



ENGINEERING

LOTUS MULTICYLINDER AVT

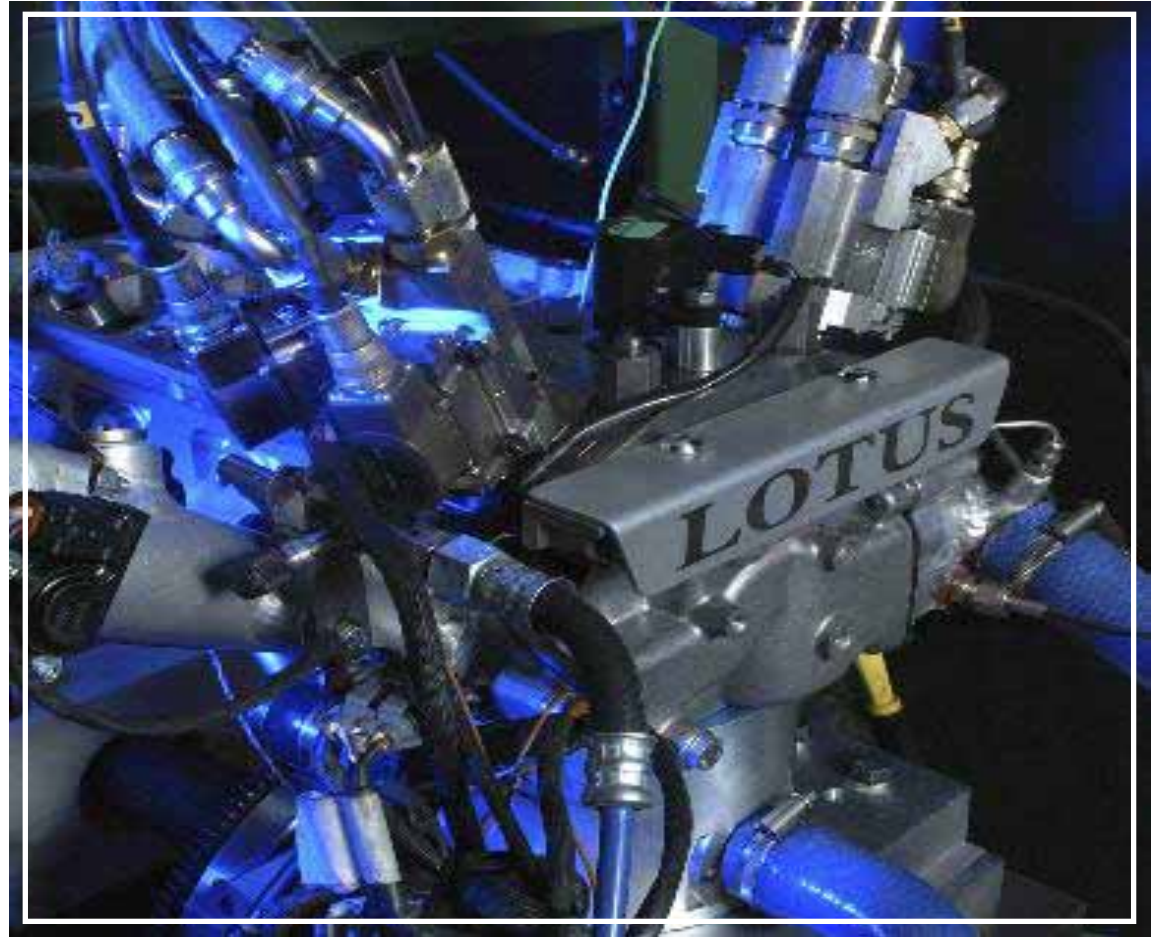
The next generation in the Lotus AVT story

Colin Peachey



AVT - Product Description

- Lotus Active Valve Train (AVT™) is a high performance Engine development system
- AVT uses double acting hydraulic actuators to operate engine valves replacing the camshaft
- **30+ systems** sold worldwide



