





Integrated Simulation Technologies

| EV, HEV & Engine Development | Staff Augmentation | Corporate Training |



IST's Capability in eMobility Development

 A2/19, Aditya Breeze Park, Balewadi, Pune-411045, Maharashtra, India  +91-9763909935

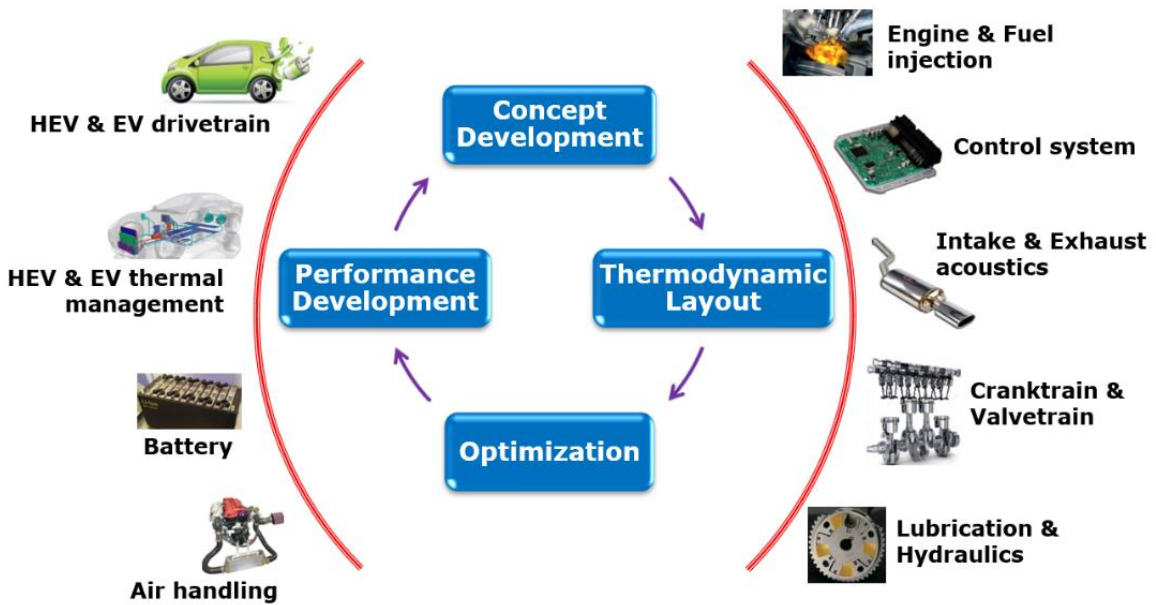
 subir.mandal@integratedsimtech.com  www.integratedsimtech.com

eMobility Development using 1D Simulation

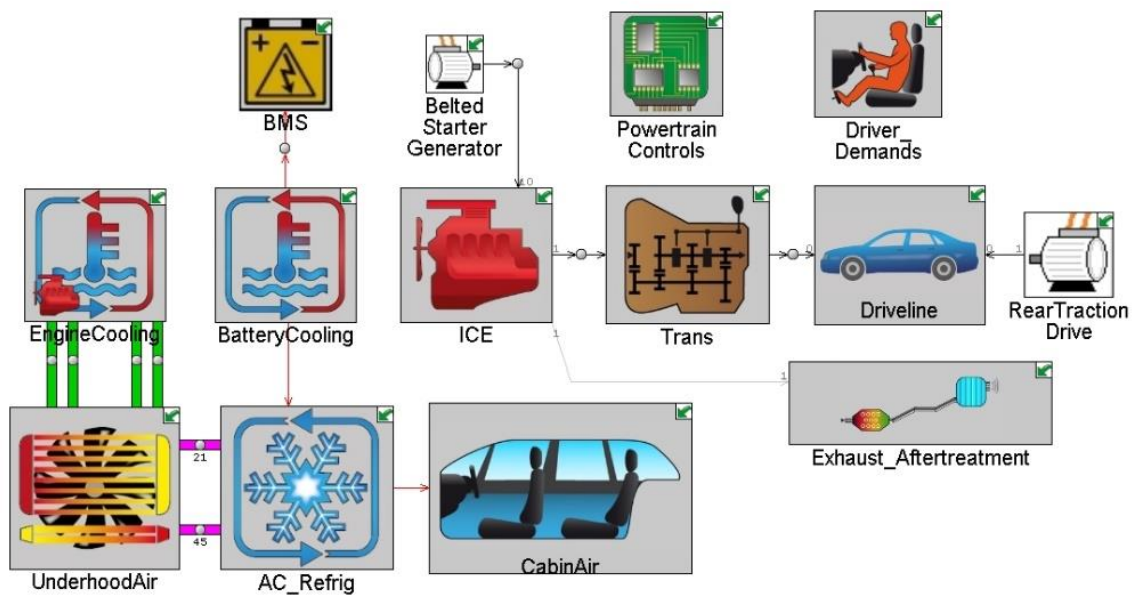
End-to-end solutions on performance development of EV, HEV & Engine



Our focus in eMobility development is to provide desired performance, energy economy, lower emissions and lower noise



All Sub-system related to EV, HEV & Engine Development



Use GT-SUITE & GT-AutoLion 1D Simulation Software



EV & HEV Drivetrain System

Performance, component sizing and architecture selection



EV & HEV performance

- Acceleration time
- Tip-in time
- Time to reach certain distance
- Max vehicle speed
- Gradability @ vehicle speed
- All electric range (AER)/ Energy economy

Battery performance

- Capacity, SOC
- Voltage, current, power
- Cycle life, calendar life

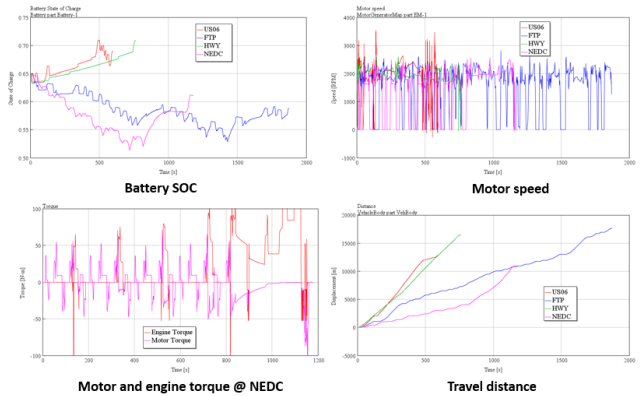
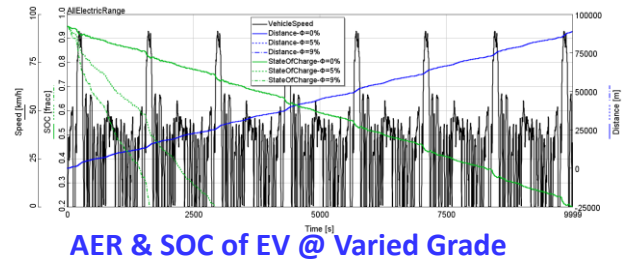
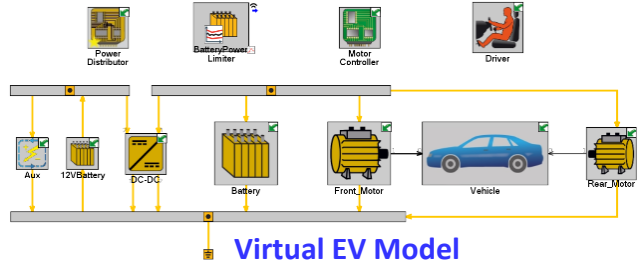
Engine start/ stop, and electric launch & assist

