

*“An integral partner in the delivery of outstanding
powertrain into future vehicles”*

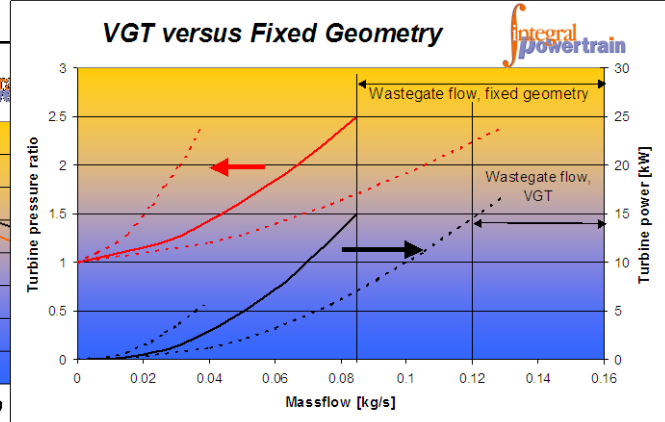
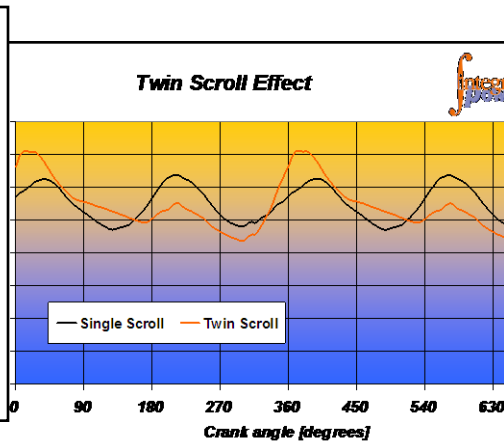
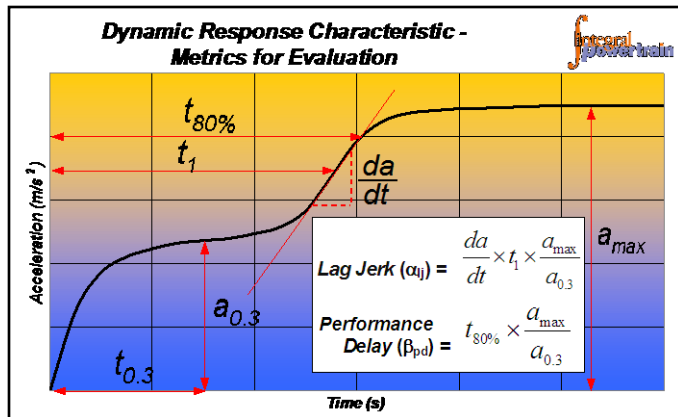
∫ integral powertrain

**Turbocharger Transient
Development**

State of the Art Turbocharging

Key features

- Variable cam phasing + DI injection + optimal gas dynamics
 - Reduced EGR
 - Reduced charge temperature
 - Very high volumetric efficiency(>1)
 - Excellent knocking performance
 - Avoidance of surge condition
- >20% reduction of T_{max} speed
- Enhancements using twin scroll or pulse converter
- Variable geometry systems in the near future



The Transient Challenge

Transient behaviour is very different from steady-state

- Exhaust to inlet pressure difference strongly affects gas exchange
- Turbine operating point (temperature, speed, flow)
- System characterisation problematic using conventional approaches (testing, sim, etc)
- Complex multi-variable calibration optimisation required. Strong effects from VCP, spark timing and fuel injection. VGT adds further complexity

