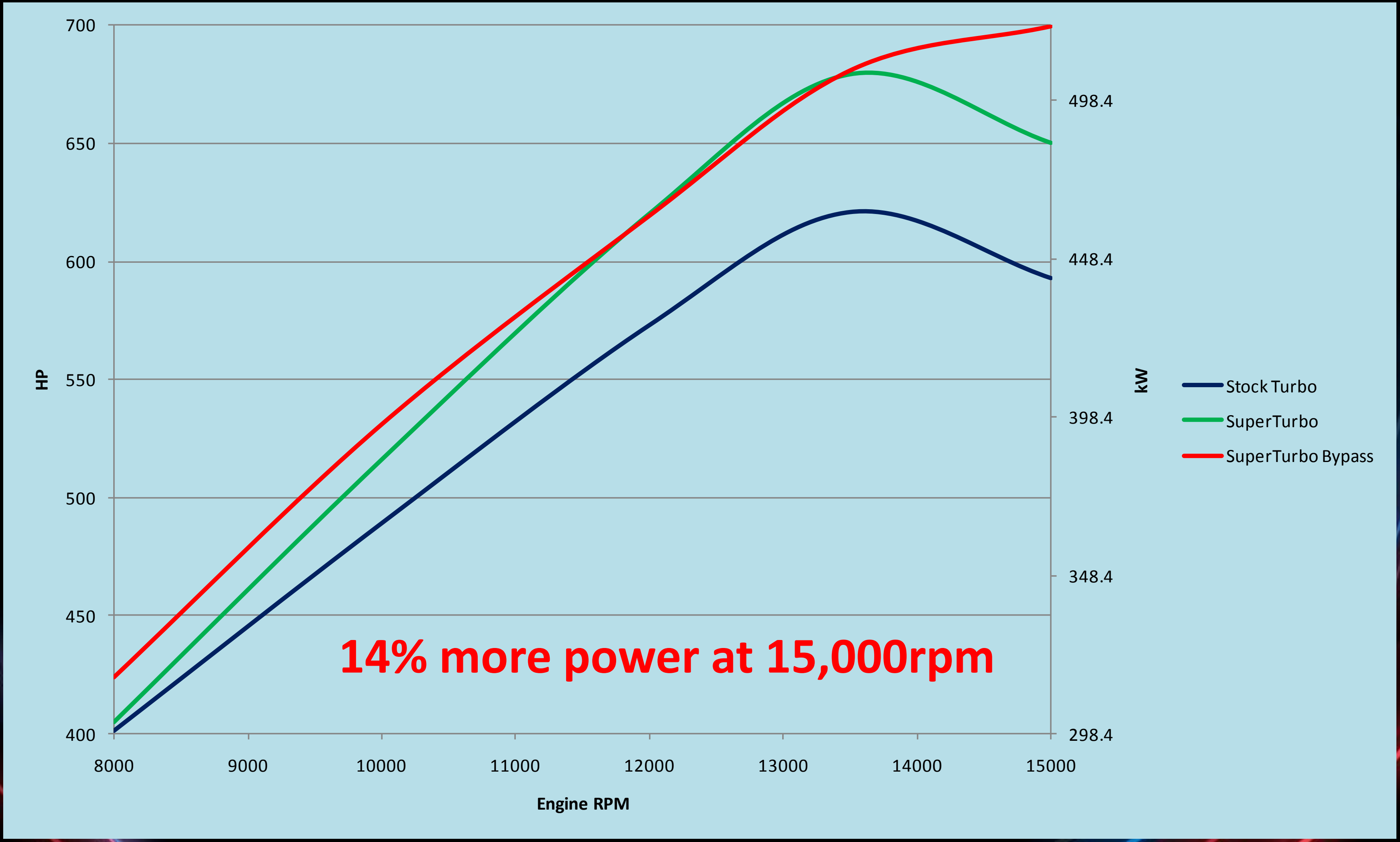


SuperTurbo with Bypass

- Maximum fuel flow limited to 120 kg/hr
- Lambda target was .92 for best in cylinder power, but was allowed to deviate for turbine temperature control and best fuel efficiency
- Same compressor map used for all cases
- In both SuperTurbo cases the turbine was customized in order to achieve the best turbo-compound power level
- Turbine inlet temp limited to 950C

