Eaton TVS Supercharger for Downsizing

Presentation to Engine Expo

Stuttgart June 16th, 2009

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Our Environment

- Global warming & pollution health risks
- Volatile fuel costs on a upward trend
- Increasing vehicle population
- Urban and arterial route congestion
- Average speeds
  - London 18 to 23 Km/hr
  - Urban UK 33 to 40 Km/hr
- Power & Torque still command a premium in the market ?????
- **DRIVING PLEASURE IS A TRANSIENT EXPERIENCE**

Supercharger Heritage

- What is the traditional image of the Supercharger?

Eaton Supercharger History

- 1988: The first Eaton production application was used on the Ford Thunderbird Super Coupe.

- 1990: GM teamed with Eaton to supercharge the Buick Park Avenue Ultra.
- Eaton has since designed and developed superchargers for 59 production vehicle applications and has manufactured over 4 million units.

Eaton Supercharger Applications (OEM)

VW Golf GT
ScTc 1.4L I4

Cobalt SS
S/C 2.0L I4

Range Rover Sport
S/C 4.2L V-8

Ford GT
S/C 5.4L V-8

Ford GT500
S/C 5.4L V-8

1.0L 1.6L 2.0L 3.8L 4.4L 5.4L 6.2L

BMW-Mini Cooper S
S/C 1.6L I4

Saturn Ion RedLine
S/C 2.0L I4

Pontiac Grand Prix GTP
S/C 3800 V-6

Jaguar XFR
S/C 5.0L V-8

Cadillac CTS-V
S/C 6.2L V-8

Ford SVT Lightning
S/C 5.4L V-8

Ford Festiva
S/C 1.0L I4

Mercedes M271
S/C 1.6L/1.8L I4

Audi S4/A6
S/C 3.0L V-6

Cadillac STS-V
S/C 4.4L V-8

GM ZR-1 Corvette
S/C 6.2L V-8

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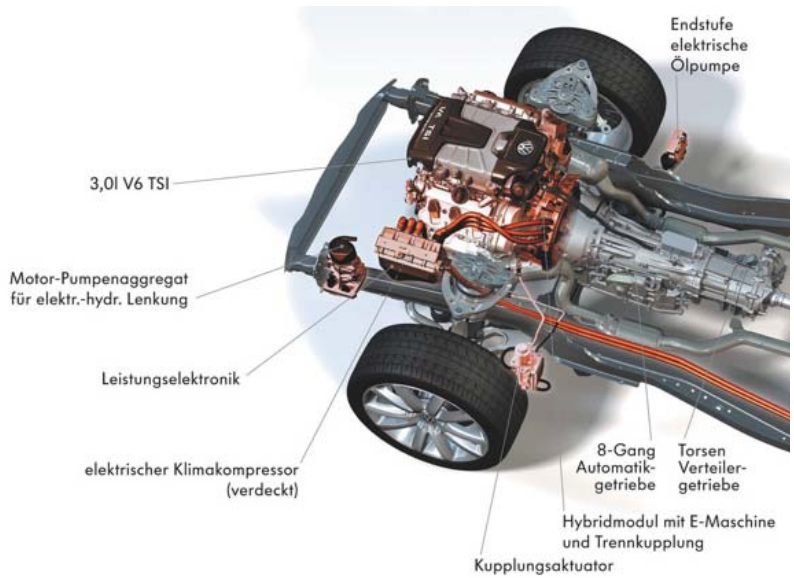
Latest Eaton TVS® Supercharger Application

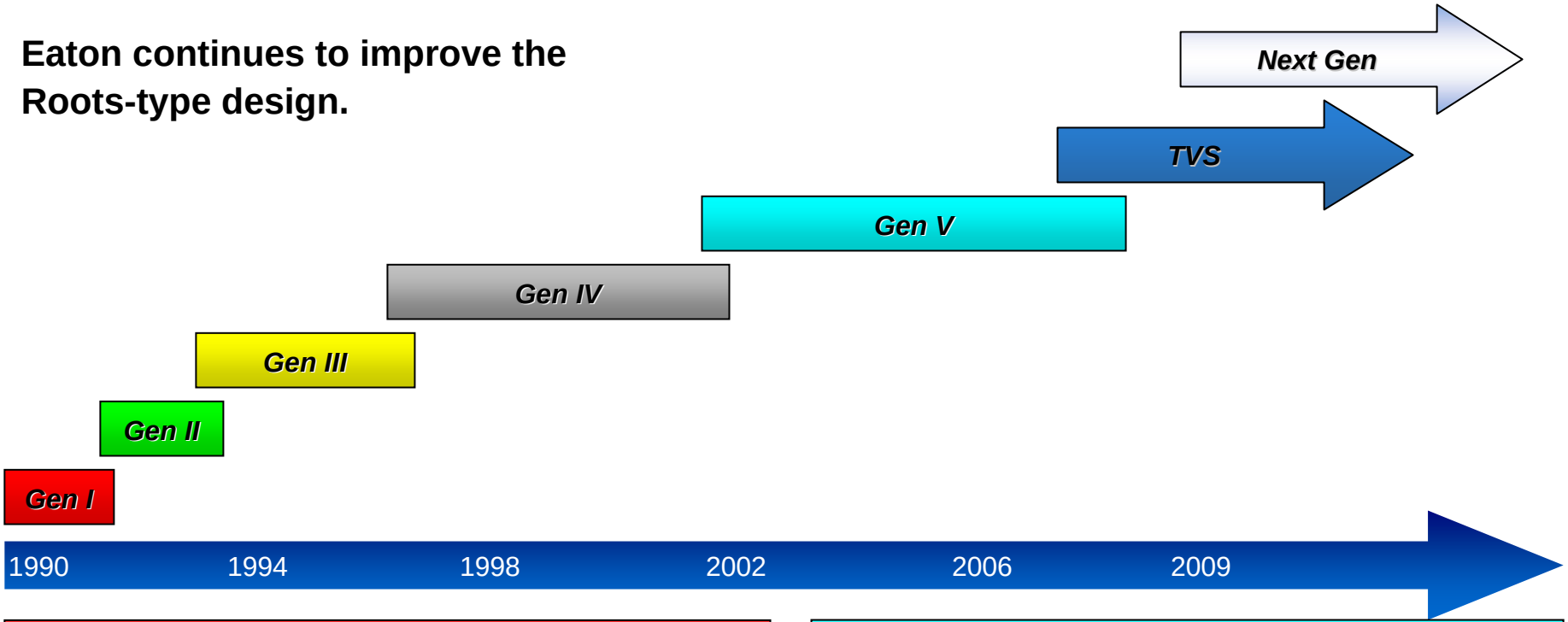
VW Hybrid Power

- VW group recently announced an all new supercharged hybrid gasoline electric drive system.
  - 3.0L Direct Injection V6 with R1320 TVS supercharger
  - 8 speed dual clutch transmission
  - 288 volt battery pack
- Initial application in VW Touareg
  - 328 gasoline HP
  - 51 electric HP
  - 0-60MPH in 6.8 seconds
- TVS supercharger technology chosen for improved efficiency, fuel economy, ease of packaging, and excellent stop / start emissions
  - 26.1 MPG combined fuel economy
  - CO2 emissions < 210 g/km
  - 2014 Euro-6 emissions compliant



Supercharger technology enhancements... An Ongoing Story

Eaton continues to improve the Roots-type design.



Gen I: Patented Rotor Profile and Outlet port

Gen II: New patented Inlet and Outlet port

Gen III: Patented rotor coating electrostatic epoxy powder

Gen IV: Patented Island Bearing Plate Outlet Port

Gen V: Patented Abradable Powder Coating

TVS: Patented high–twist rotors

Next Gen: New levels of boost and efficiency

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Automotive News
PACE Award Winner 2008

Automotive News PACE™ AWARD

ERNST & YOUNG
Quality In Everything We Do

TRC Transportation Research Center Inc.