Mastering this area can lead to critical improvements to driving behaviour



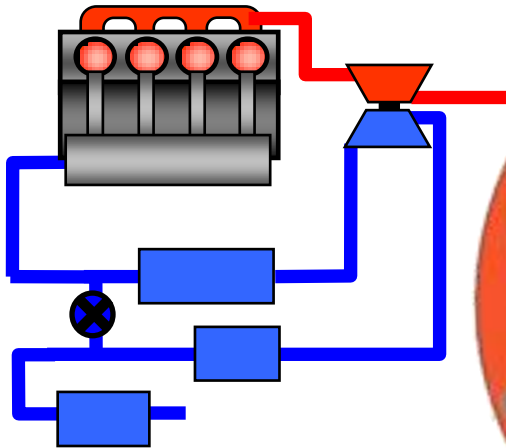
IP's "Inside the Transient" Toolset



Three components in one

Testing

- Test process for transient characterisation



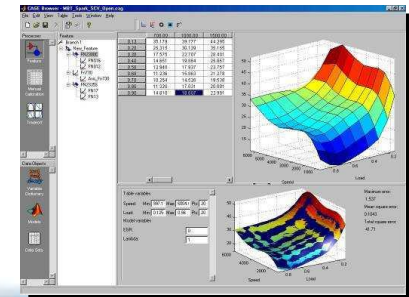
Physical Simulation

- Powertrain in vehicle model for evaluation of hardware / control options



Response Characterisation

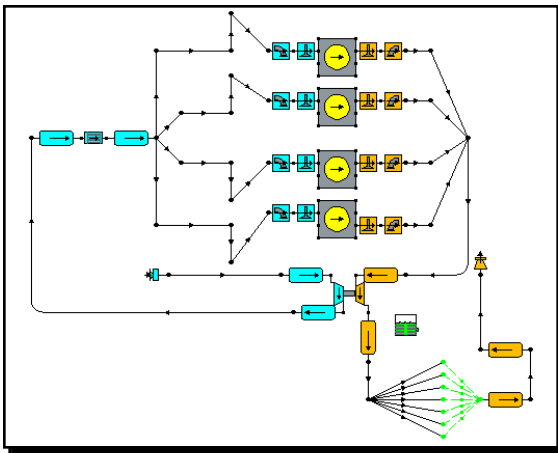
- Transient calibration optimisation (DoE based)



1-D Strengths / limitations

- Accurate predictive simulation of pressure conditions in cylinder, inlet and exhaust using wastegate control (free float behaviour more problematic)
- Detailed scavenging behaviour requires extensive test correlation
- Turbine work not truly predictive. Emulation possible with extensive correlation:
 - Cycle resolved turbine inlet temperature
 - Efficiency modifiers typically up to 30% in either direction
- Integration of control system strategy possible but not seamless
- High levels of skill and time resources required, even for steady state modelling

Click here for detailed discussion of 1-D applied to turbocharged SI

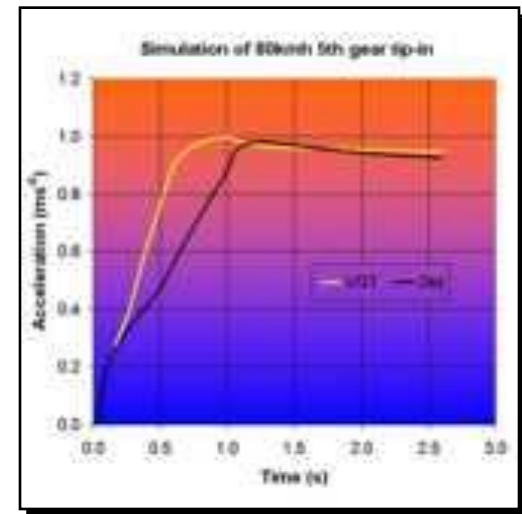
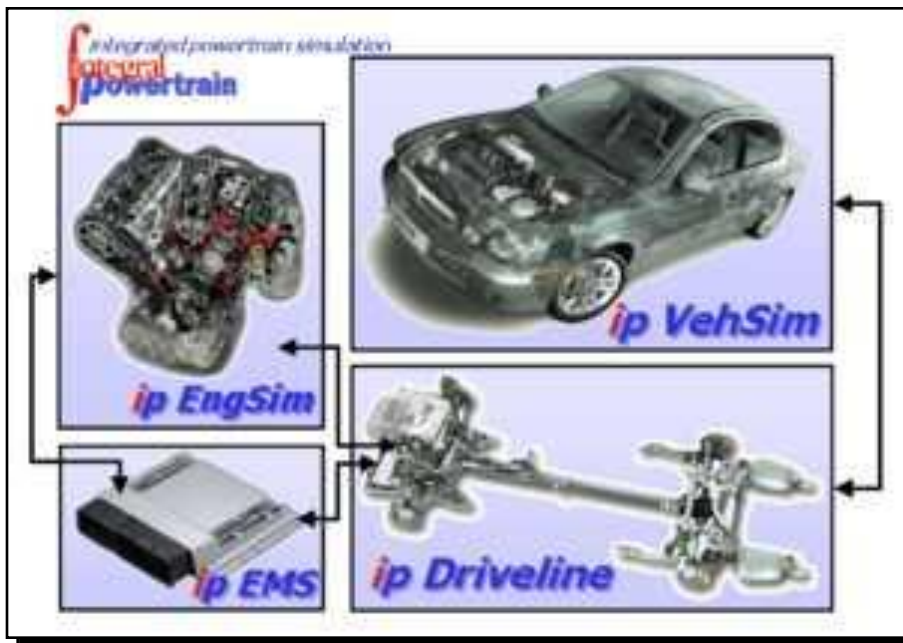