Horsepower Gain



Equations

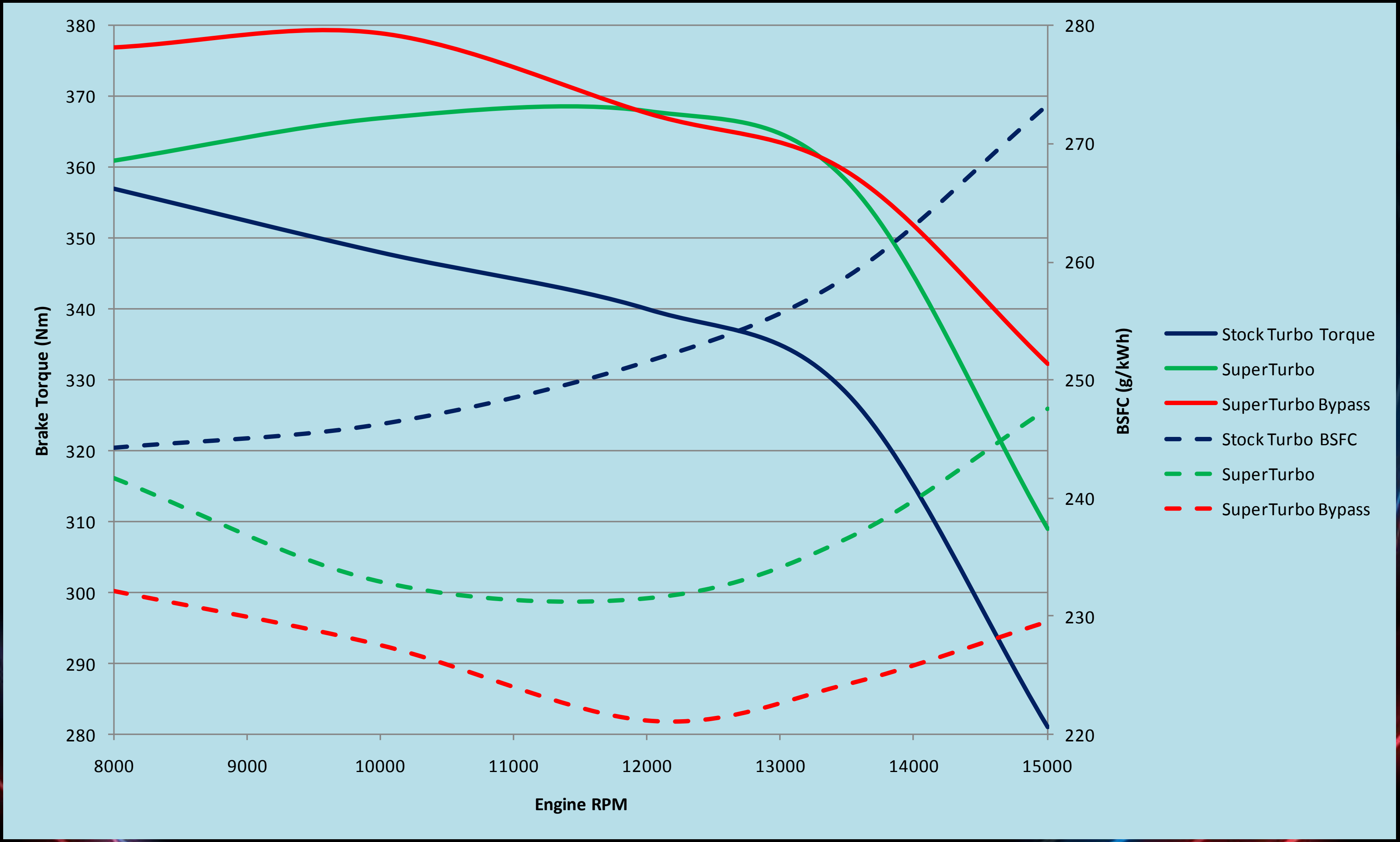
$$P_{ad} - P_{Fr} = P_C + P_T = P_C\left[1 + \frac{P_T}{P_C}\right]$$

$$P_C = \frac{\dot{m}_C}{\eta_{Cis}}\left(\frac{\overline{c_p}}{R}\right)_{air} R_{air} T_{Ci}\left(\frac{T_{Cois}}{T_{Ci}} - 1\right) = \frac{\dot{m}_C}{\eta_{Cis}}\left(\frac{\overline{c_p}}{R}\right)_{air} R_{air} T_{Ci}\left(\pi_C^{\left(\frac{R}{\hat{c}_p}\right)} - 1\right)$$

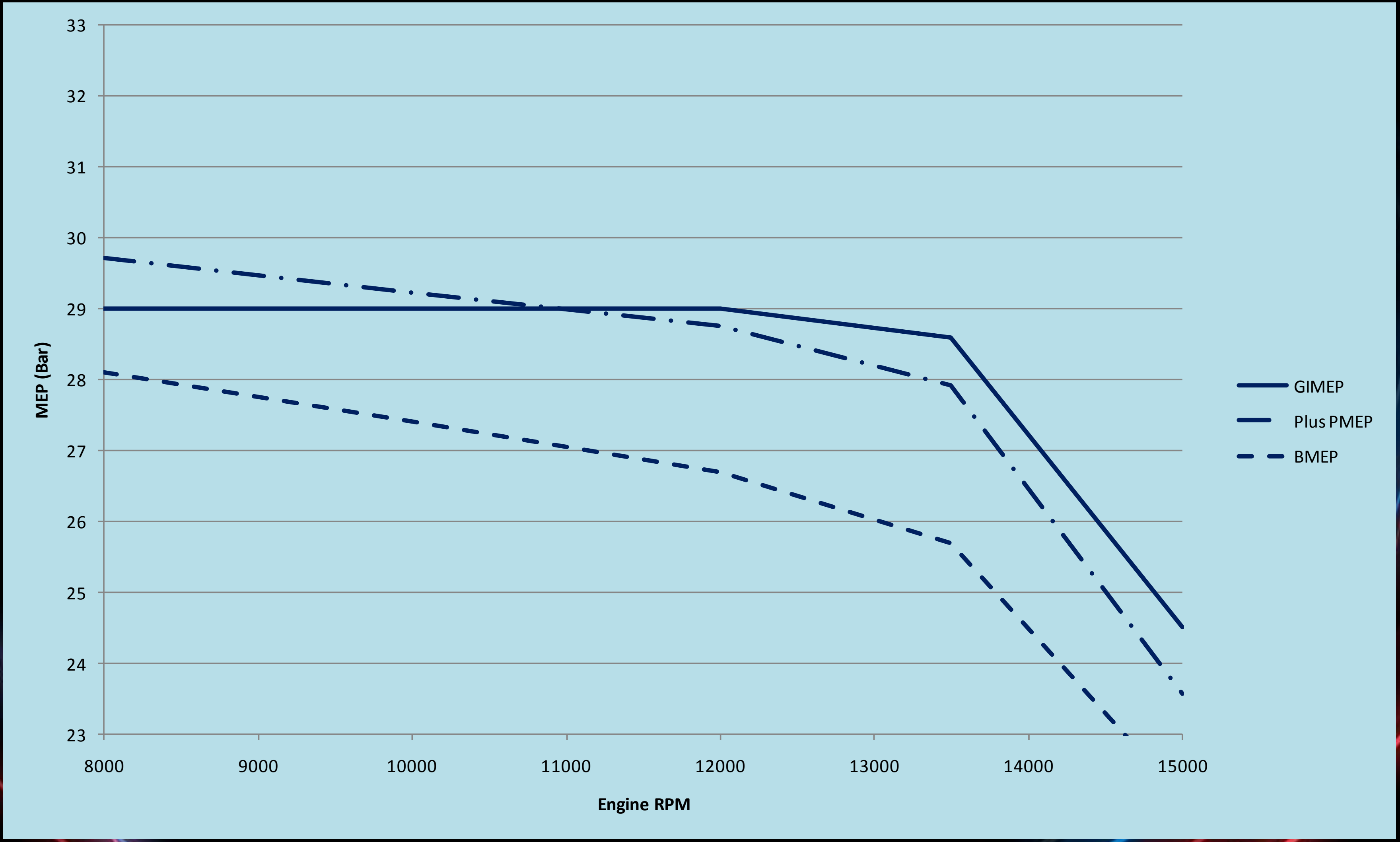
$$\dot{m}_T = \dot{m}_C + \dot{m}_F - \dot{m}_{Wg} = \dot{m}_C\left(1 + \frac{\dot{m}_F}{\dot{m}_C} - \frac{\dot{m}_{Wg}}{\dot{m}_C}\right) = \dot{m}_C(1 + \beta - \gamma)$$