Component sizing & selection – battery, motor, transmission, engine for energy & emissions optimization

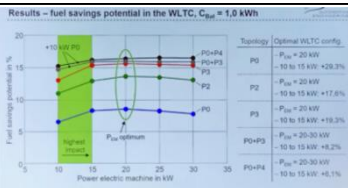
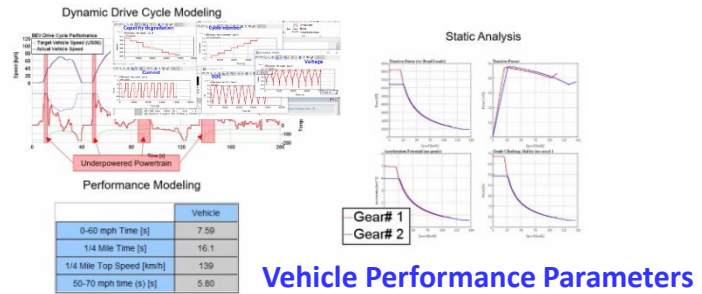
Architecture selection (series, parallel, P0, P1, ...P4)

Regenerative braking

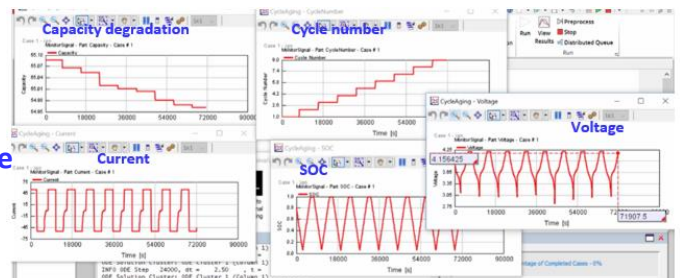
Control strategy optimization



EV Various Parameters at Different Driving Cycles

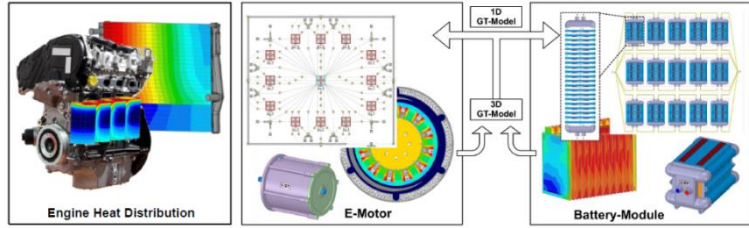
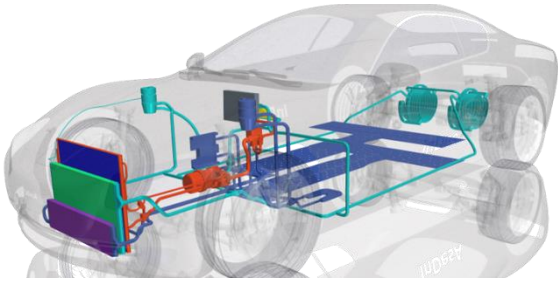


Battery Performance Parameters



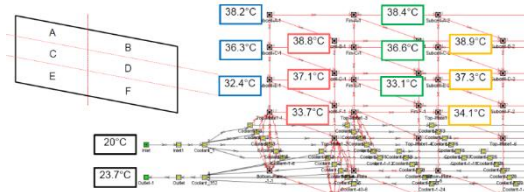
EV & HEV Thermal Management System

Energy management optimization



Detailed Motor & Battery Cooling System Modeling

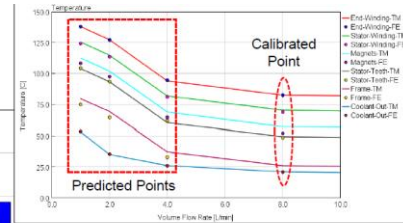
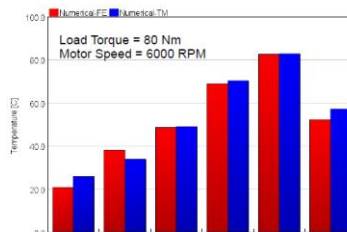
- Temperature Distribution (single cell)



Battery Core Temperatures

Calibration Parameter:

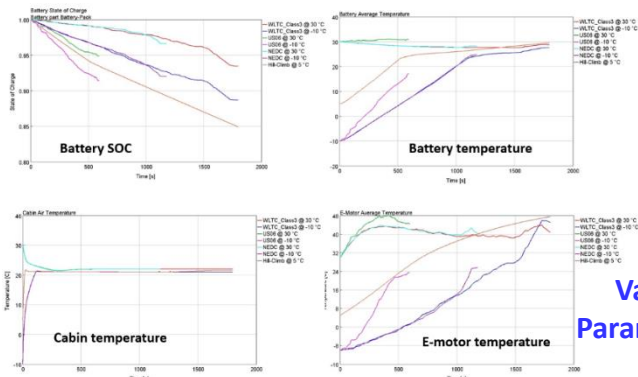
Distance to mass center of 1D thermal mass components



- 1D model is calibrated for a single operating point with targeted component temperature supplied from the 3D model

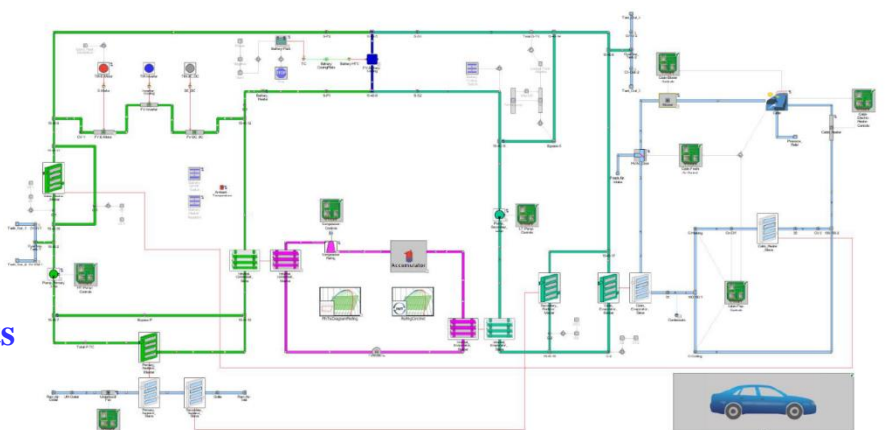
Motor Section Temperatures

- Modeling & integration of engine, underhood, HVAC cooling systems; and battery, motor, power electronics components
- Detailed modeling of cabin, battery & motor cooling system
- Control strategy optimization
- Vehicle level energy management optimization for driving cycles



Various Cooling System Parameters for Driving Cycles

Temperature/ Flow/ Heat Distribution for Complete Vehicle Level Coolant Circuits



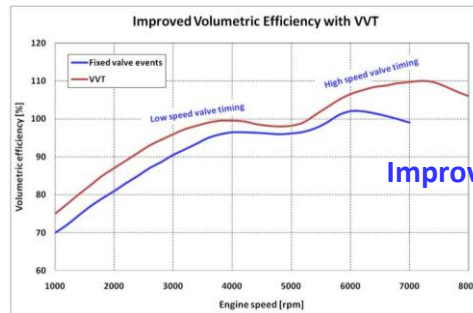
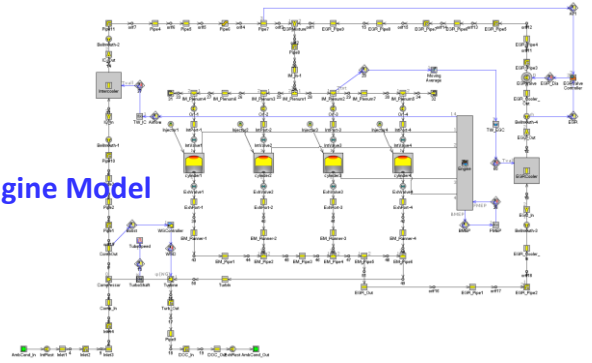
Engine Performance