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Essential tool for understanding gas exchange and energy transfer mechanisms
Not suitable for routine system optimisation

IP Matlab / Simulink model

- Characterisation / emulation using zero-dimensional bulk properties for gas exchange and turbine work.
- Rapid **automatic** correlation when used with “inside the transient” test process.
- Fully dynamic in-vehicle simulation of hardware and control system strategies.
- Capable of supporting development for transient variable cam-phaser strategies, turbocharger size, variable turbine control, gearing change
- Efficient use of time and skill resource

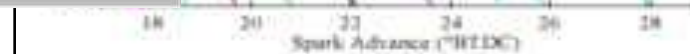
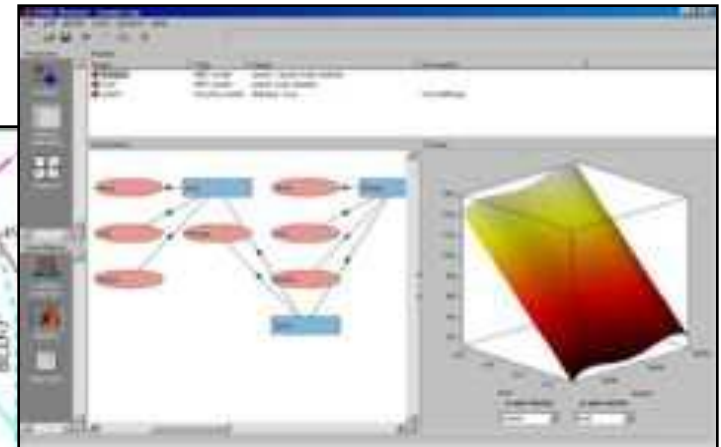
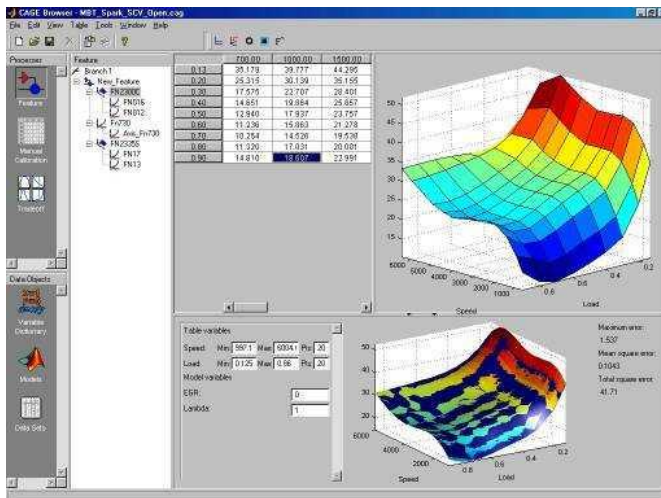