$$P_T = \eta_{Tis}\dot{m}_T\left(\frac{\overline{c_p}}{R}\right)_{gas} R_{gas} T_{Ti}\left(\frac{T_{Tois}}{T_{Ti}} - 1\right) = \eta_{Tis}\dot{m}_T\left(\frac{\overline{c_p}}{R}\right)_{gas} R_{gas} T_{Ti}\left(\pi_T^{\left(\frac{R}{\hat{c}_p}\right)} - 1\right)$$

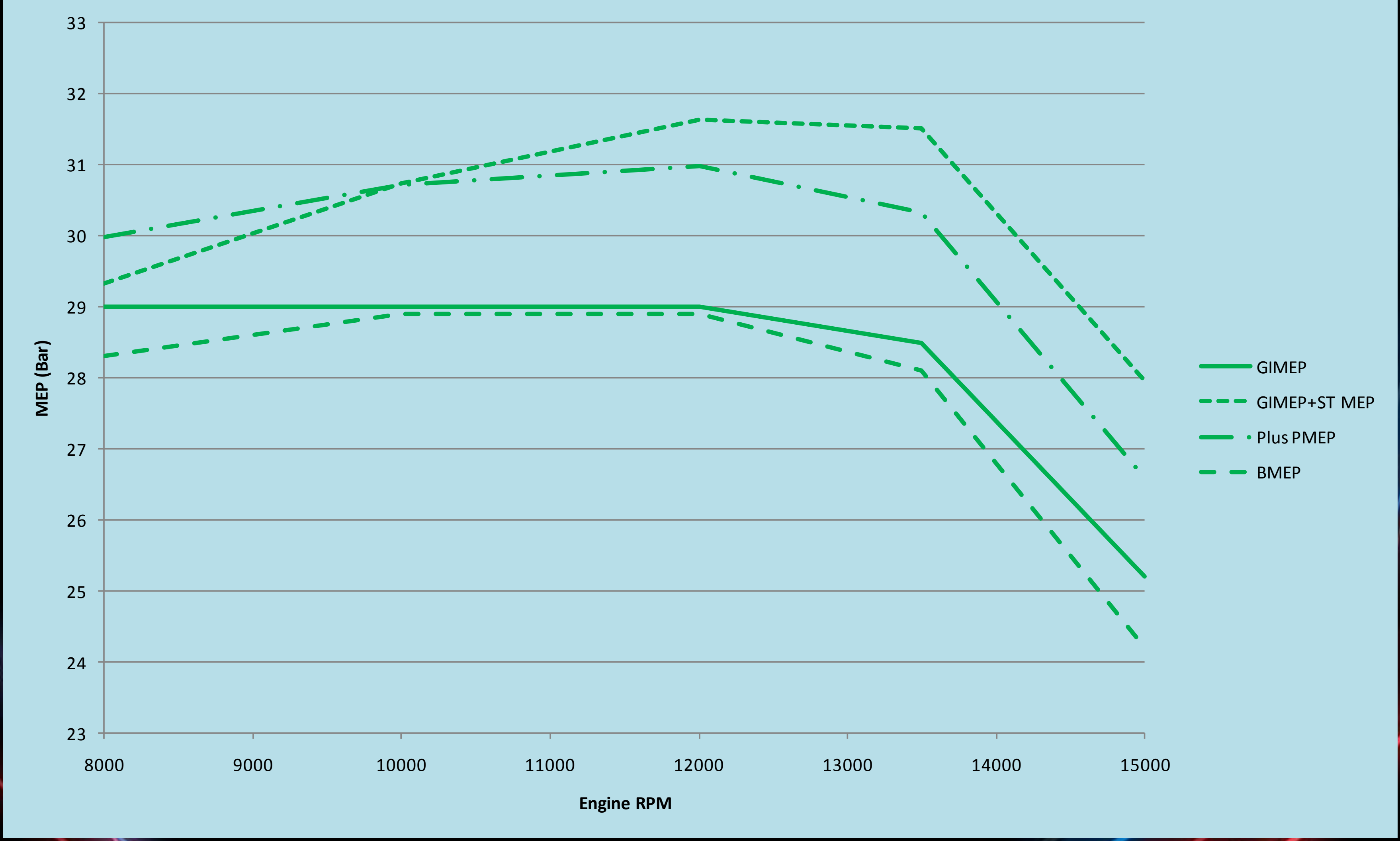
Torque and Fuel Consumption