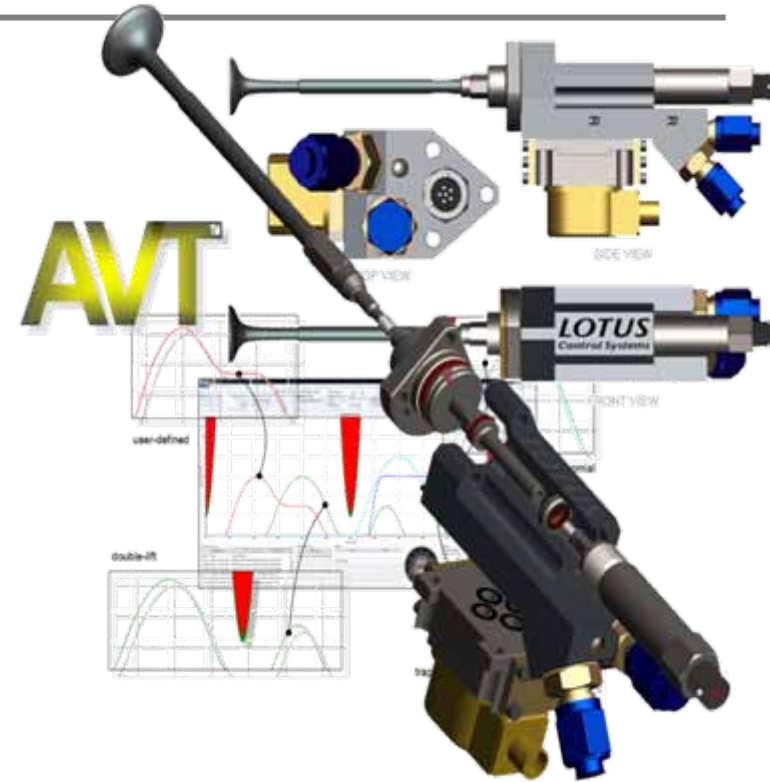
Lotus AVT - A long collaboration with Industry

- AVT derived from Lotus F1 1980's active suspension
- OEM interest resulted in Lotus AVT (AVT-g1) in 1993
- Upgrades and new features to respond to end user requests
- 20 years integration into our clients' engine development process
- Lotus is proud our AVT system assists our clients developing class leading engines



Benefits of the Lotus AVT system

- Improved **data quality & quantity** – ultimate optimisation
- **Rapid development** iterations & **time savings**
- **Major cost savings** on prototype camshafts
- Precision **measurement of valve positions**
- **Speed up to 8,000rpm**
- Massive **flexibility for R&D**
- VVT / Cam switching , High CR development, Double lift valve strategies, Air hybridisation, Tolerance studies, HCCI, EGR, Combustion cycle switching (e.g. 4 to 2 stroke), Divided exhaust periods (DEP), Stratified charge, Fuel research and development, Combustion (with optical engine)



AVT – Global Clients



- Automotive OEM
- Truck OEM
- Motorcycle OEM
- Heavy duty OEM
- Universities
- Fuel companies
- Research companies