A practical approach to support development of optimal driving behaviour

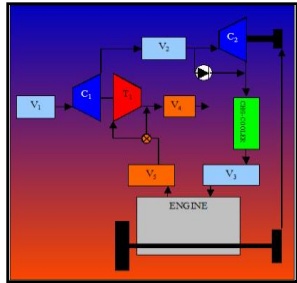
Optimising the Transient

Combining “inside the transient” test process with advanced DoE

- Response to critical variables mapped under transient representative conditions (VCP, spark timing, fuel injection and VGT if fitted)
- Multi-variable functions constructed for torque and available turbine work
- Torque response profile mathematically optimised for minimum lag, maximum tip-in torque or according to target metrics

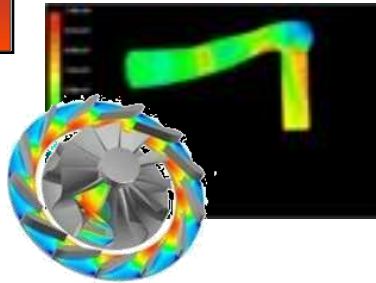


Turbo Engineering Toolsets



O-D Application tool

- Rapid matching and performance calculations for all types of pressure charging system (gasoline, diesel, single and multi-stage)

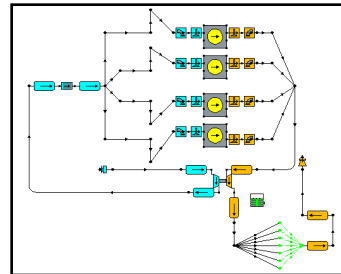


3-D CFD

- Compressor inlet design to optimise effective map-width

1-D Simulation

- Understand detailed gas exchange mechanisms / sensitivities



IP Dynamic vehicle simulation

- Unique MatlabSimulink model covering total vehicle hardware and control system
- Accurate replication of transient events
- System optimisation



Mobile test bed

- On-vehicle high-speed transient data acquisition



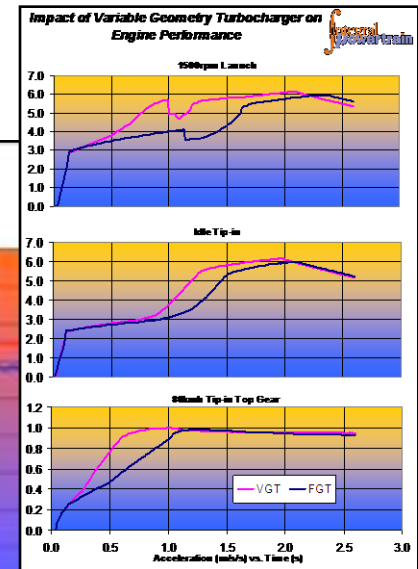
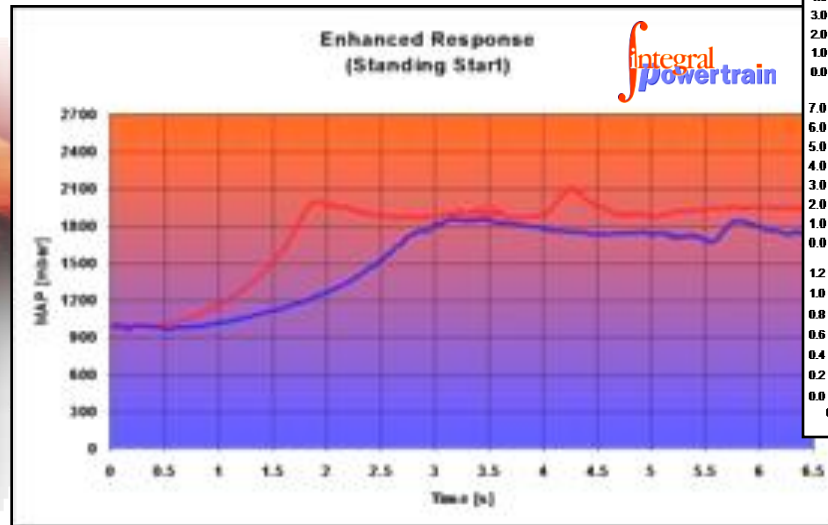
Conclusion

Sophisticated and Effective Approach

Developed in-house for use on OE programs

Processes proven on in-production programs

Ready to help you achieve the desired response!



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Thank You