Winner

Eaton TVS® Supercharger recognized for Innovation in the New Product Category

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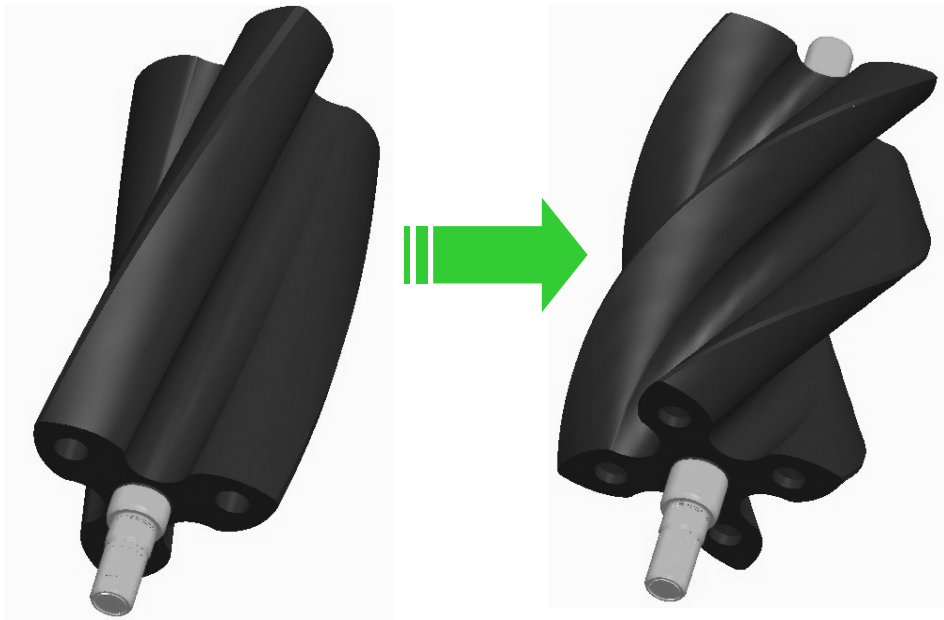
Eaton TVS® Supercharger Engineered for Fuel Economy.

The Eaton **Twin Vortices Series (TVS®)** supercharger delivers an attractive value proposition to competitive technologies:

- **The ability to Downsize & Downspeed for fuel economy (CO2 reduction) without compromising performance particularly response.**
- **25% reduction in packaging size & weight**
- **Patented design featuring:**
  - 2.5 pressure ratio capability
  - 75%+ thermal efficiency
  - Improved NVH characteristics