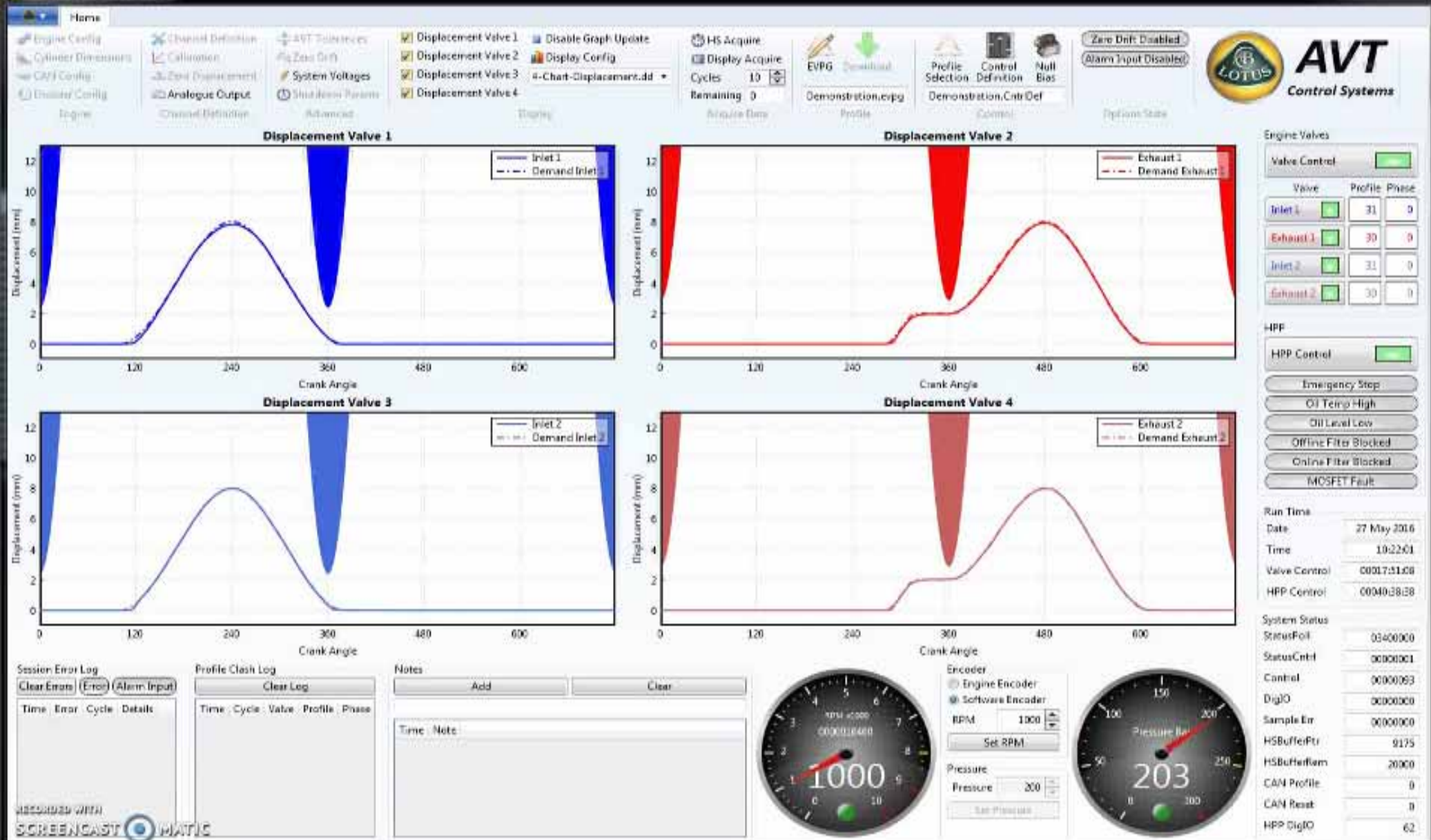
Lotus AVT Purchased by

- 4 of the top 10 car manufacturers
- 3 of the top 5 truck manufacturers

- Total service offering
 - Installation & Training
 - Service & support
 - Spares