Performance, fuel economy, emissions and optimization



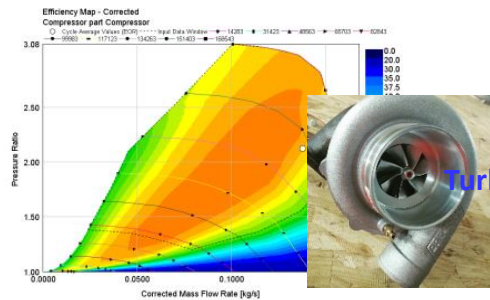
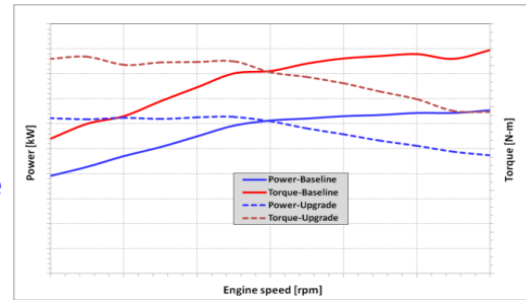
- ❑ Power upgradation
- ❑ Engine downsizing & downspeeding
- ❑ Fuel economy improvement
- ❑ Engine emissions & knock reduction
- ❑ Genset engine load step prediction
- ❑ Turbocharger selection
- ❑ Turbocharger transient response improvement
- ❑ High altitude performance & power deration
- ❑ Camshaft optimization
- ❑ EGR architecture selection
- ❑ Advanced technologies implementation
- ❑ Diesel, gasoline, and alternate fuel
- ❑ Engine performance optimization
- ❑ Test bench development
- ❑ Customer specific new methodology/tool development

Virtual Engine Model

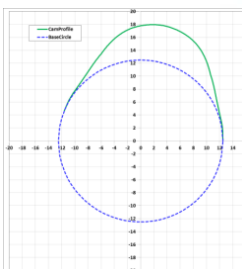


Improved VolEff with VVT

Power Upgrade

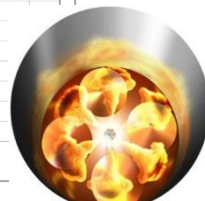
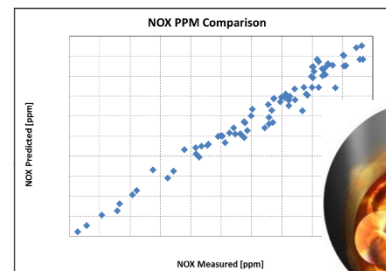


Turbocharger Selection



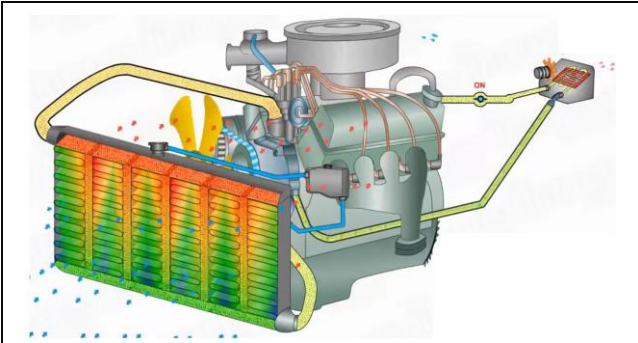
Camshaft optimization

Emissions Prediction

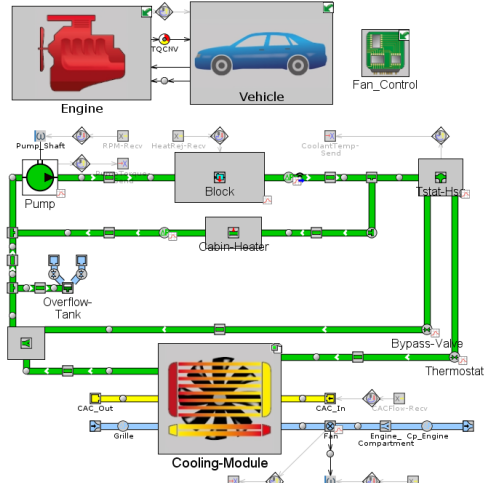


Engine Cooling & Underhood Cooling

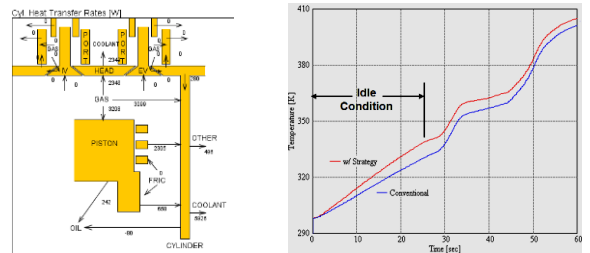
Performance, component sizing & selection, architecture optimization



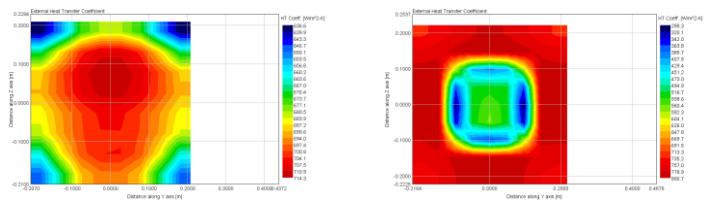
- Heat exchanger design
 - New HEX
 - Modify existing HEX to suite new requirements
 - Performance of existing HEX for new conditions
- Component sizing, specification & architecture optimization
 - Radiator, CAC, EGR cooler
 - Fan, fan shroud, location, number
 - Pump
 - Orifice, thermostat
- HEX scaling & stacking
- Transient performance
- Integration with engine, vehicle and other sub-systems
- Engine warm-up and optimization
- Provide engine cylinder boundary conditions for CFD and CAE analysis



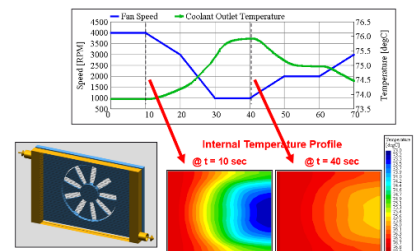
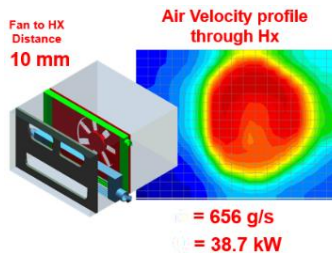
Virtual Engine & UHC System Integrated with Engine & Vehicle Drivetrain