5th Gen Rotors
3 lobes
60 degree twist

TVS® Rotors
4 lobes
160 degree twist

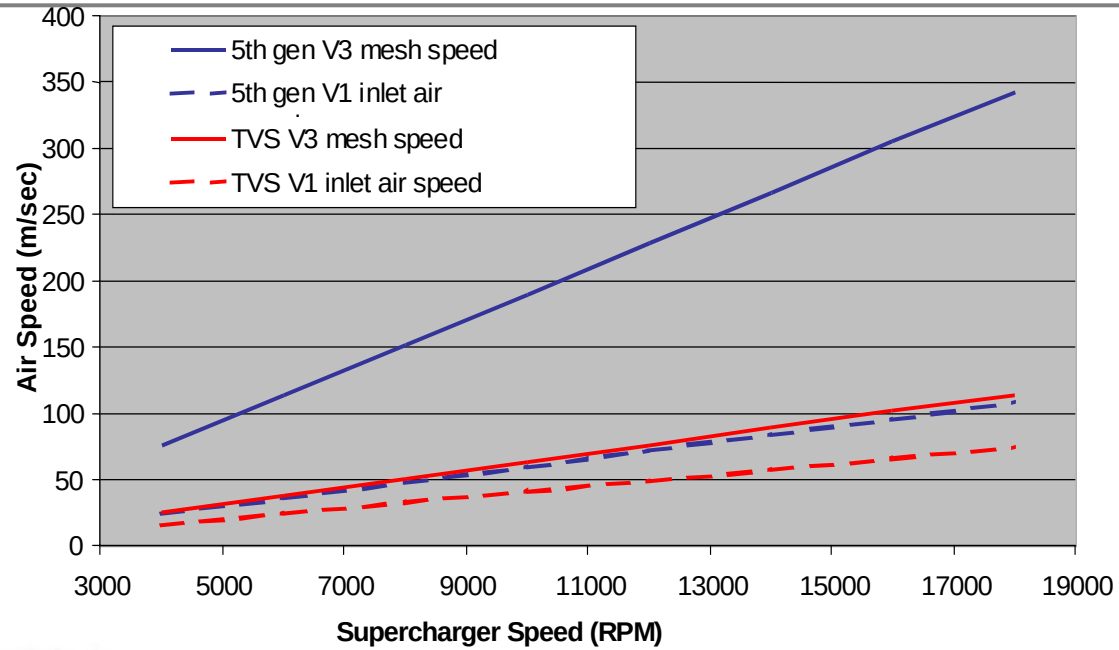


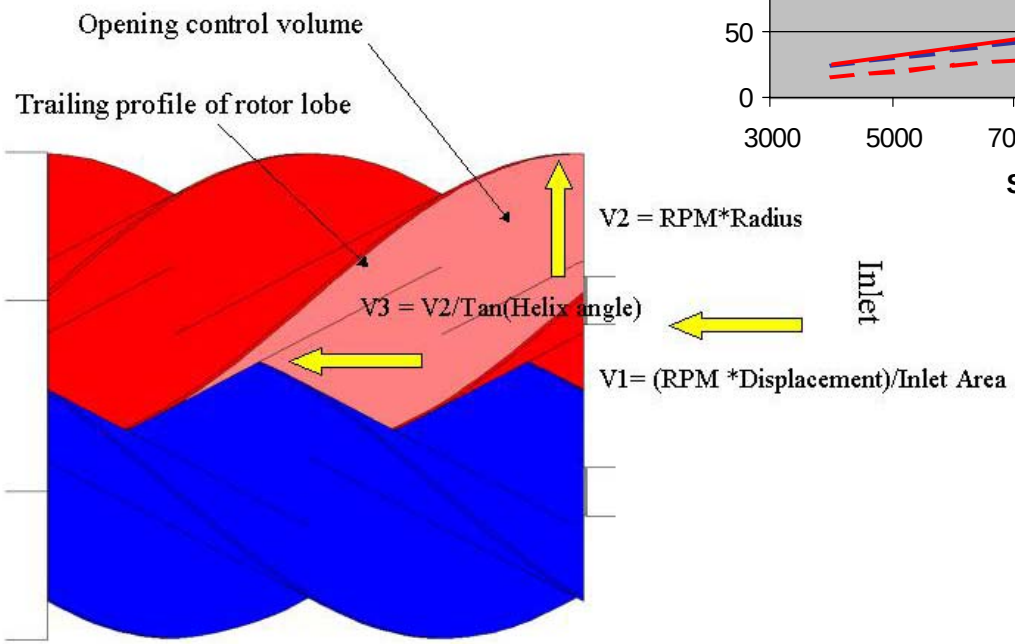
TVS® Supercharger – Rotor Design

V1 = Inlet Air Speed

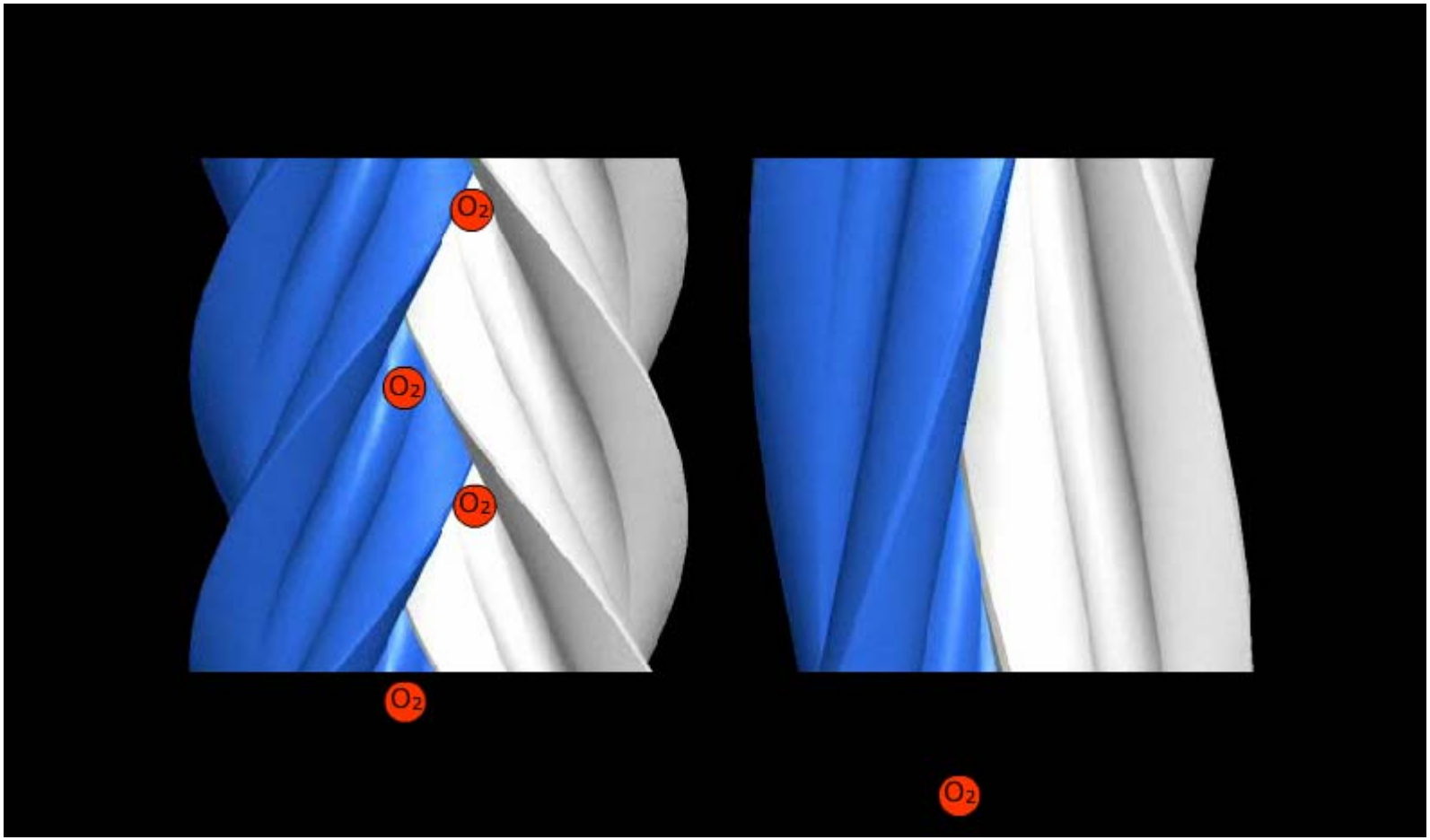
V2 = Speed of rotor separation

V3 = Speed of rotor mesh





Rotor Mesh Comparison

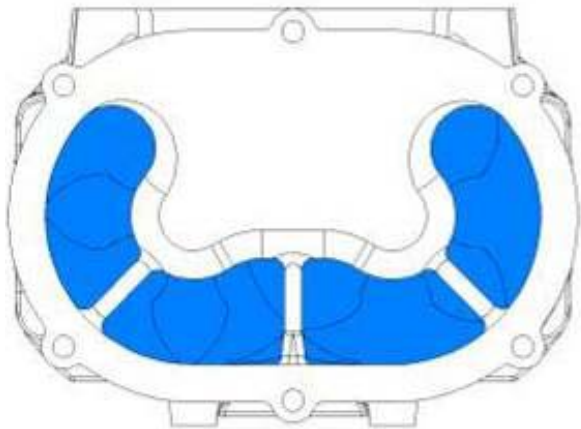


TVS Rotors: 4 lobes,160° twist 5th Gen Rotors: 3 lobes, 60° twist

Inlet Side

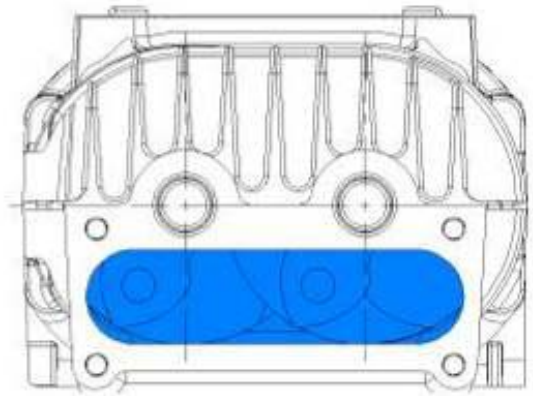
Inlet Port Design

- Improved airflow handling characteristics
  - Larger inlet port – lower air velocity
    - Driven by higher face to face twist



TVS

Large inlet shape.
Increased fill time for