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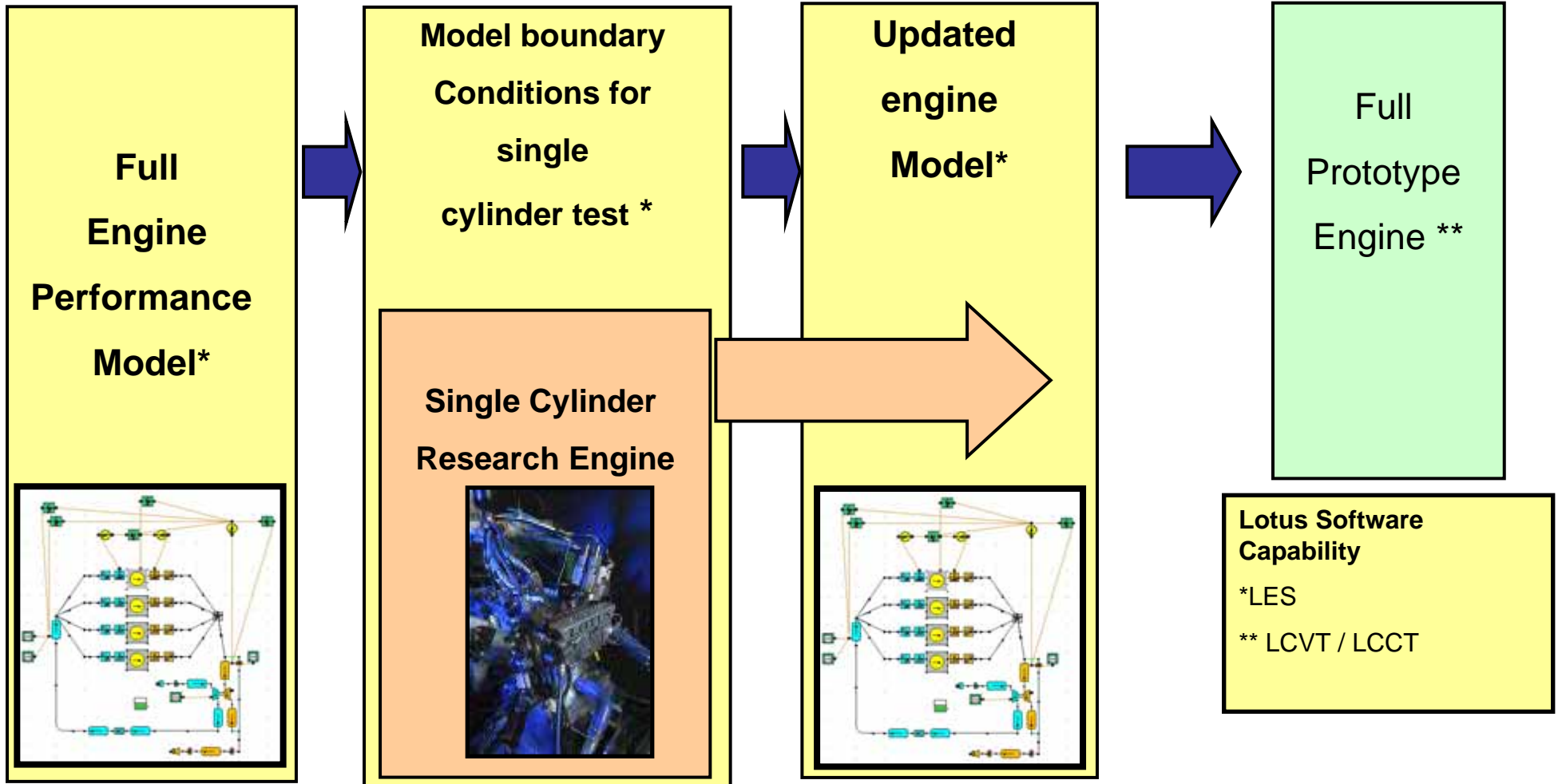


Single cylinder engine limitations

- Single cylinder engines optimise “in cylinder” performance
- High value where analysis accuracy is limitation
- Production engines require a stage of full engine development to account for real world cylinder interfaces
 - Fuelling variability
 - Operating temperatures and cylinder to cylinder heat transfer
 - Coupling interactions of gas flows recirculation in manifolds / backpressure
 - Engine transient / dynamic response
- A Multi cylinder research engine provides real interface conditions and allows the cylinder to cylinder variations to be understood



Single cylinder engine development process



How Multi Cylinder AVT improves development

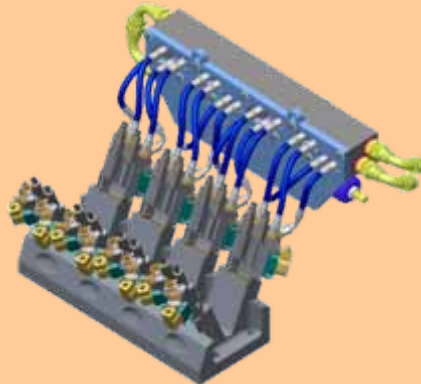
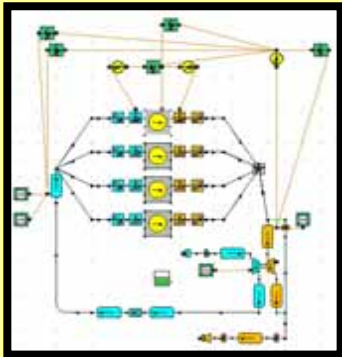
**Full
Engine
Performance
Model***