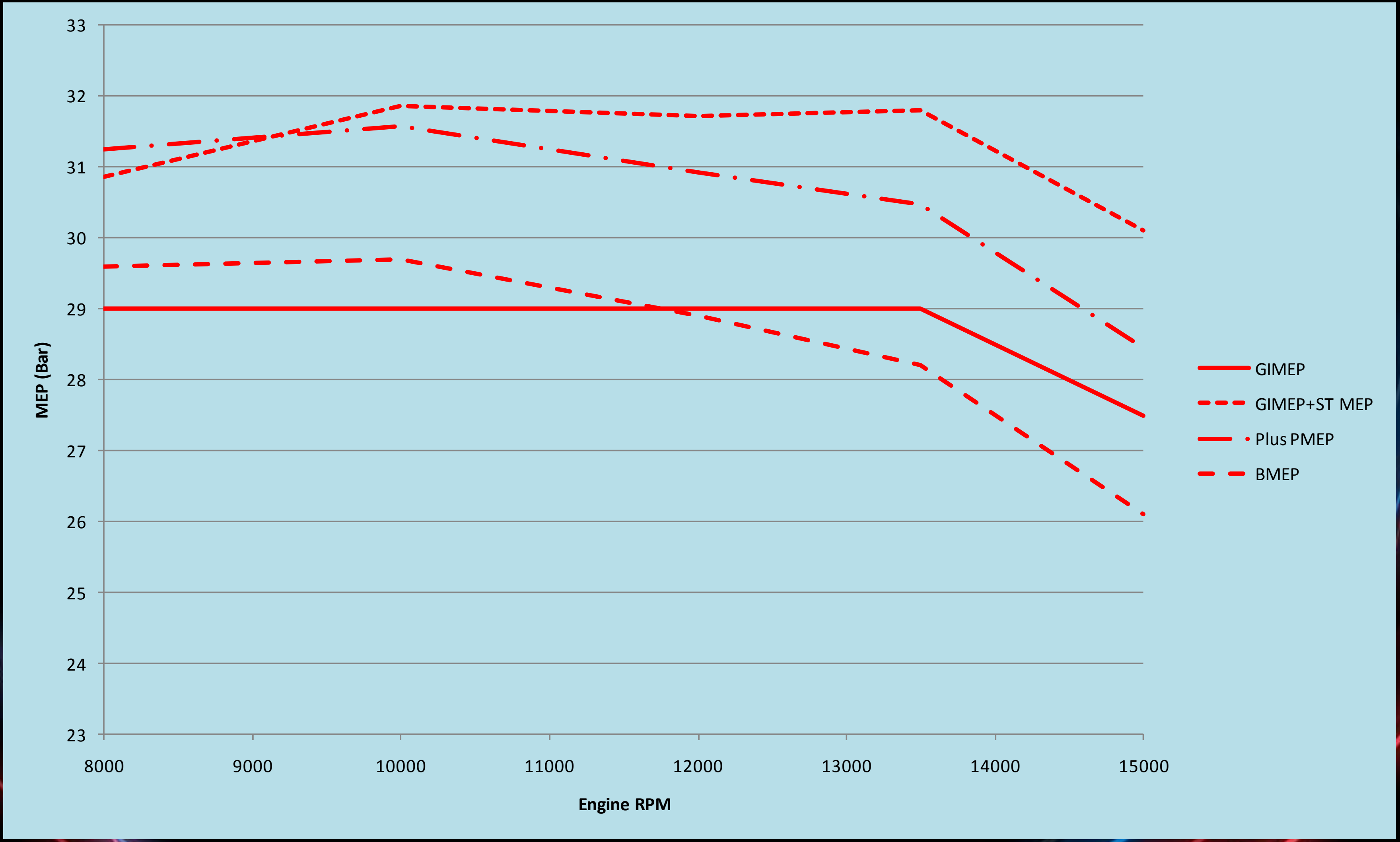
Stock Turbo Mean Eff. Pressure



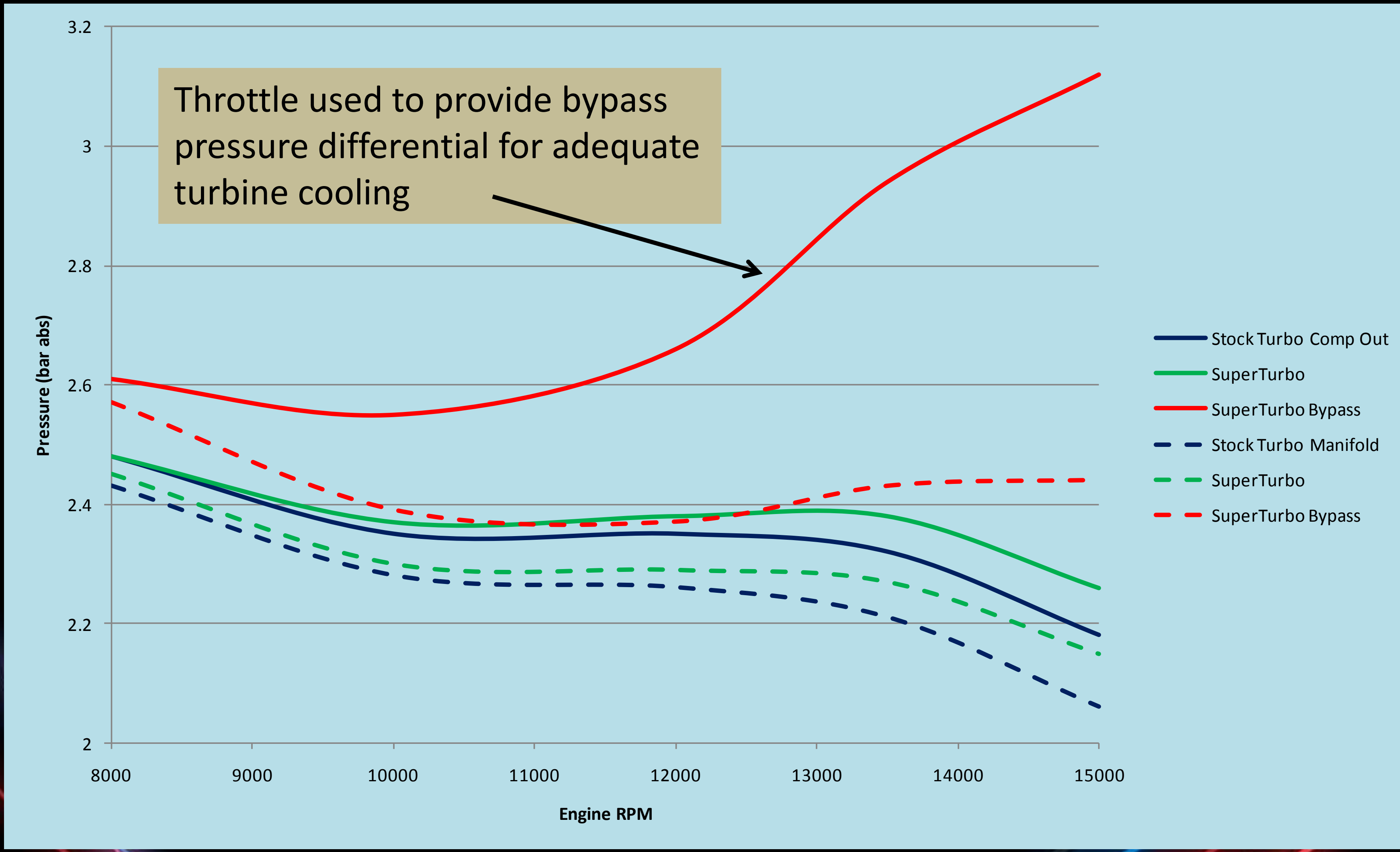
SuperTurbo Mean Eff. Pressure



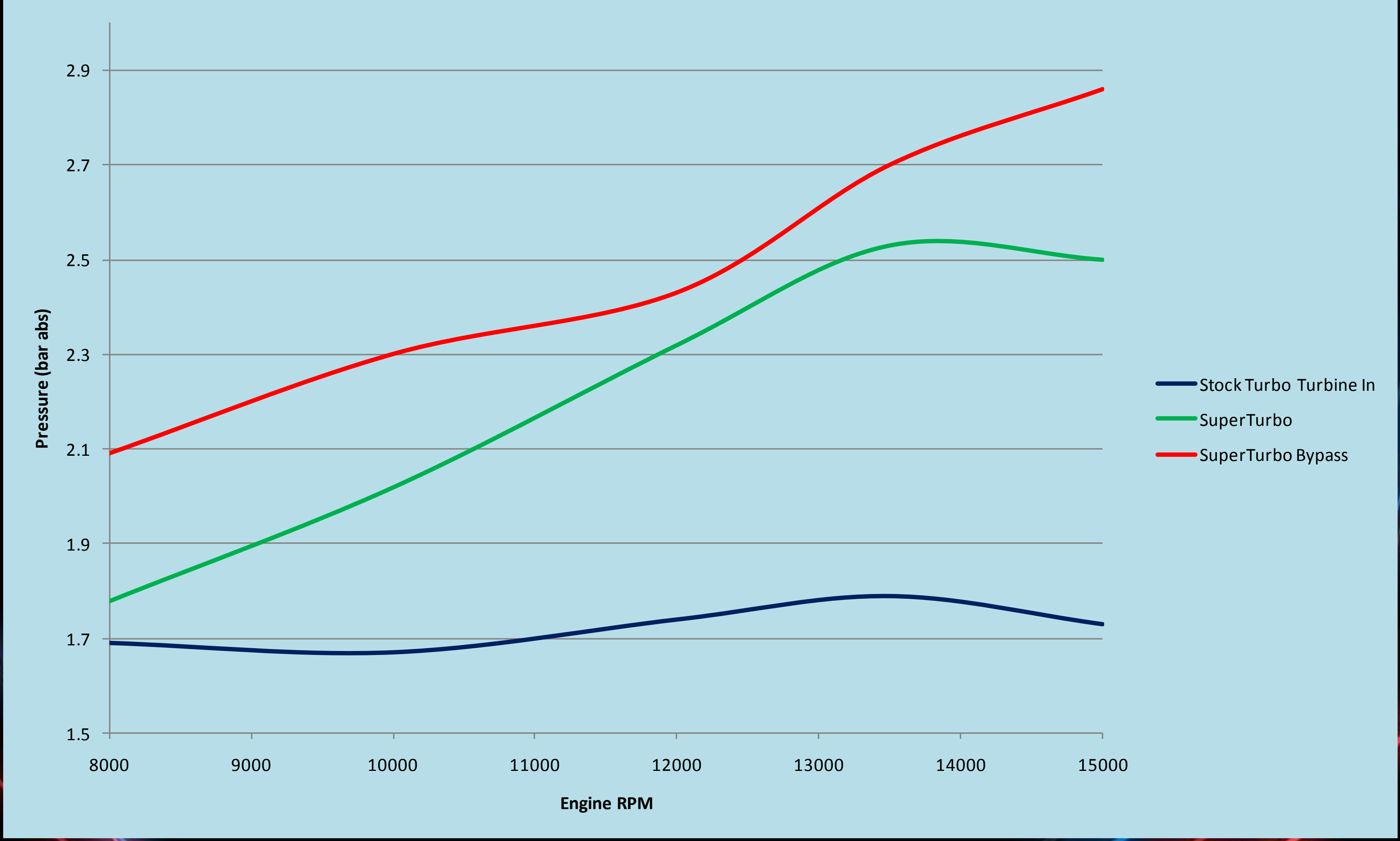
Bypass Mean Effective Pressure



Intake System Pressures



Turbine Inlet Pressures



Racing Engine Benefits

- Catalytic converter becomes a burner when fed with oxygen from the compressor
- Smaller catalytic converter is possible because of higher density before turbine
- Higher engine backpressure is beneficial to a SuperTurbo at high IMEP levels
- Better in cylinder fuel utilization is possible when a fuel flow limitation exists
- Highest amount of turbocompounding when using the bypass configuration