160 degree twist rotors.

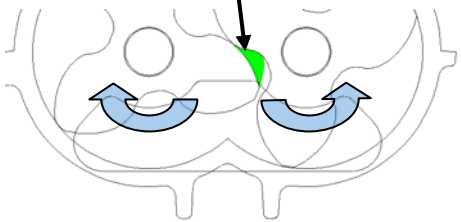


5th Generation

Standard inlet shape.
Typical inlet timing for
60 degree twist rotors.

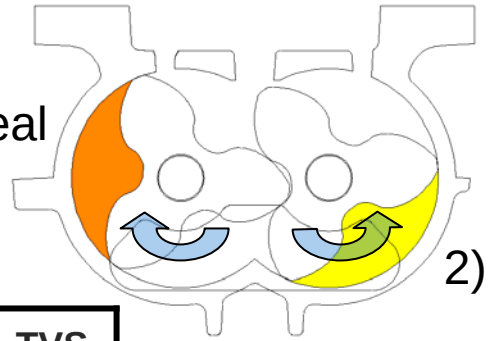
Fundamental Cycles of Eaton Roots Type Supercharger

1) Expansion



Low-Pressure Inlet Events

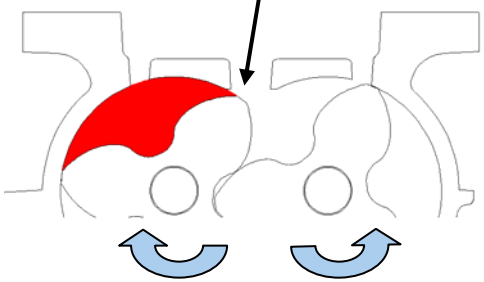
3) Seal



2) Dwell

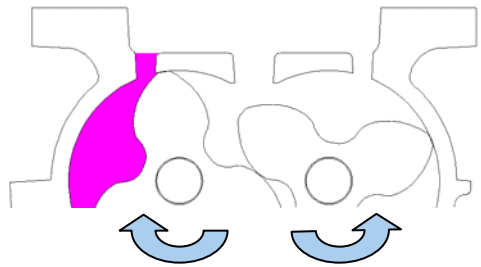
5th Gen	Event	Degrees Rotation	TVS
210	1	Inlet (Expansion)	280
50	2	Dwell	20
40	3	Seal	10
40	4	Backflow (Compression)	80
200	5	Outlet (Exhaust)	220

5) Exhaust



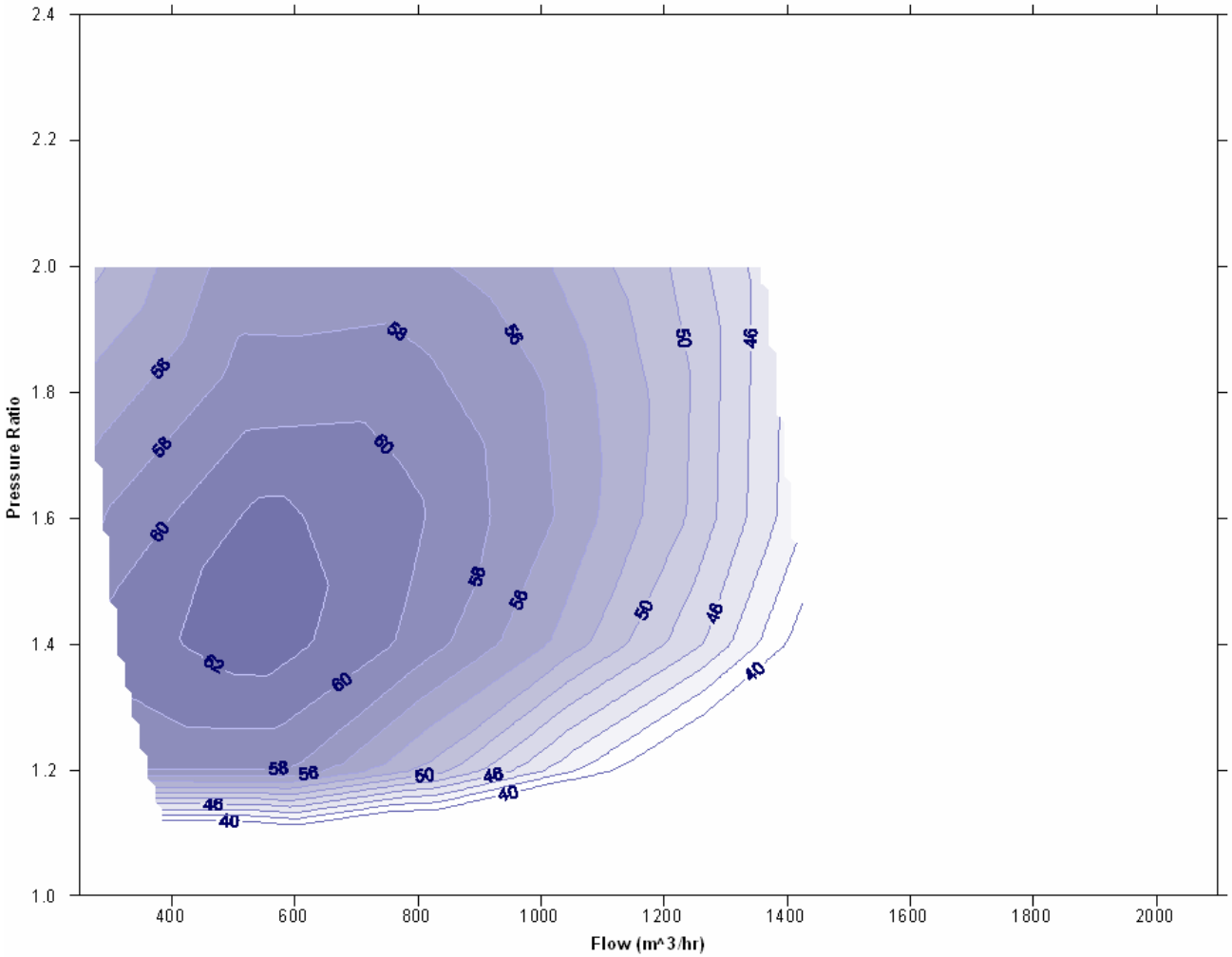
High-Pressure Outlet Events

4) Backflow



Eaton M112 5th Generation Map (1.86L)