Engine Warm-up



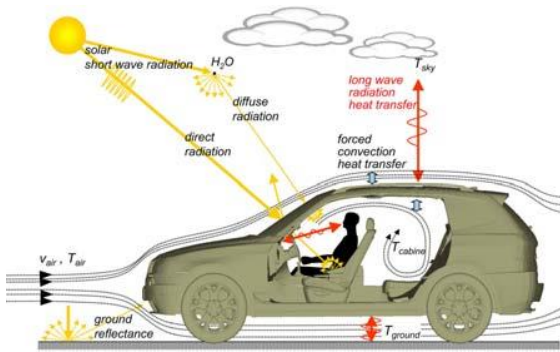
Radiator Air Side HTC w/o Blockage & with 25% Blockage at the Centre



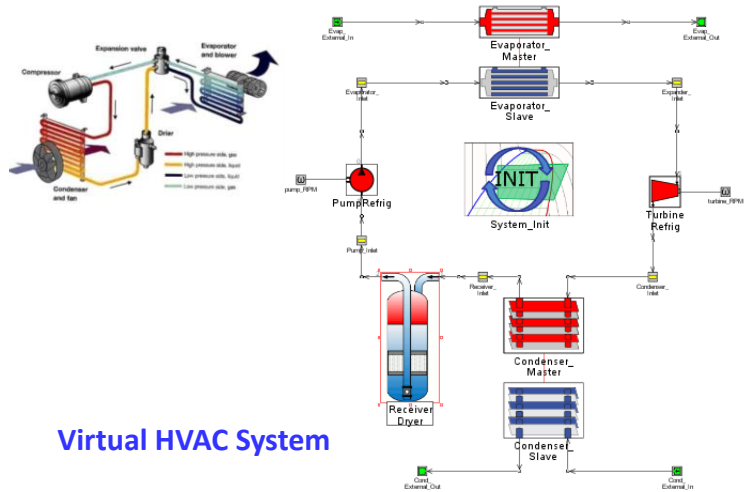
Coolant Outlet Temperature with Transient Fan Speed

HVAC System

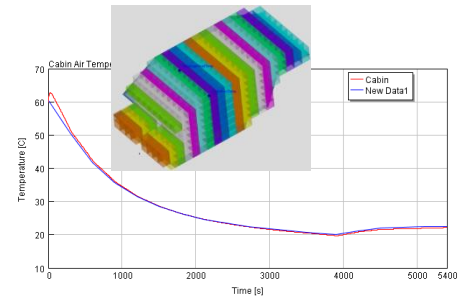
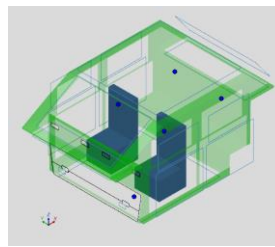
Optimization for passenger comfort and energy economy



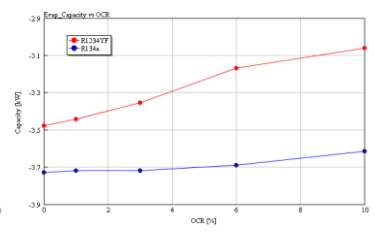
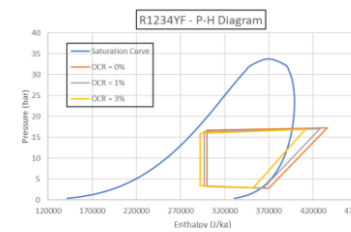
- ❑ System configuration
- ❑ Component sizing - compressor, condenser, evaporator
- ❑ Optimization of energy management control algorithms for cabin cooling
- ❑ Vehicle transient performance, energy consumption
- ❑ Refrigerant selection and charge determination
- ❑ Study influence of oil/refrigerant mixtures
- ❑ Waste heat recovery (WHR)
- ❑ Detailed cabin design
- ❑ Cabin heat up/ pull down characteristics
- ❑ Integration of different sub-systems which include UHC, HVAC, engine cooling, vehicle driveline etc



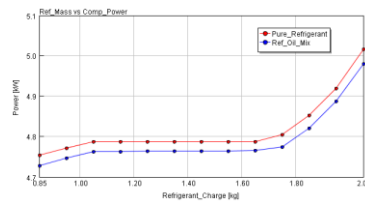
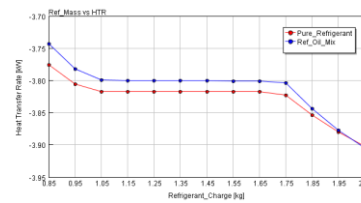
Virtual HVAC System



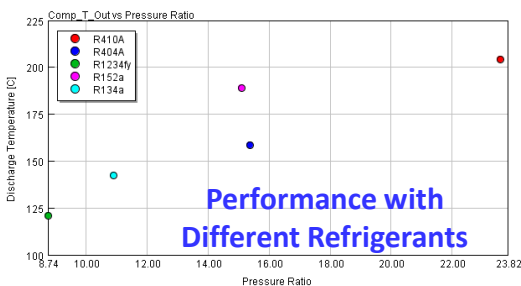
Cabin Pool Down Characteristics



Influence of Refrigerant & Oil Mixture



Refrigerant Charge Quantity Determination

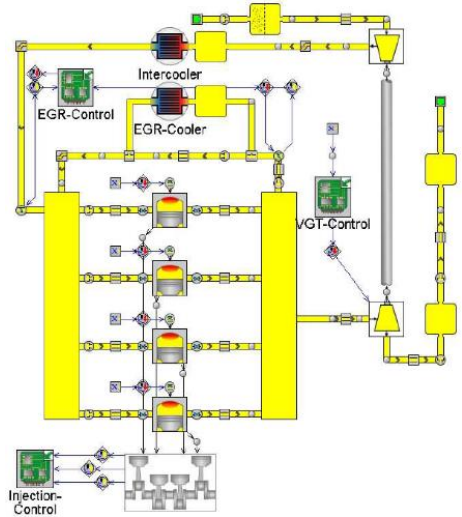
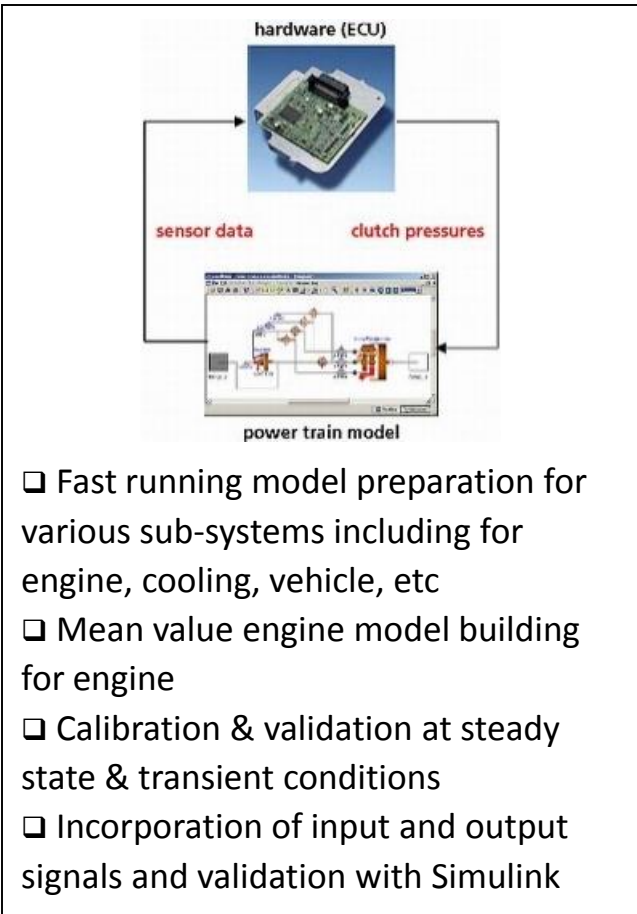