**Multi Cylinder
Research AVT
Engine**



**Full
Prototype
Engine****



In a MC AVT each cylinder has correct gas flows, fuelling and heat exchange



Multicylinder AVT – advanced research applications

- **Duel Fuel development**

- Combining direct injection and port fuel injection – cylinder to cylinder fuelling variation

- **Diesel Low temperature Combustion (LTC)**

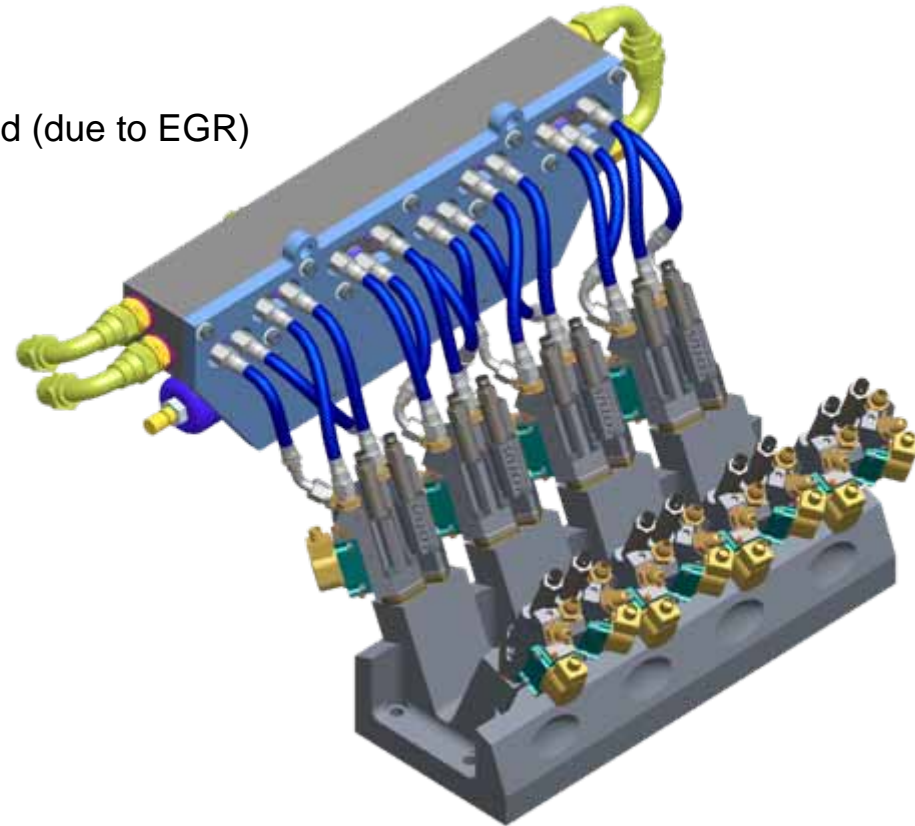
- High cylinder to cylinder variation identified at low speed (due to EGR)

- **New Pressure charging concepts (eg DEP)**

- **Variable valvetrains – existing and new concepts**

- **New engine operating concepts**

- 5 stroke engine concept
- Split cycle engines
- 2 to 4 stroke switching
- 2 stroke Diesel
- Air hybridisation