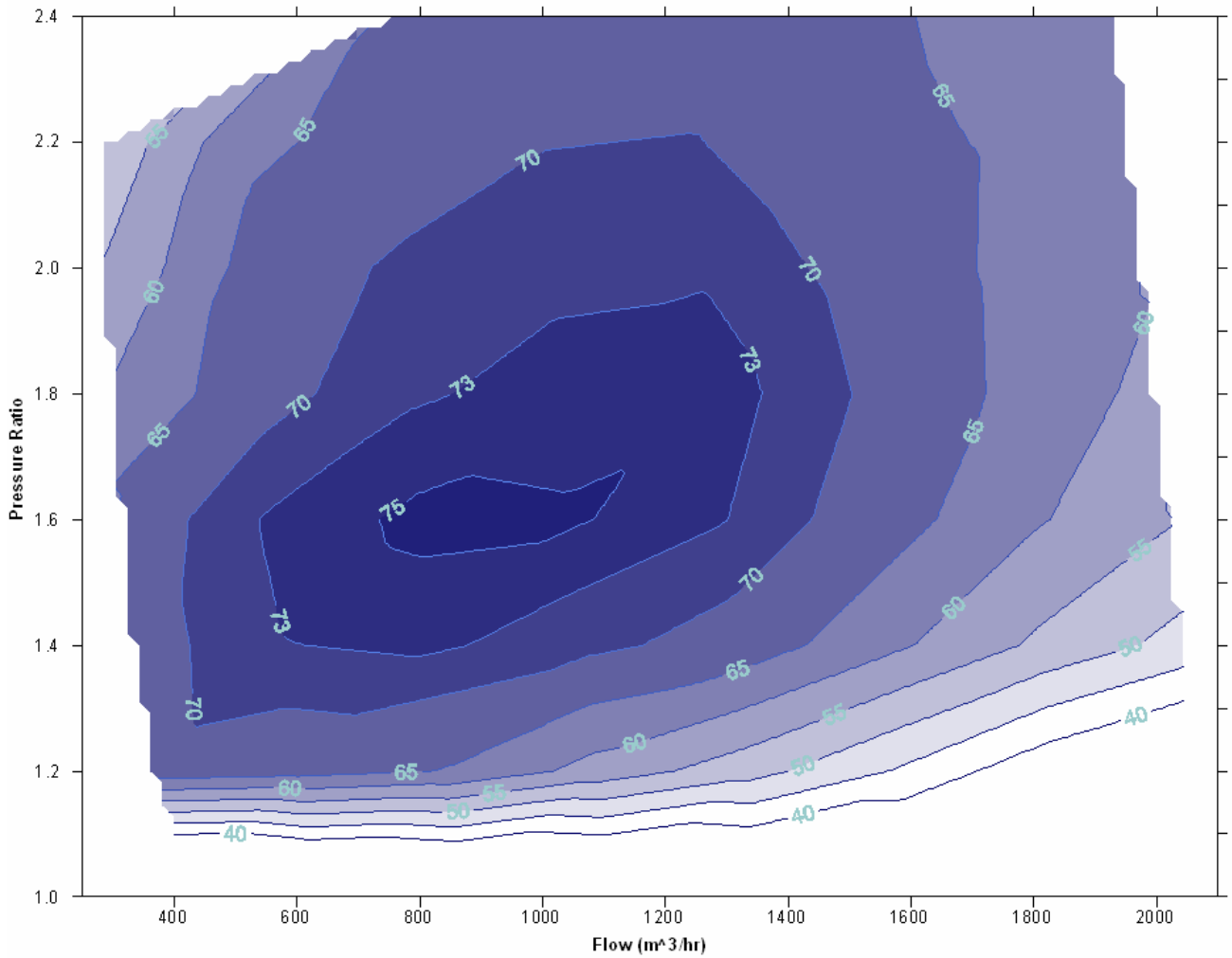
Isentropic Efficiency Map (Thermal)



Pressure ratio and speed is limited by outlet temperature.

R1900 TVS Map (1.90L)

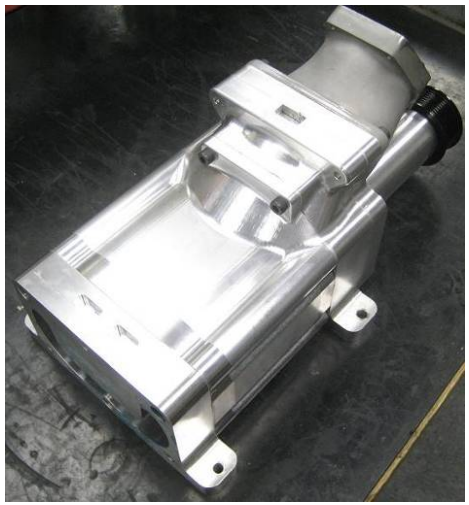
Isentropic Efficiency Map (Thermal)



Pressure ratio is limited by temperature.

SC speed is limited by bearings.

Next Generation TVS® Supercharger

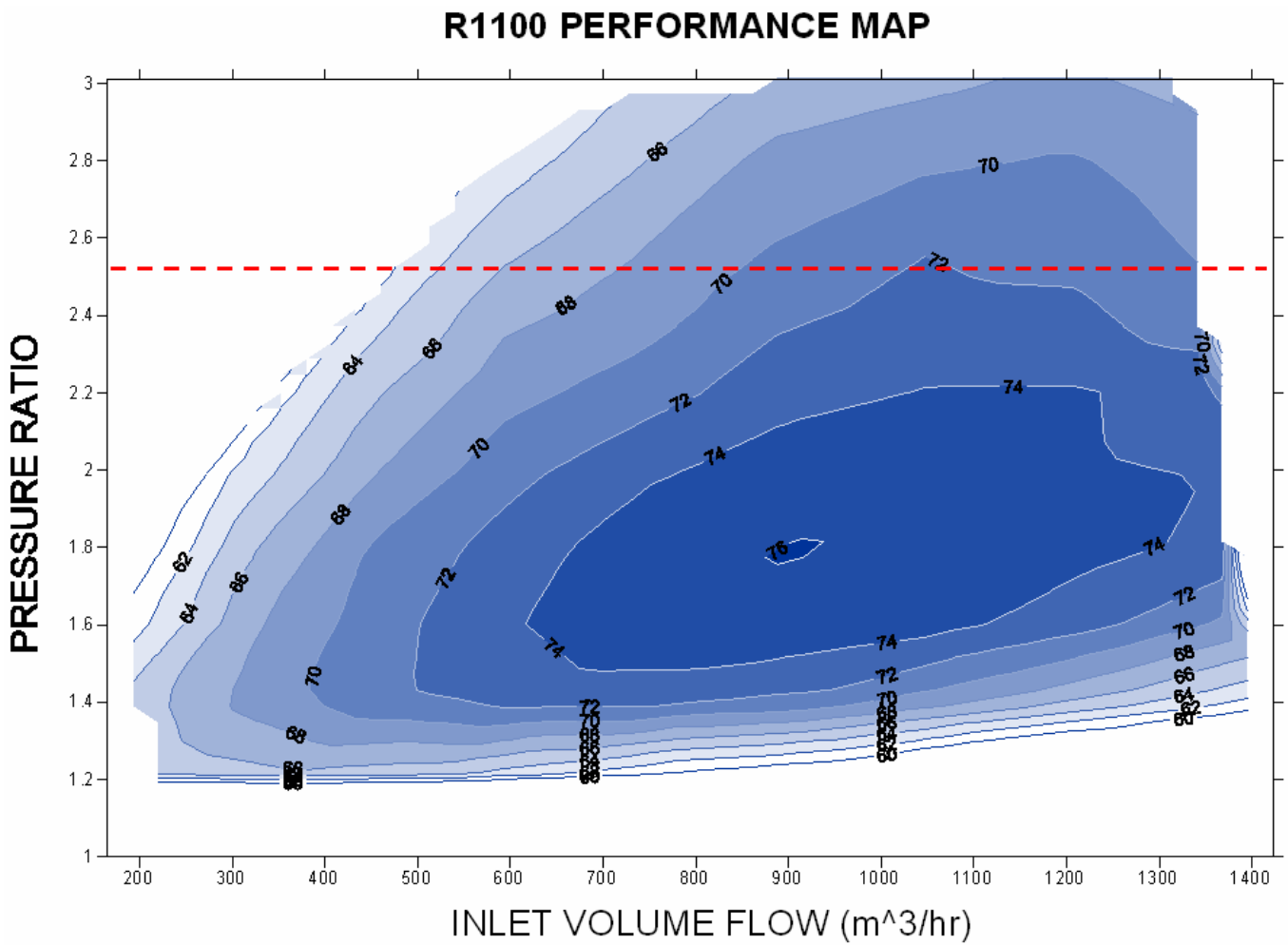


Next Gen Goal:

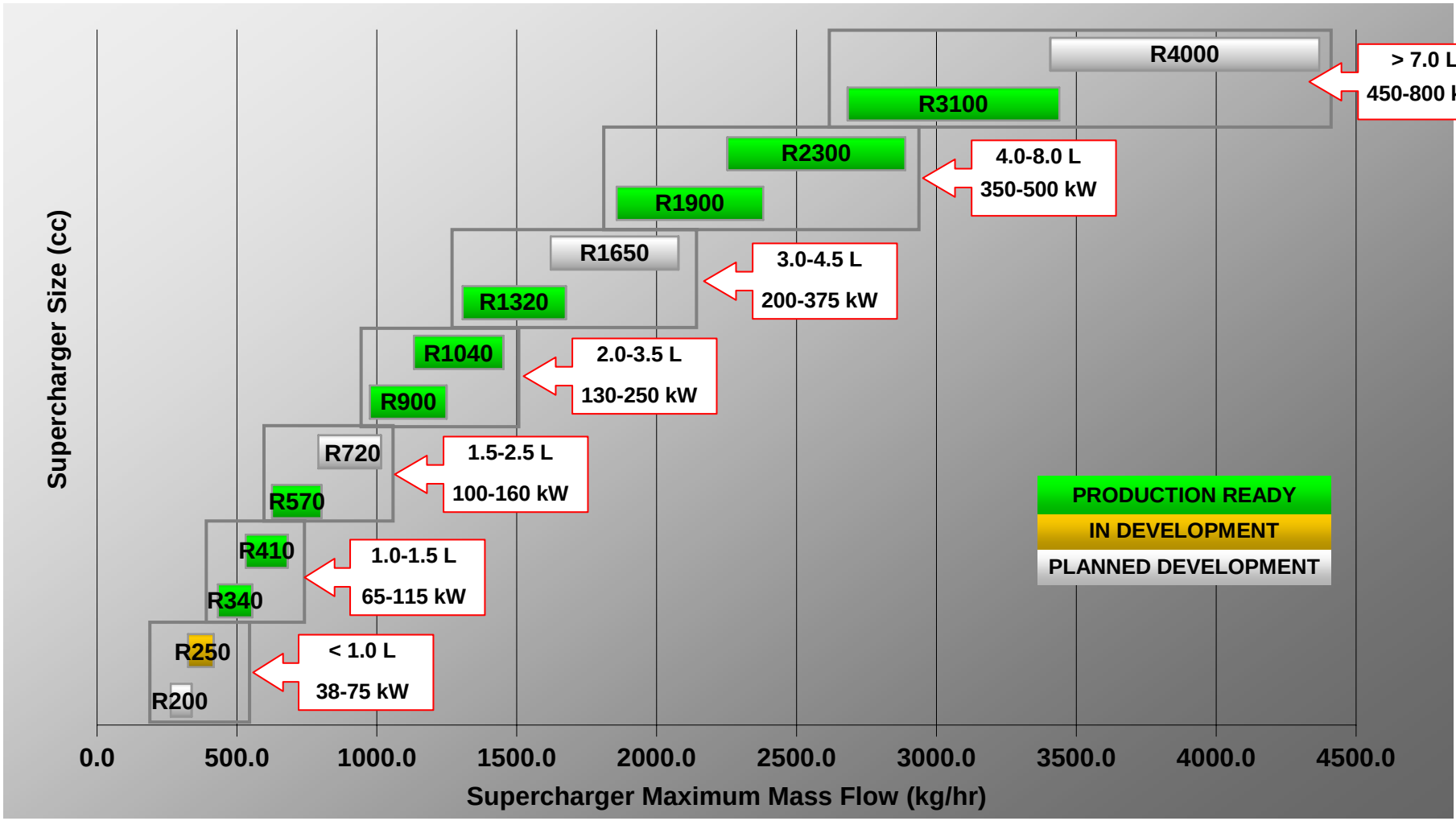
>3.0 PR

Current limit at

2.5 PR



TVS® Supercharger Family Table



Supercharger Input Power Requirements

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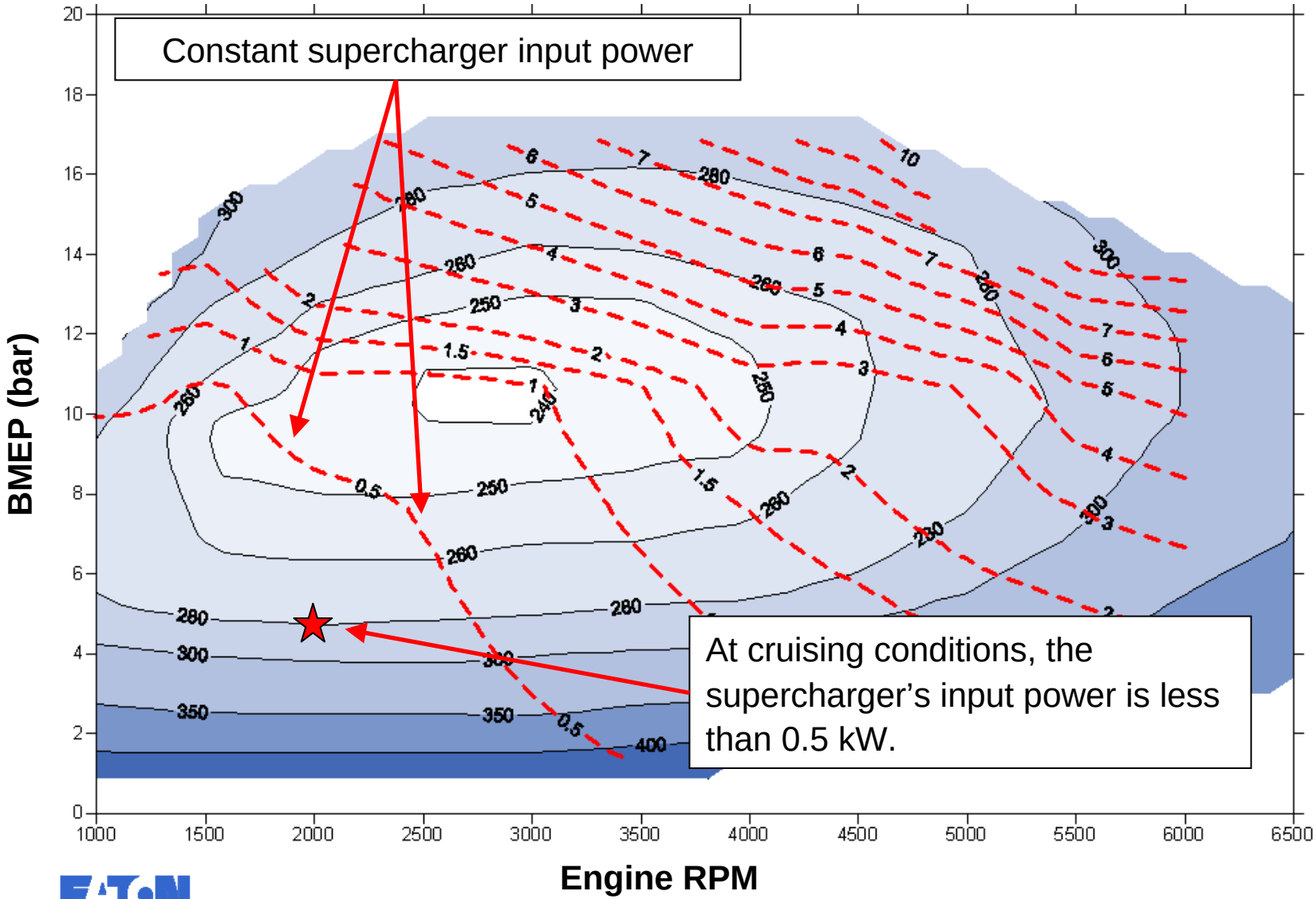
Supercharger Input Power Requirement