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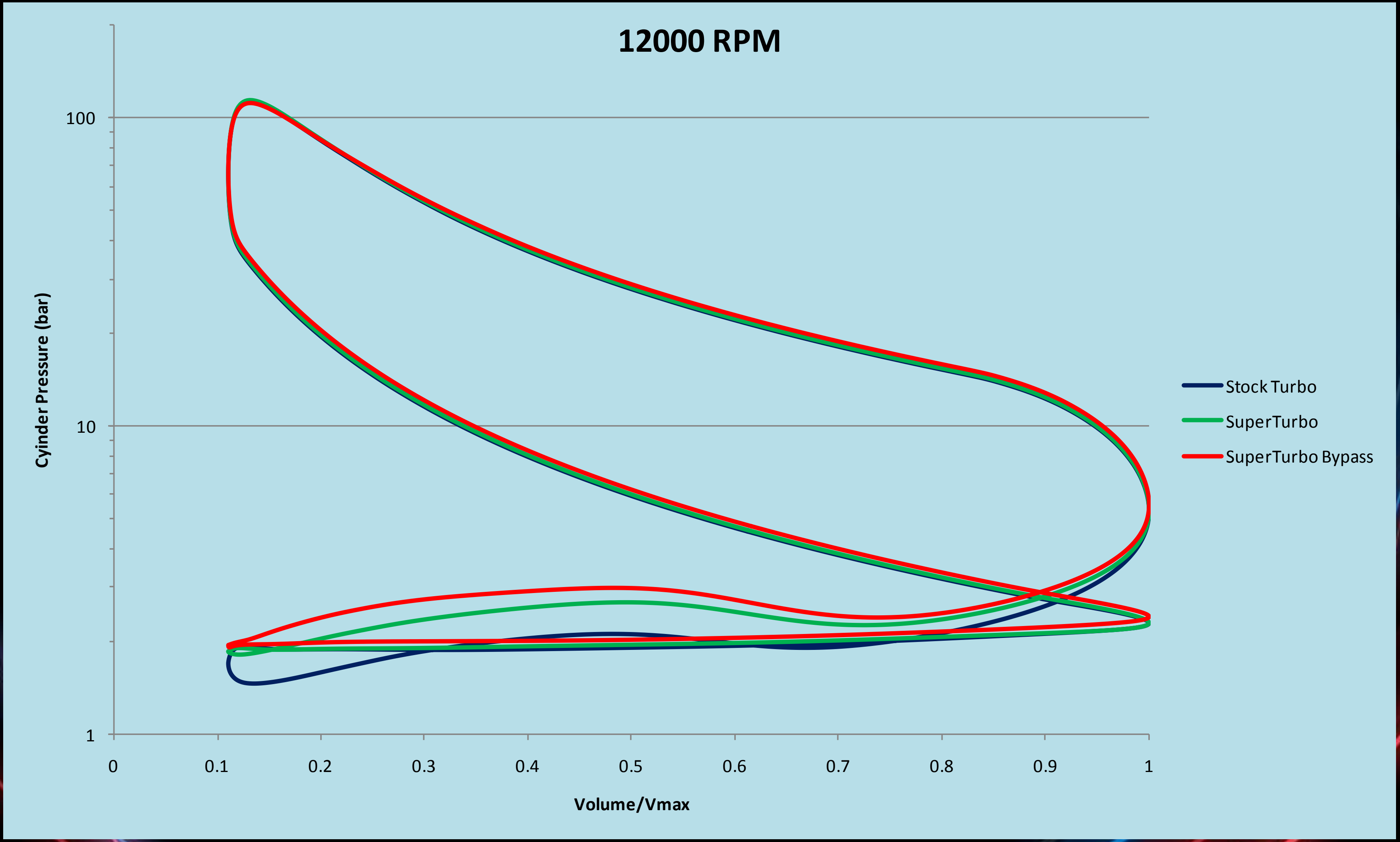