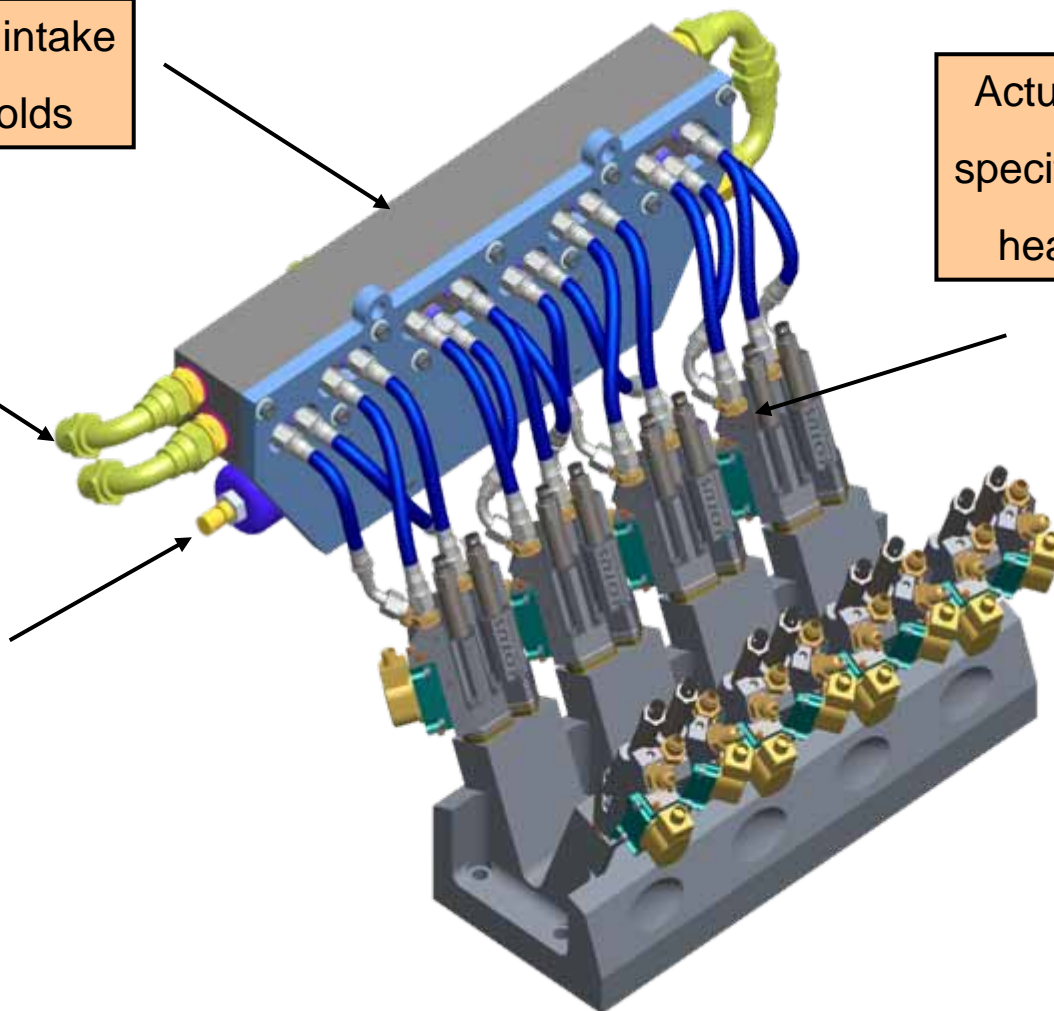
Initial Schematic layout – 4 cylinder option