Response & Downspeeding

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TVS® Supercharger Drives Fuel Economy

- Engine downspeeding is required for improvements in vehicle fuel economy
  - Downspeeding decreases frictional losses
    - Following a constant power curve in a BMEP vs. engine speed BSFC map
      - BSFC decreases as engine speed decreases
  - Current turbocharged vehicles are challenged to support engine downspeeding with downsizing due to transient response
  - Supercharger instant response drives downsizing and downspeeding
    - Enables the customer-required vehicle dynamics

Response: Supercharger vs. Turbocharger

GM Ecotec Comparison

- Supercharged Configuration (Eaton Prototype)
  - 2.0L I4 with TVS® Supercharger
  - R900 Supercharger (0.9L/rev)
  - 270hp (201 kW) Estimated
  - 203-210 kPa Boost Pressure
- Turbocharged Configuration (Production Vehicle)
  - 2.0L I4 with Borg-Warner K04 turbocharger
  - 260hp (194 kW)
  - 224 kPa Boost Pressure

Cobalt SS

Baseline Configuration

- 2.8L V6 Naturally Aspirated
- 208 hp (155 kW)

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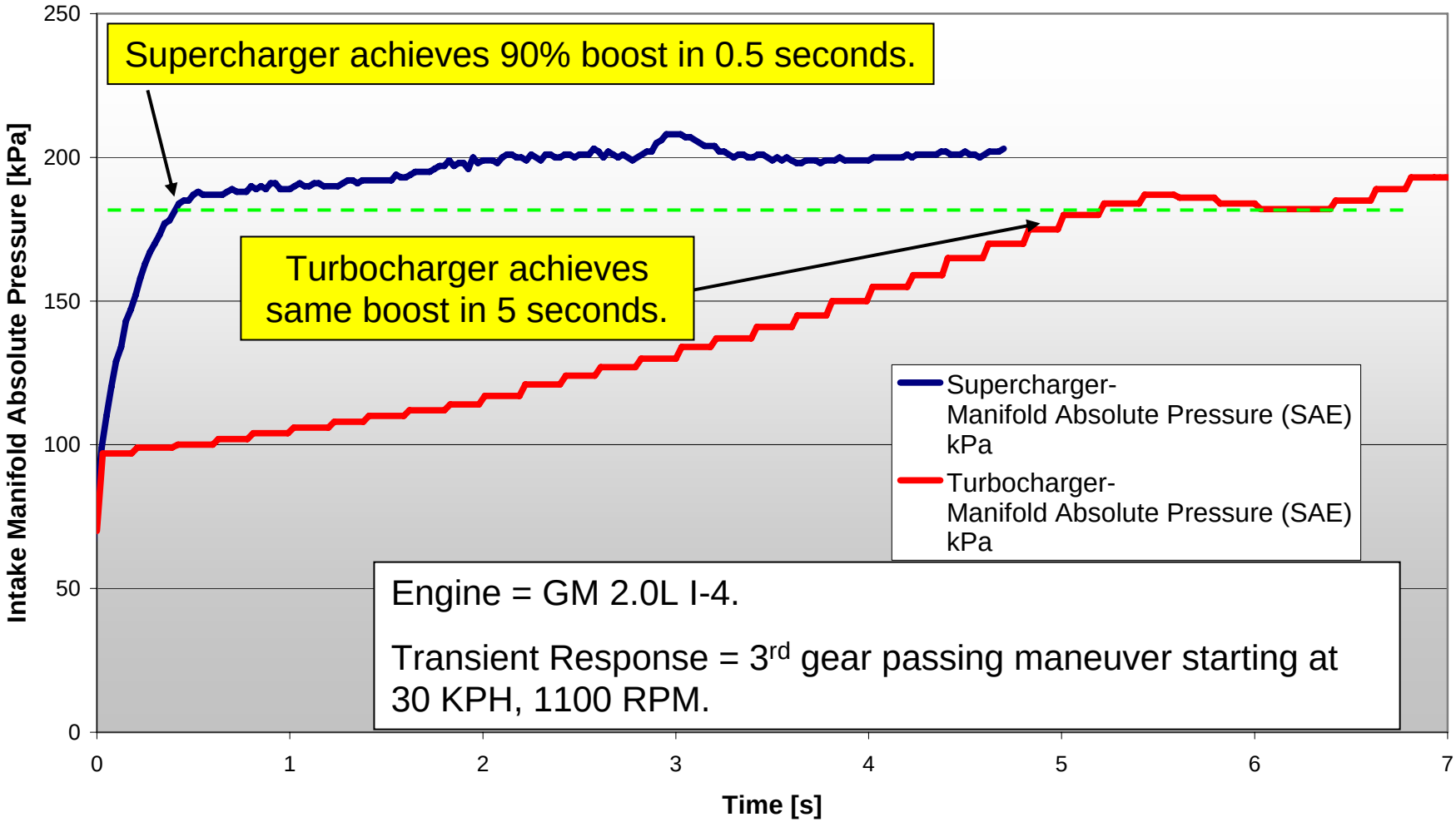
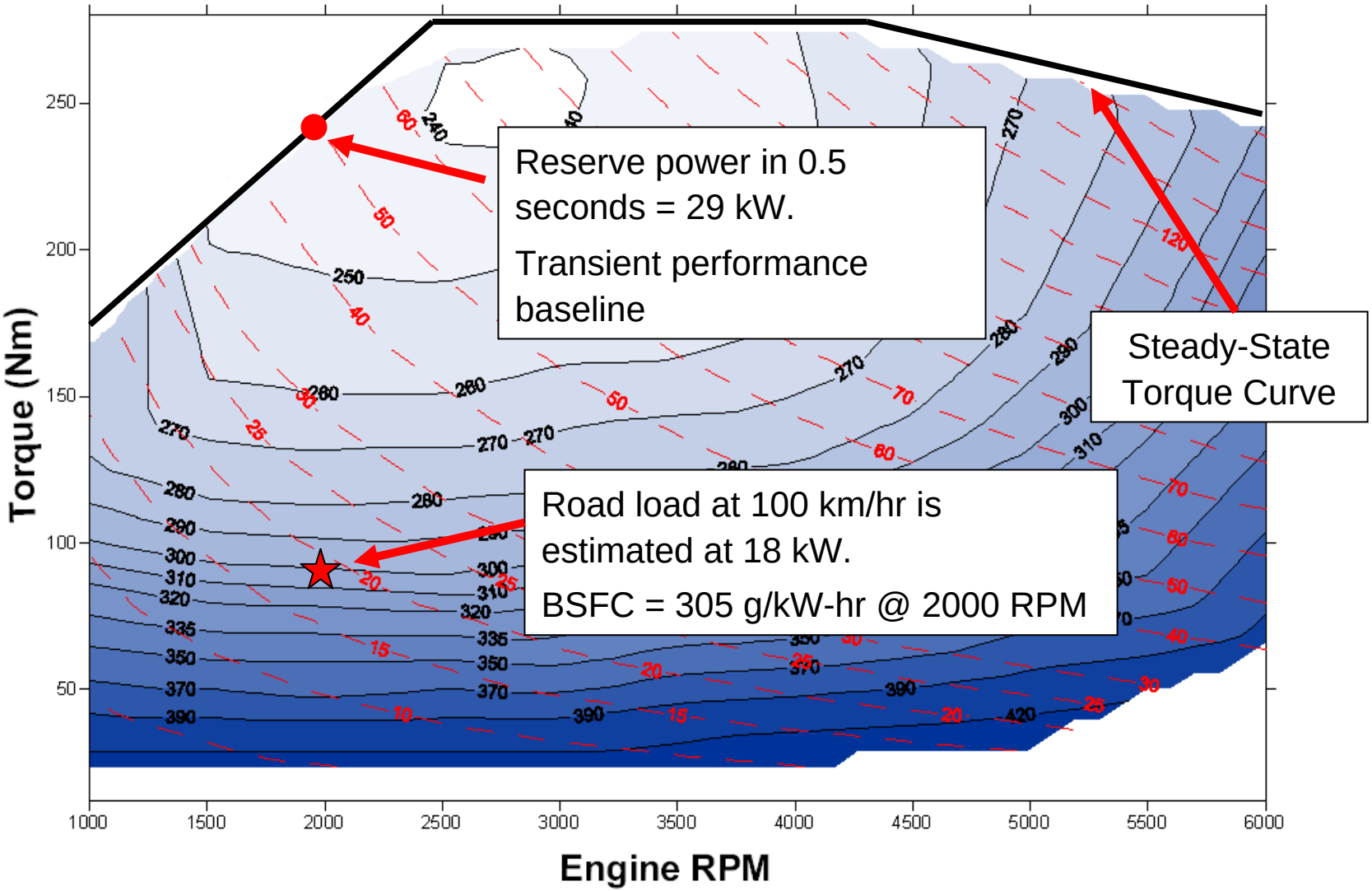
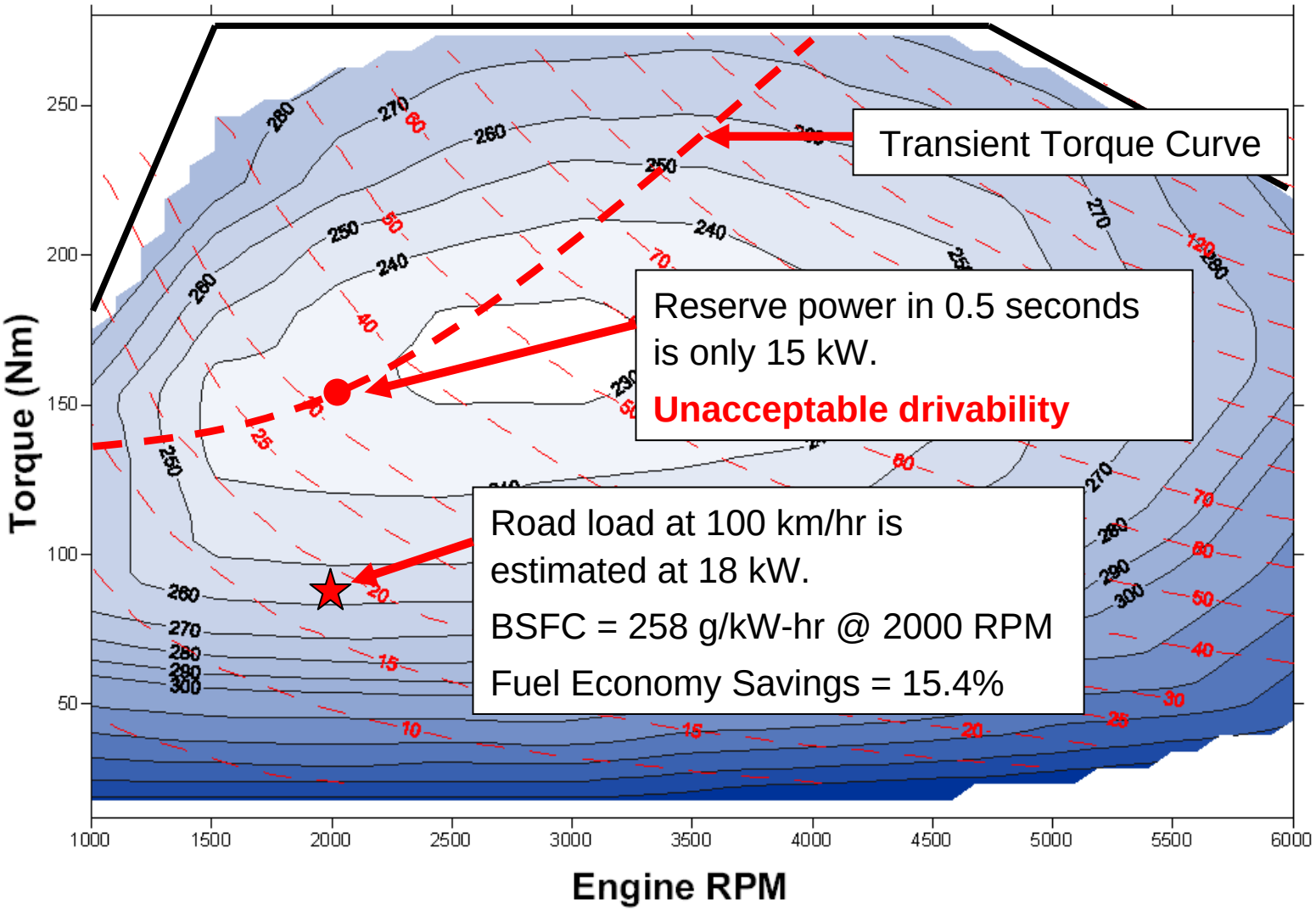
Response: Supercharger vs. Turbocharger