Performance with Different Refrigerants

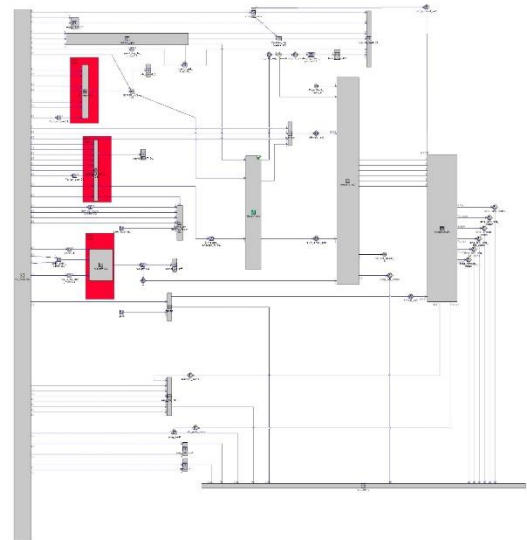


Plat Model Development for RT Simulation

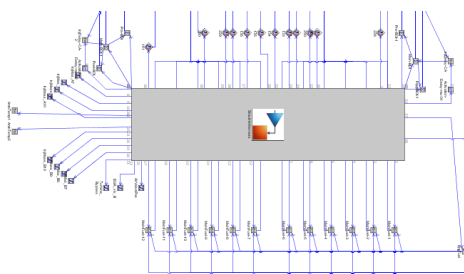
FRM & MVEM Model Preparation



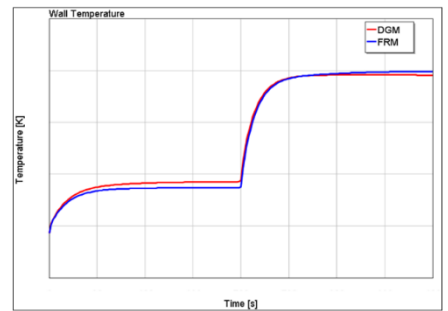
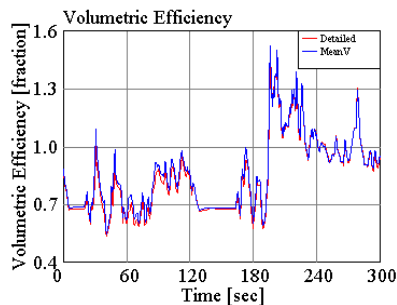
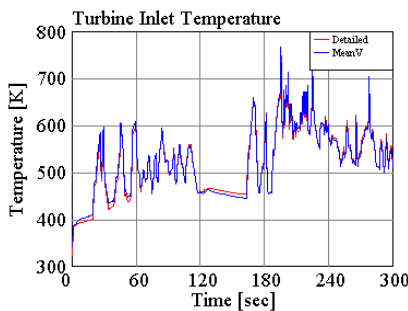
Fast Running Model (FRM)



Mean Value Engine Model (MVEM)



Input & Output Signal Transfer with Simulink



FRM Transient Response Validation

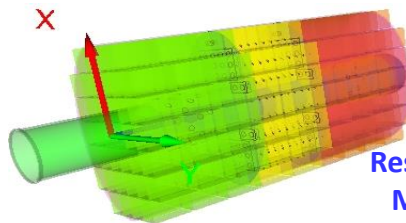
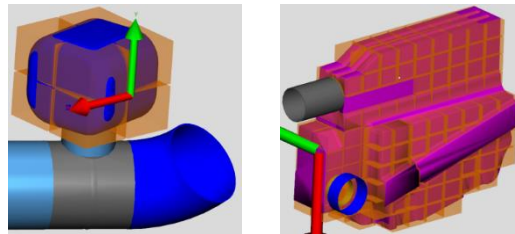
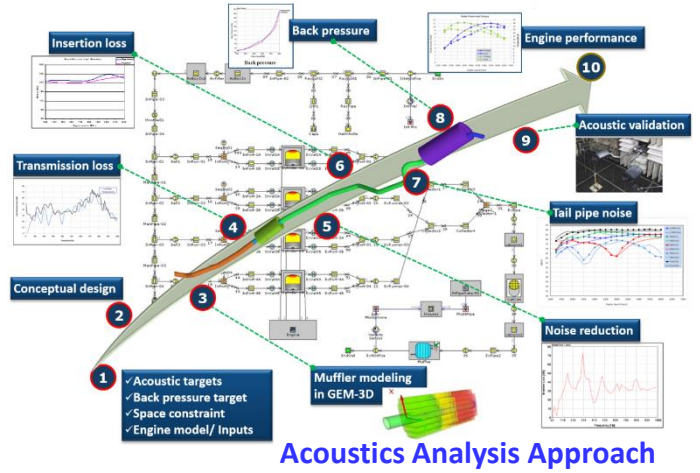


Acoustics Components

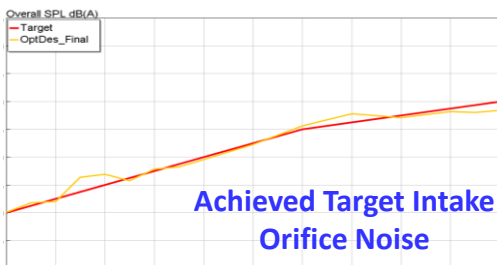
Intake and exhaust systems design and optimization



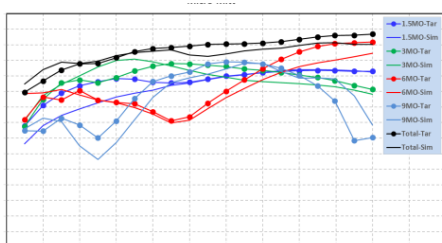
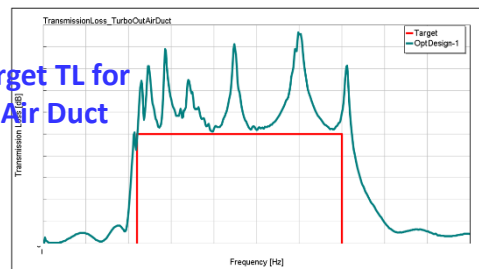
- ❑ Airfilter, resonator, piping, dirty air duct, clean air duct, turbo out air duct design & optimization
- ❑ Muffler design & optimization
- ❑ Tail pipe noise, intake orifice noise
- ❑ Transmission loss (TL), insertion loss
- ❑ Sound files from simulation (WAV format)
- ❑ Pass-by noise and transient noise
- ❑ Campbell diagram
- ❑ Multiple noise sources
- ❑ Pressure loss
- ❑ Effect on engine performance



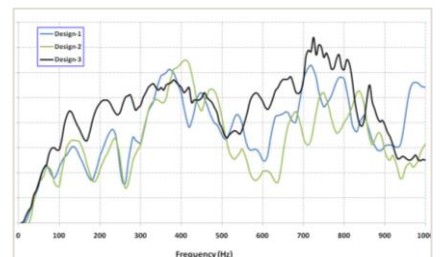
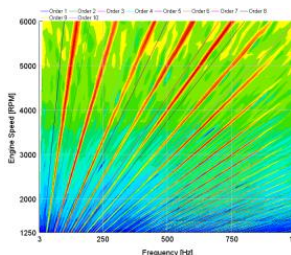
Resonator, Airfilter & Muffler Modeling & Discretization