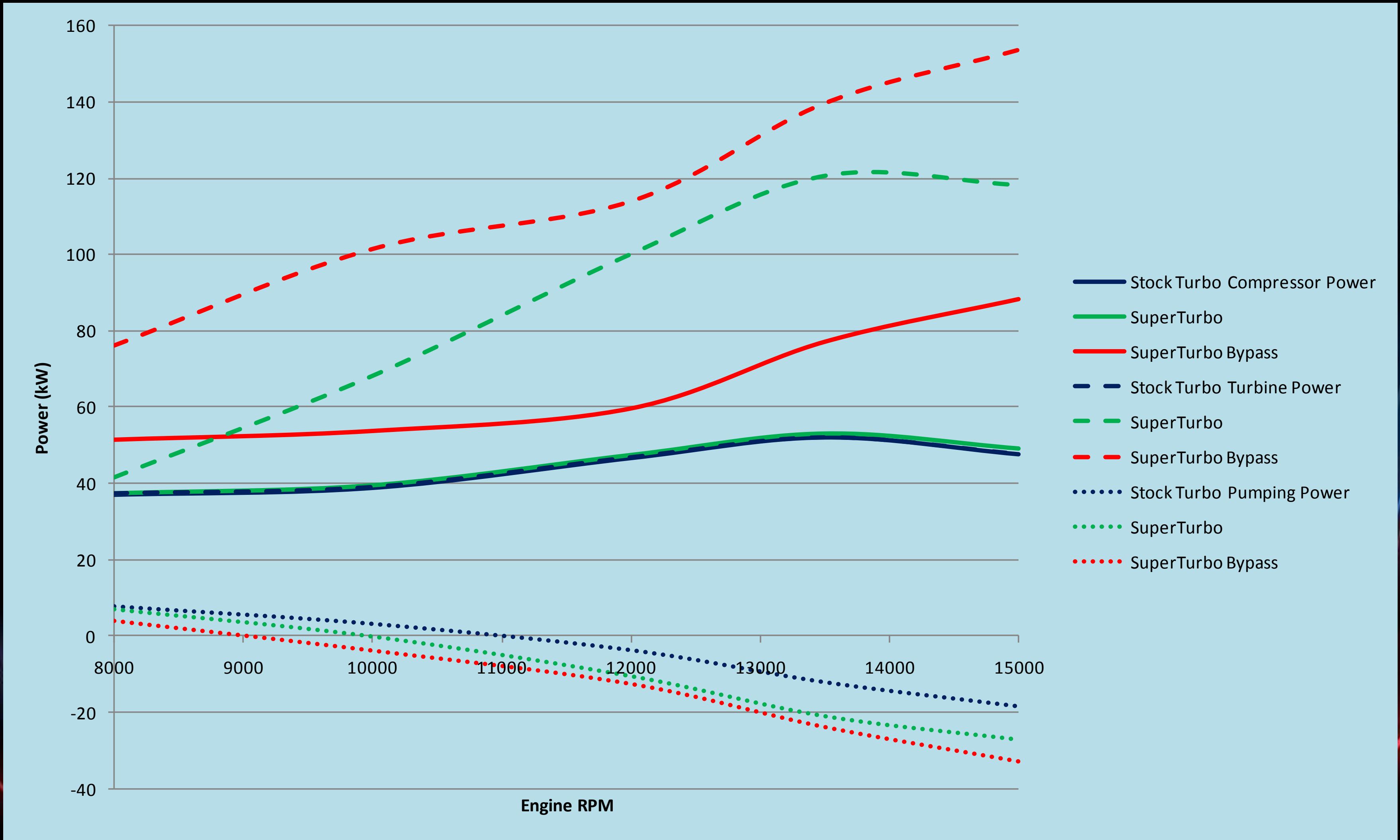
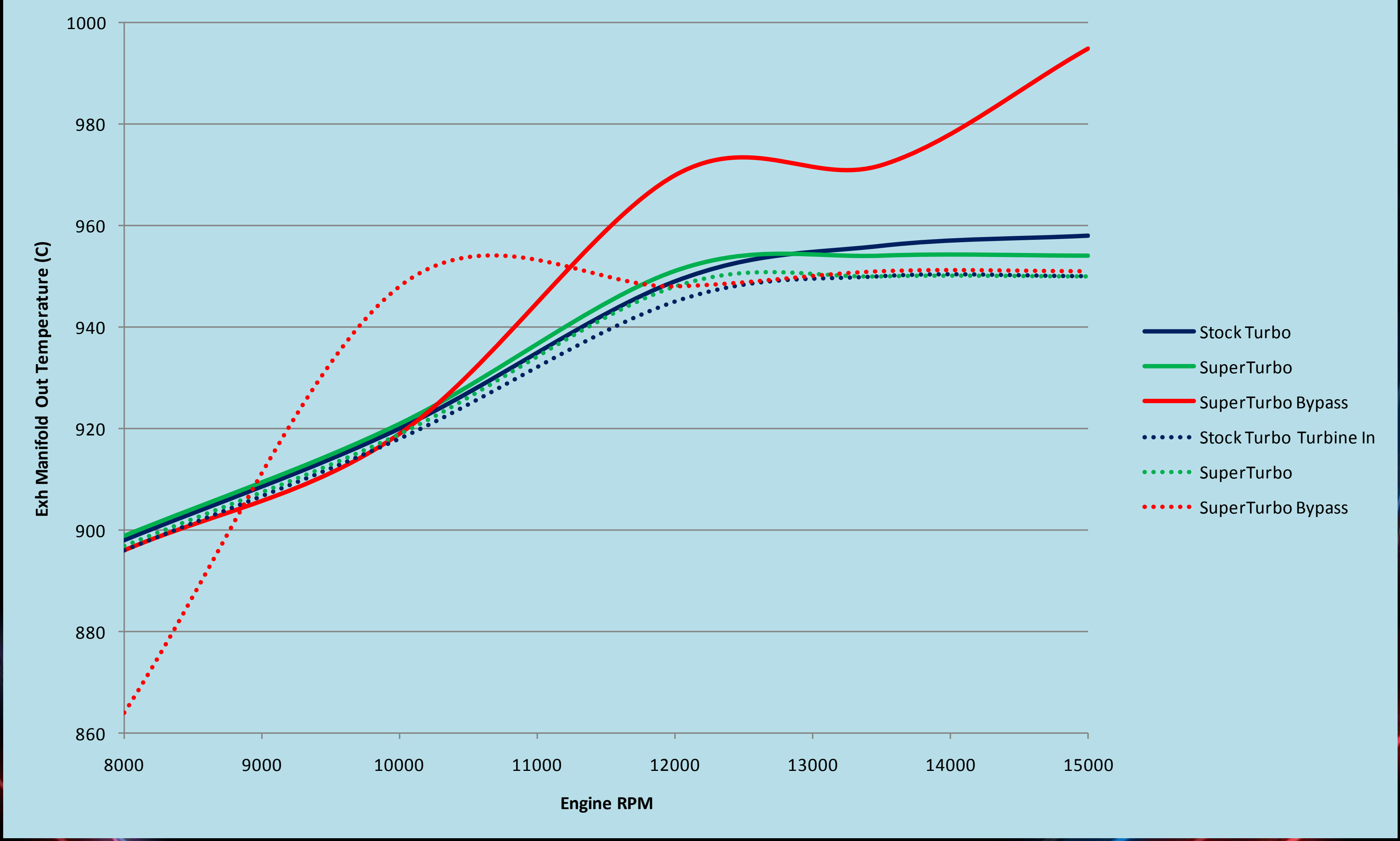
Pressure vs. Volume Diagram