Separate Hydraulic intake
and exhaust manifolds

Actuator package
specific to cylinder
head geometry

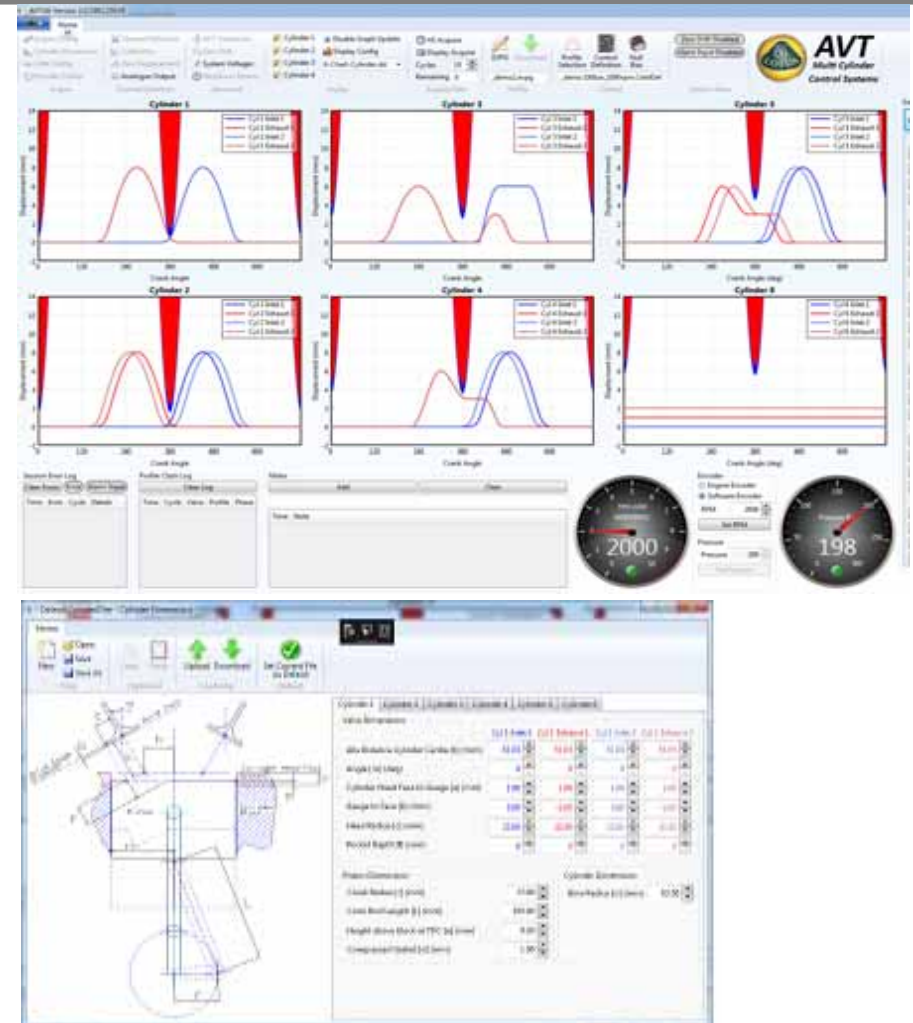
Increased
Hydraulic
Capacity

Local accumulators
on hydraulic supply



Development of Multicylinder AVT-g6 Software

- Phasing of multiple cylinders (up to 6)
 - 24 independent valve profiles
 - New graphic interface layout
 - Automated profile fine tuning *
 - Improved transient response*
-
- **Enhancements will upgrade to single cylinder AVT-g5 systems*