Achieved Target TL for Turbo Out Air Duct



Achieved Target Tail Pipe Noise

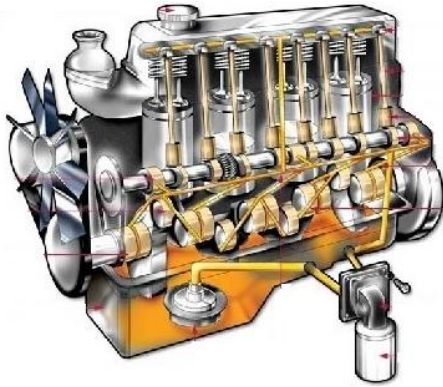


TL for Different Muffler Designs

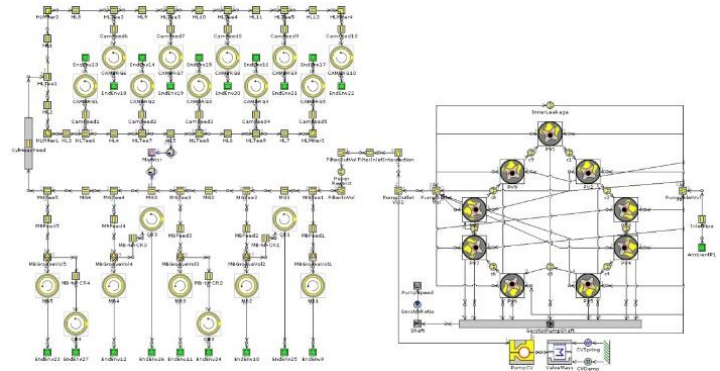


Lubrication System

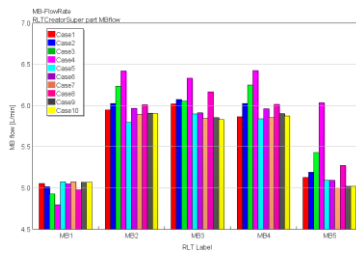
Performance, component sizing, design and optimization



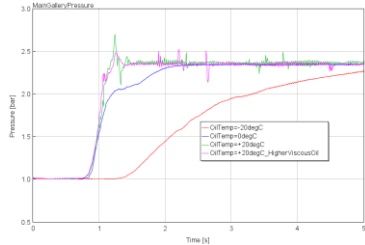
- ❑ Steady state simulation for oil flow rate, pressure drop, minimum oil film thickness, bearing pressure, orbit, power loss, thermal parameters
- ❑ Lube system priming & oil aeration
- ❑ Oil grade/ ambient temperature effects
- ❑ Thermal warm-up & integration with cooling system
- ❑ Pump sizing for energy consumption over driving cycle
- ❑ Detailed pump modeling
- ❑ Optimize bearing design variables



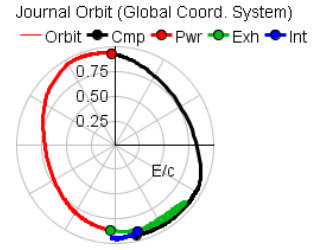
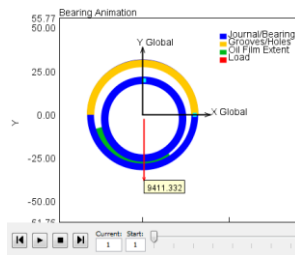
Virtual Lube System with Detailed Pump



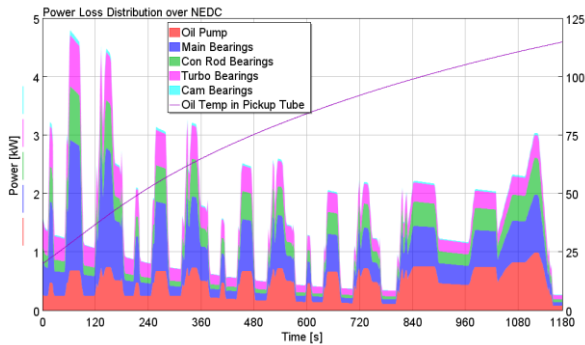
MB Oil Flow



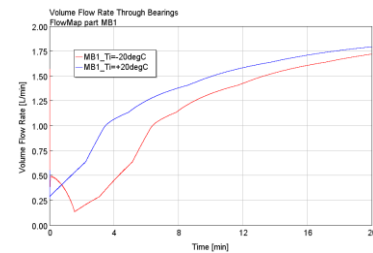
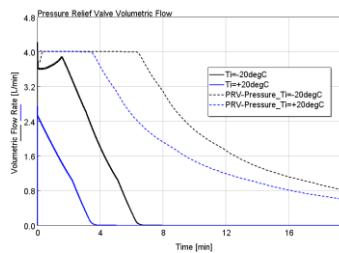
System Priming with Different Temperature & Oil Types



Journal Orbit



Different Component Power Loss over Driving Cycle



Transient Thermal Response

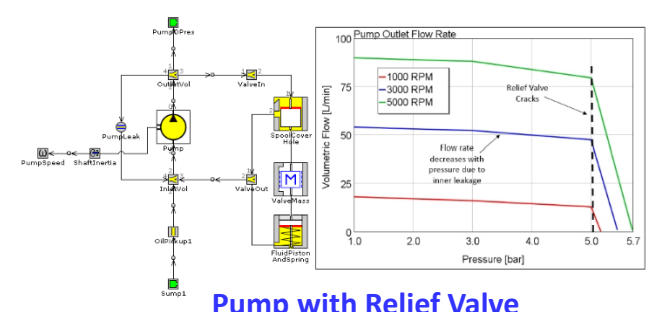
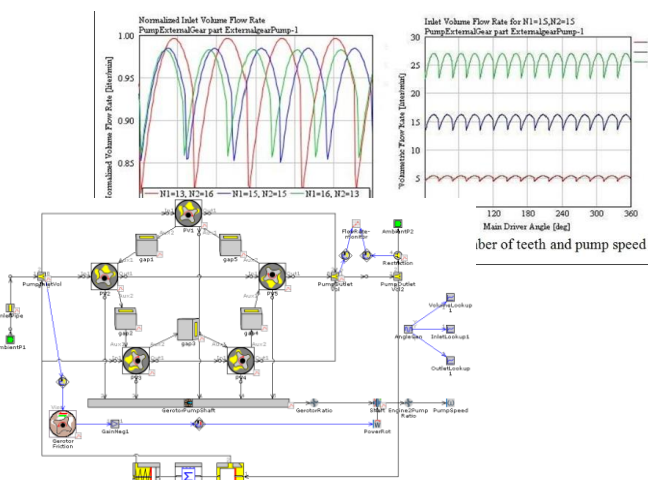
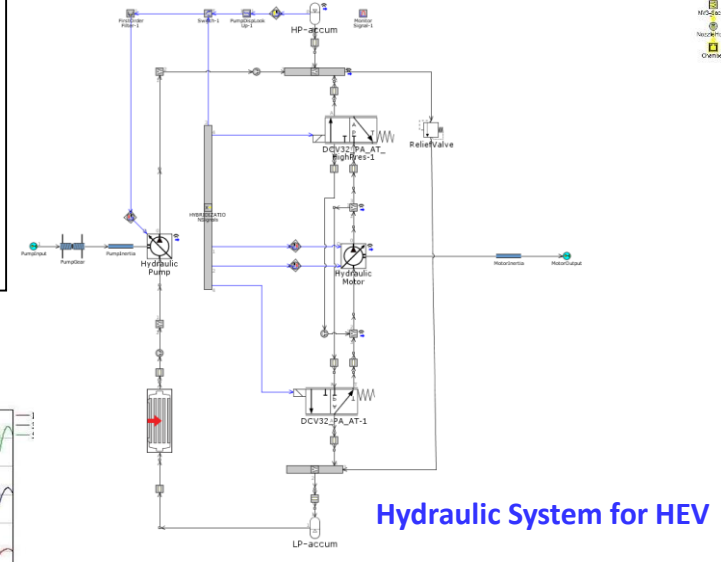
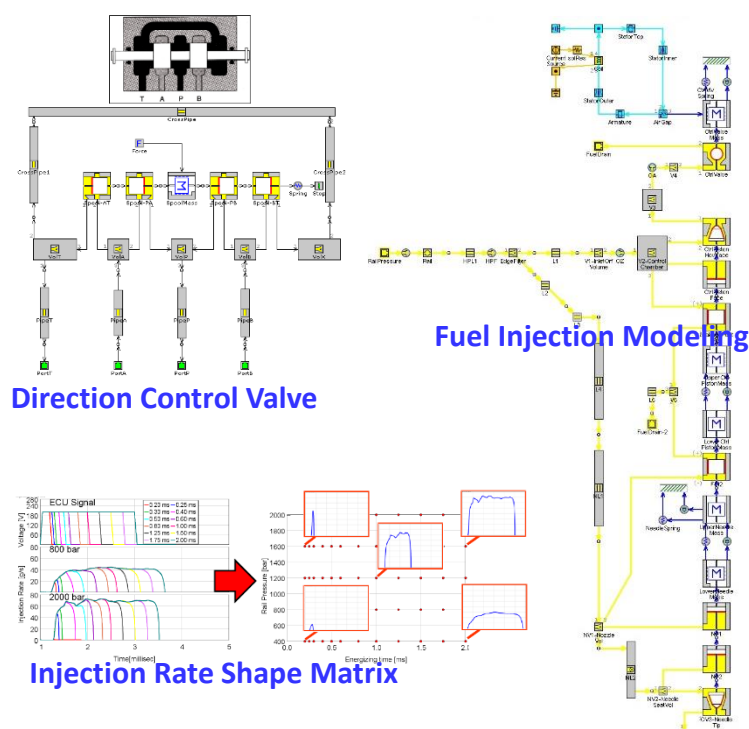