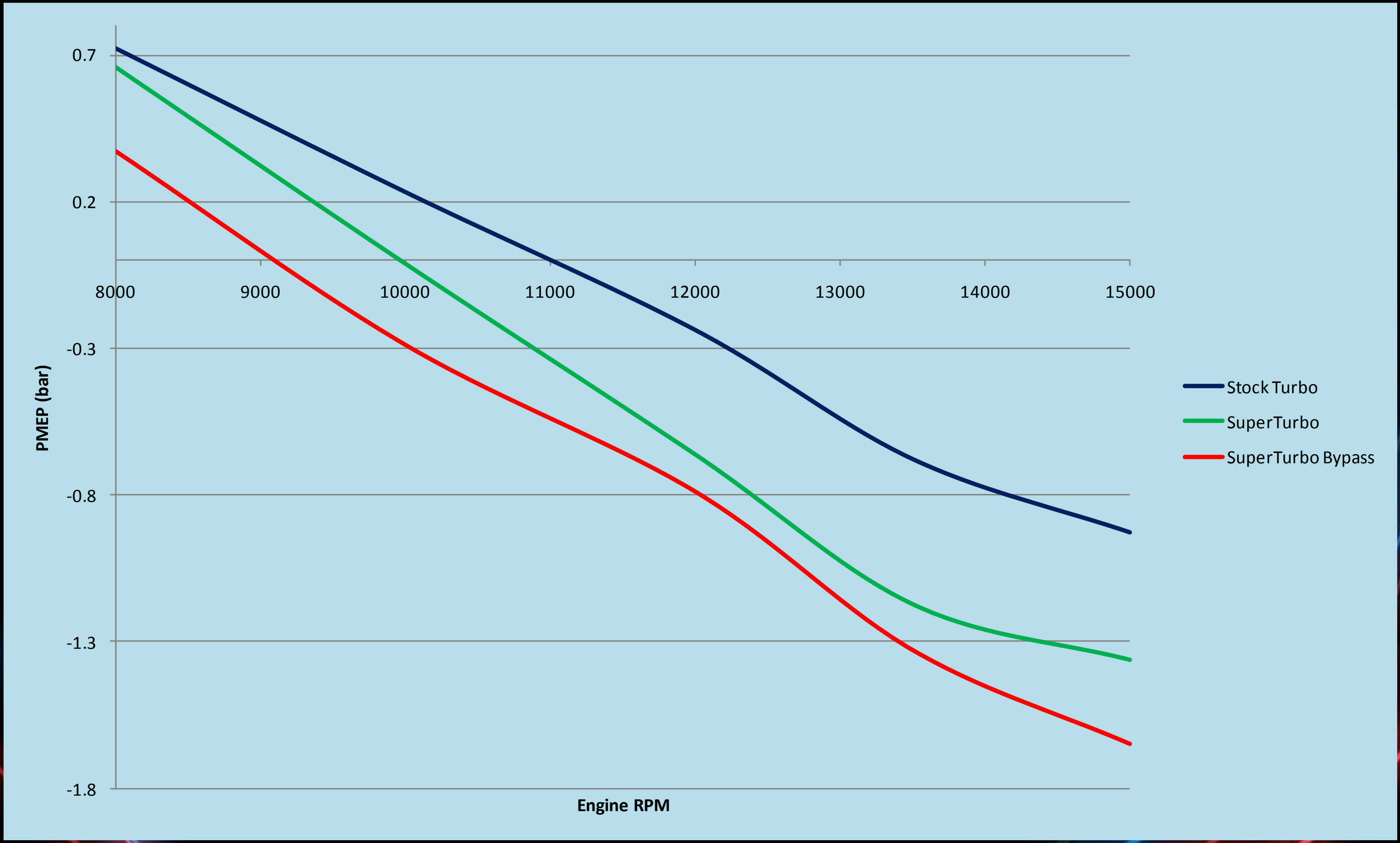
Turbine vs. Compressor Power



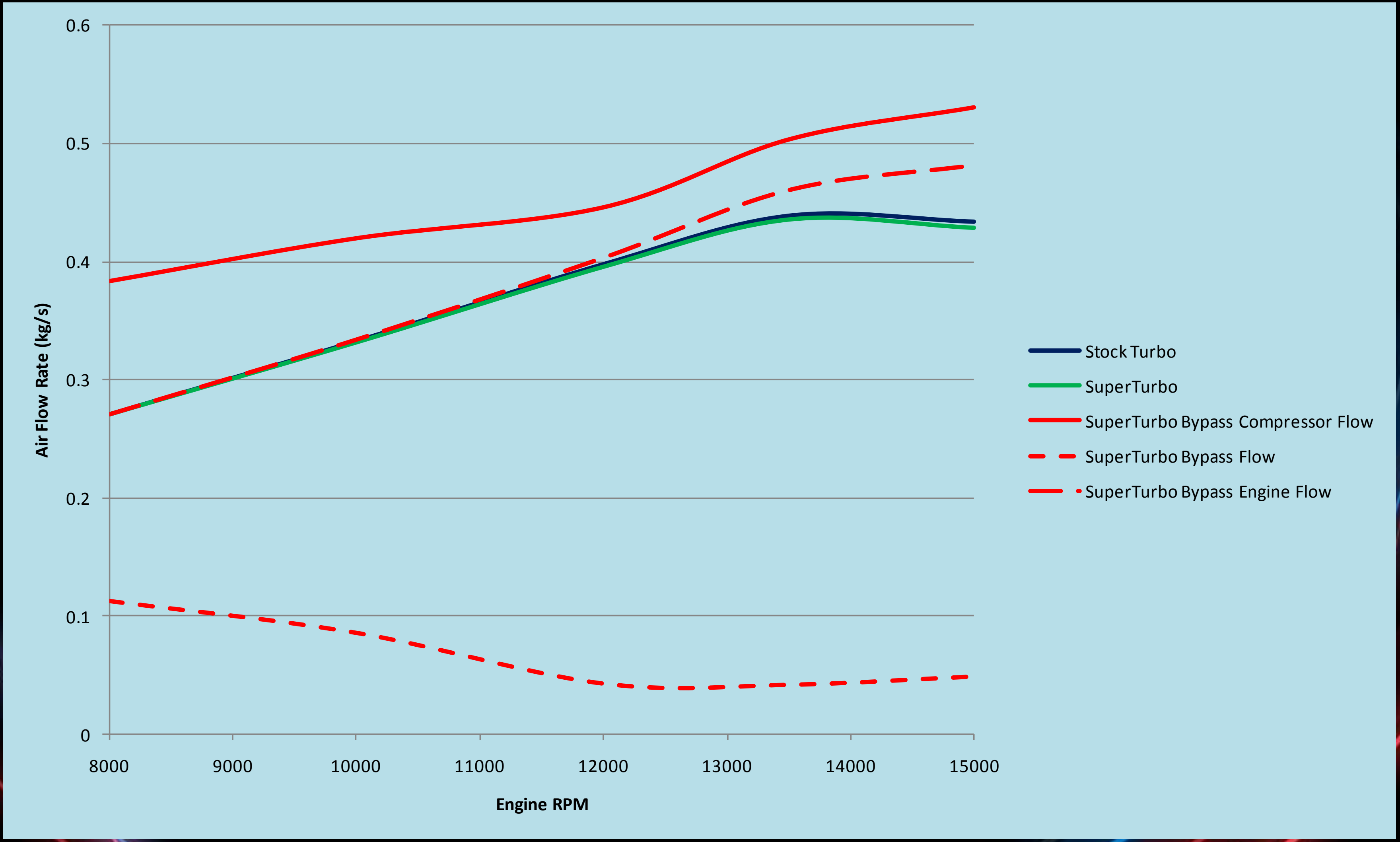
Exhaust System Temperatures



Pumping Mean Effective Pressure



Air Mass Flow



Horsepower Gain

- 100 Horsepower more with Bypass and the same fuel flow limitation at 15,000 rpm
- 5% to 10% more power over the whole curve just from waste heat energy with the same in cylinder power
- 5% lower fuel consumption with Bypass at 13,500 rpm for the same power gain as a conventional SuperTurbo

SuperTurbo vs. Competition

- We win on peak power: Turbocompounding
- We win on peak torque: Supercharging
- We win on efficiency: Lambda 1
  - May require a clutch to win at all points
- We win on emissions: Pre-turbine catalyst
- We win on turbo lag: Transmission
- We win on COST: ½ size catalyst

Powering the way to greater fuel efficiency!

THANK YOU

Ed VanDyne

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