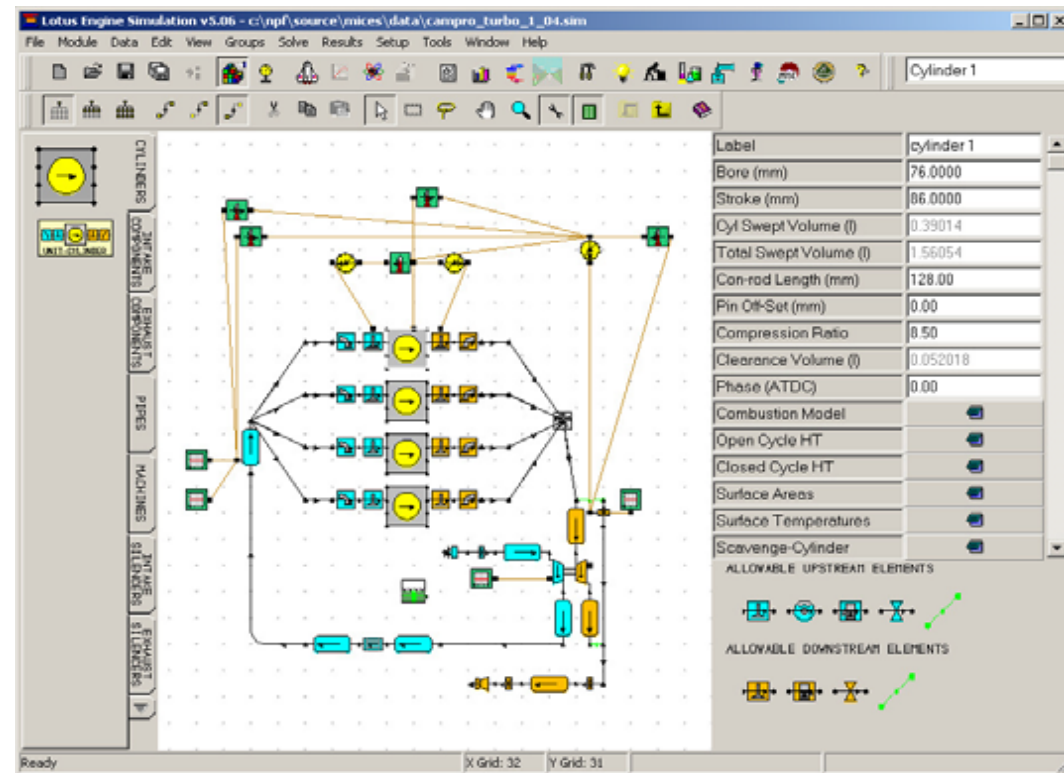


Multi cylinder User interface – 6 cylinder engine



Software tools : Lotus Engine Simulation (LES)

- Lotus engine cycle simulation tool - advanced numerical algorithms to model gas dynamics
- 2/4 stroke, gasoline, diesel, naturally aspirated, supercharged and turbocharged engines
- Simulink interface
- Transient analysis response
- STL environment to build 1D models from CAD



LES software can be used to create the initial engine model



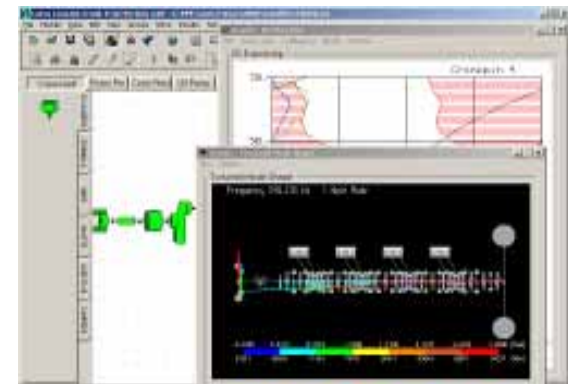
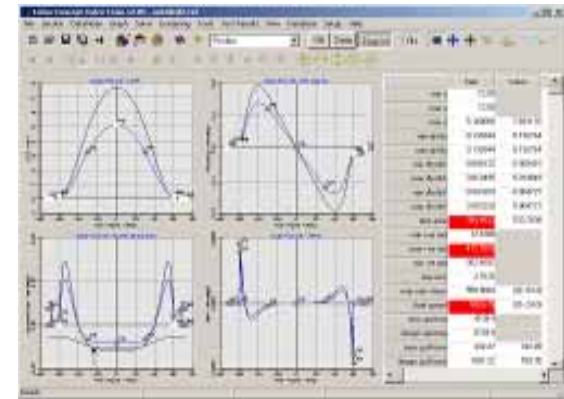
Software tools : Lotus Cam and Cranktrain design tools

Lotus Concept Valve Train (LCVT)

- Software for the design and development of camshafts
- Covers all aspects of valvetrain detailed dynamic behaviour, including contact stress, float speed, radius of curvature and valve to piston interference.

Lotus Concept Cranktrain (LCCT)

- Software to build a full crankshaft models
- Analysis functionality includes bearing loads, oil film analysis, out of balance forces and couples, torsional vibration and fatigue analysis.



LES software can generate physical camshaft designs to the required lift profile

Conclusions

- Lotus AVT offers total freedom to operate valves to any desired profile
 - Optimise emissions, economy and power
 - Explore new engine concepts and cycles
- Lotus single cylinder AVT is the benchmark for flexibility, control and precision
- Evolution to full multicylinder offers increased capability and performance
- Proof of concept complete -Now adapting hardware, controls and software for production early 2017
- This will provide a major software upgrade to our single cylinder system
- We are excited to discuss how our extended AVT capabilities can assist you





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**TO DISCUSS HOW LOTUS AVT
CAN HELP YOU TODAY -
PLEASE CALL ME ON**

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