Hydraulic & Fuel Injection System

Performance, component selection and architecture optimization



- ❑ Modeling & simulation of hydraulic & fuel system components - check valve, DCV, pressure control, flow control valves, pumps, injector, etc
- ❑ Detailed pump modeling – Gerotor, gear, swashplate, etc
- ❑ Pressure pulsation & flow ripple predictions
- ❑ Modeling of a complete fuel injector and associated components & circuits
- ❑ Predict injection rate shape matrix
- ❑ Impact of various operating and design variables on hydraulic system performance



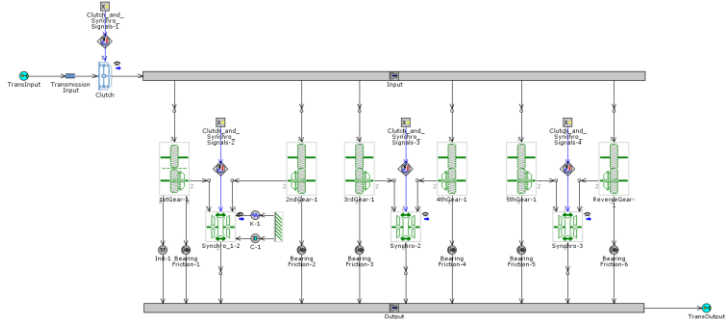
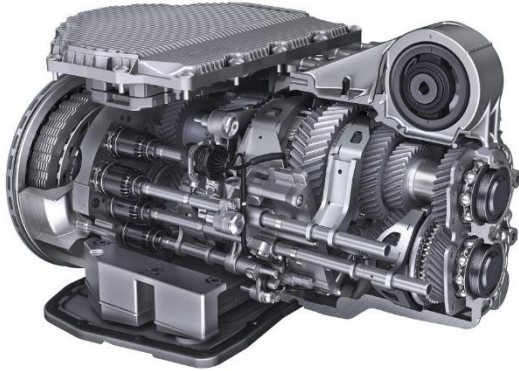
Detailed Pump Modeling

Pump with Relief Valve



Transmission System

Detailed transmission system modeling



Manual Transmission

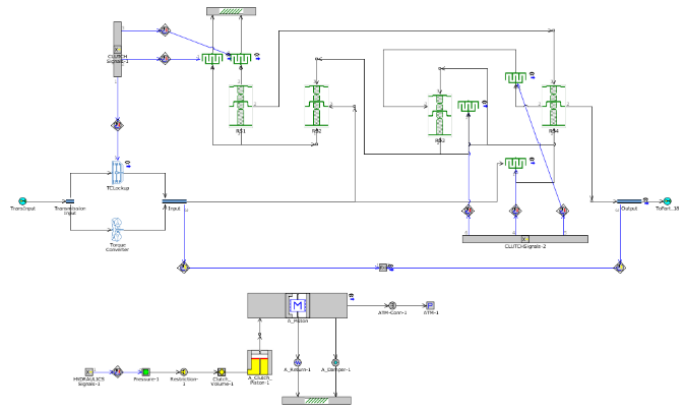
□ Detailed modeling of different transmission systems

- Automatic transmission
- Manual transmission
- Automated manual transmission
- Dual clutch transmission
- CVT
- Dry clutch & wet clutch

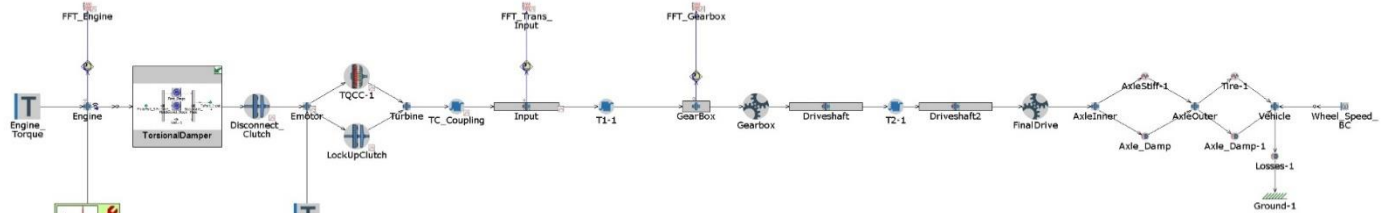
□ Hydraulic and control system development

□ Cooling system optimization

□ NVH analysis



Hydraulically Operated Automatic Transmission



NVH Analysis

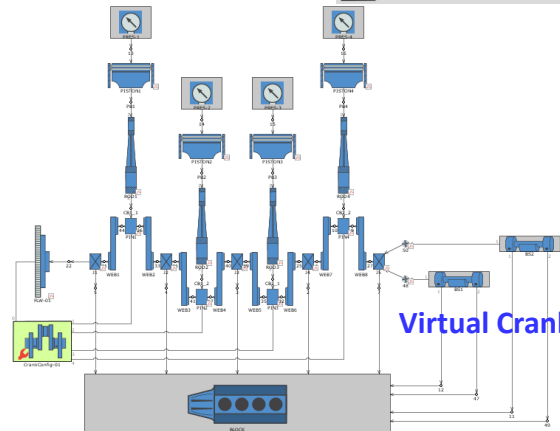
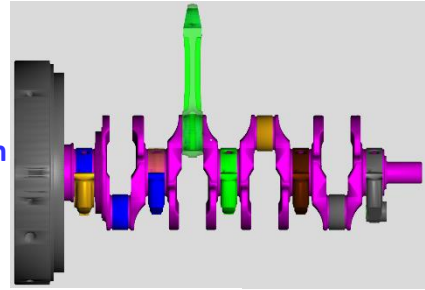
Cranktrain System