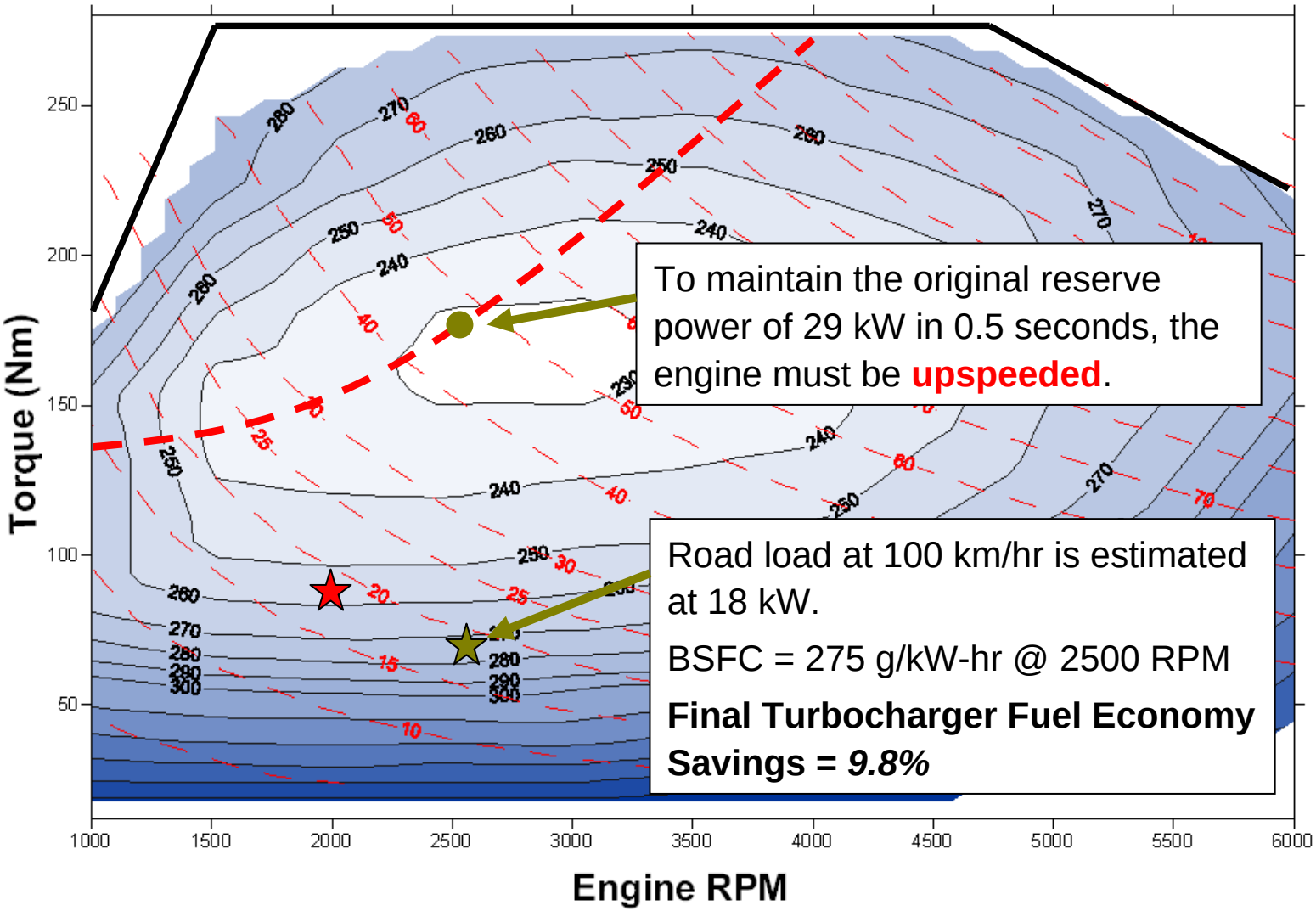
2.8L V6 Naturally Aspirated BSFC Map



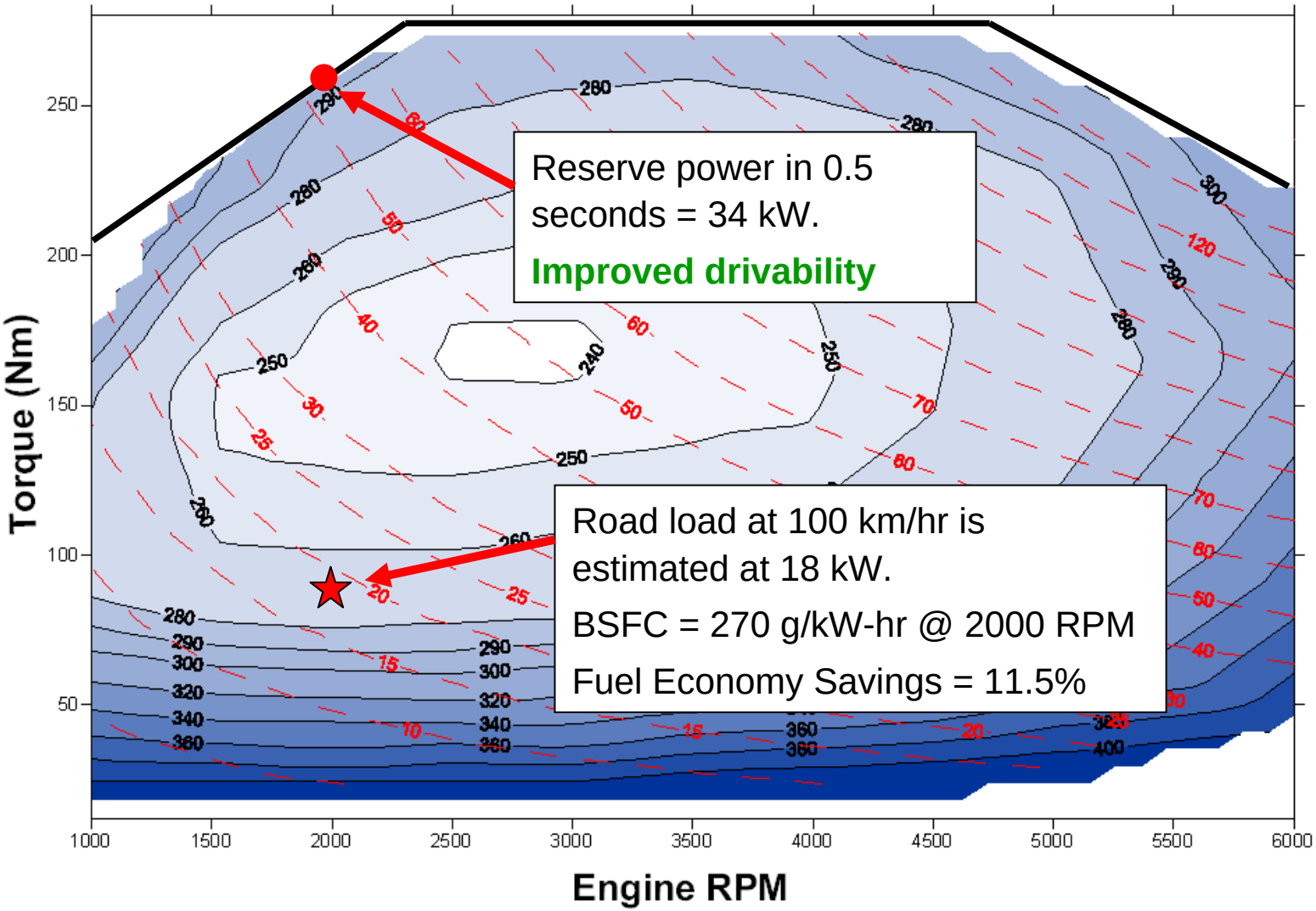
Downsizing – 2.0L Turbocharged



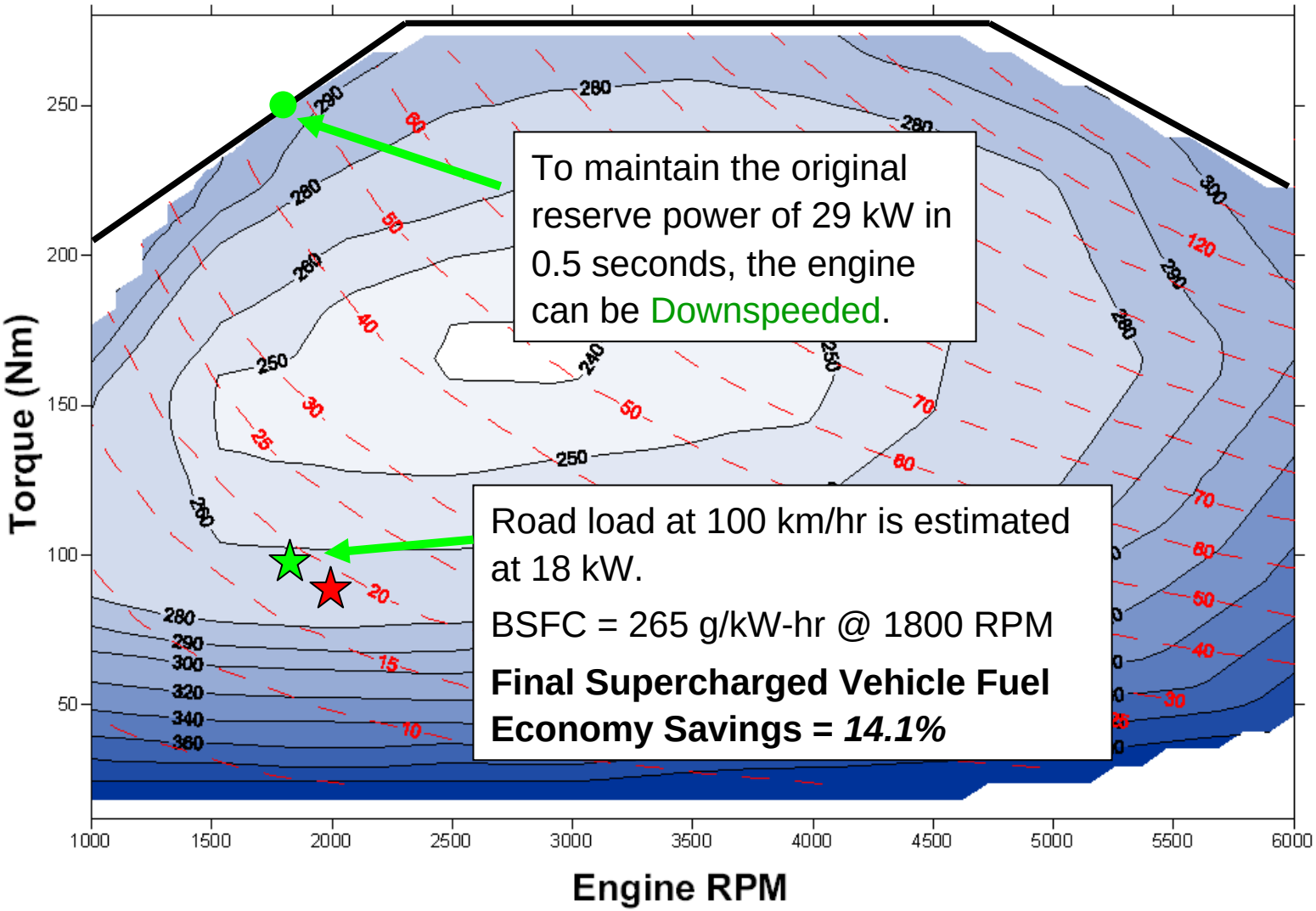
Downsizing – 2.0L Turbocharged



Downsizing – 2.0L Supercharged



Downspeeding – 2.0L Supercharged



Fuel Economy Comparison

4.3% Fuel Economy Savings Versus Competitive Turbocharged vehicle!

	BMW 535xi	Lincoln MKS		Mercedes E350	Cadillac CTS-4	Audi A6
Combined L/100km	**11.8 L/100km**	**12.7L/100km**	**12.3L/100km**	**12.9L/100km**	**11.7lL100km**	**11.3L/100km**
Power (kW)	224 @ 5800	204 @ 6250	**250 @ 5700**	200 @ 6000	227 @ 6400	224 @ 5100
Torque (Nm)	407 @ 1400	366 @ 4250	**475 @ 3500**	350 @ 2400	370 @ 5200	420 @ 2400
Engine	**3.0L Twin Turbo**	3.7L	**3.5L Twin Turbo**	3.5L	3.6L	**3.0L Supercharged**
Transmission	Auto - 6	Auto - 6	Auto - 6	Auto - 5	Auto - 6	Auto - 6
Drive	AWD	AWD	AWD	AWD	AWD	AWD

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TVS® Supercharger Summary

- Instantaneous boost response and torque availability enables engine downsizing while maintaining downspeeding for maximum fuel economy.
- High efficiency supercharger design drives high specific engine outputs and improves packaging.
- Boost available at all speeds and temperatures.
- Internal lubrication system not impacted by engine stop start

TVS® Supercharger engineered for excellent drivability and best-in-class fuel economy!


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