Crankshaft design

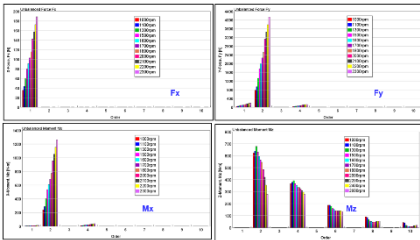


- Balancing of unbalanced forces and moments
- Torsional analysis
- Bearing analysis
- Bending analysis

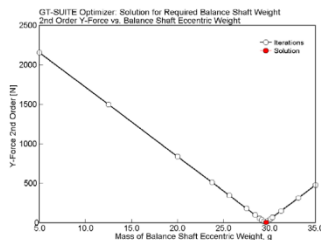
Crankshaft Discretization



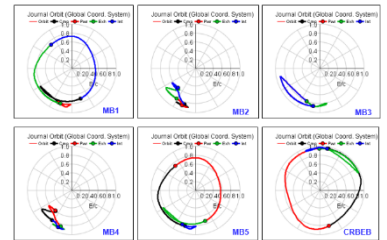
Virtual Cranktrain Model



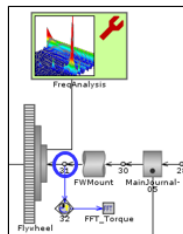
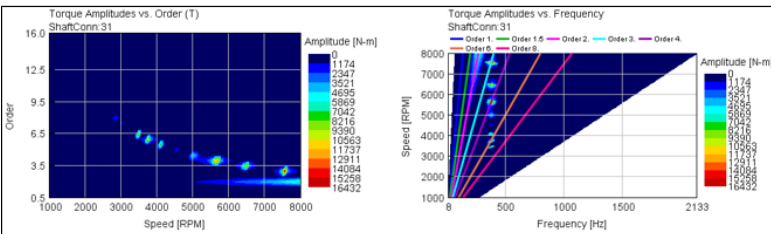
Unbalanced Forces & Moments



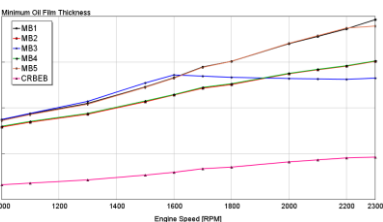
Balancing weight optimization



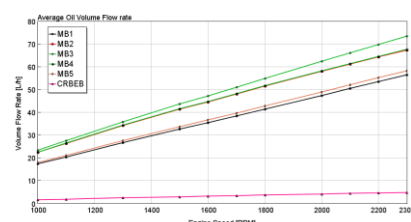
Journal Orbit



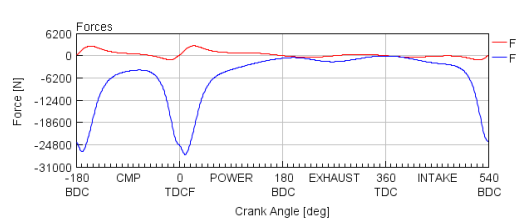
Torsional Analysis



Minimum Oil Film Thickness



Oil Flow



Bearing Load

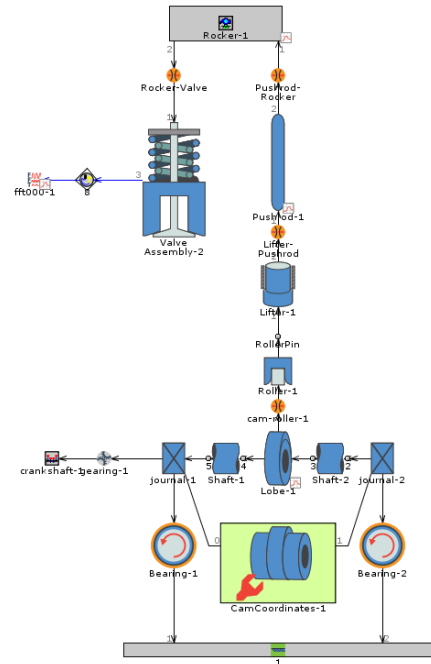


Valvetrain System

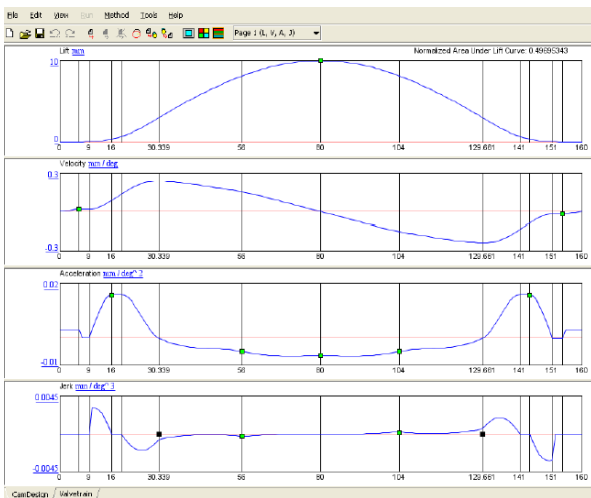
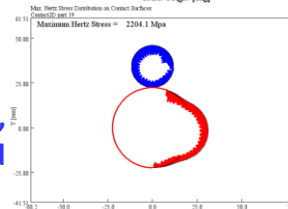
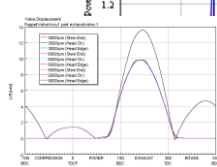
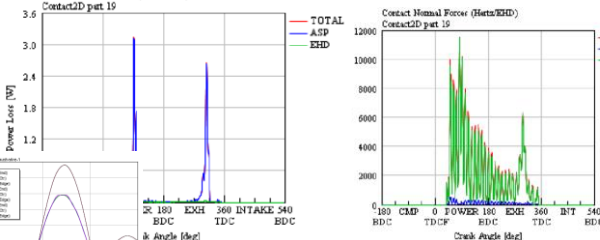
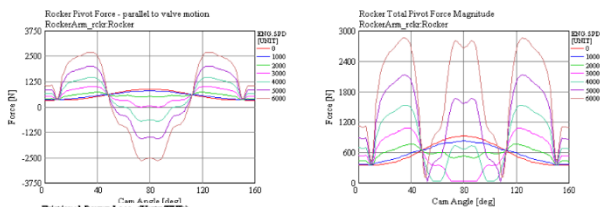
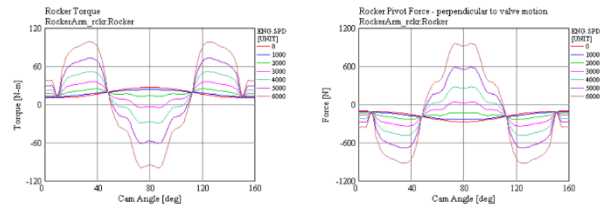
VT design and performance



- ❑ Kinematic analysis
- ❑ Dynamic analysis – Margin, surge, coil clash, stress
- ❑ Valvetrain design
- ❑ Single branch, single or multi-cylinder engines
- ❑ Different types of valve arrangement



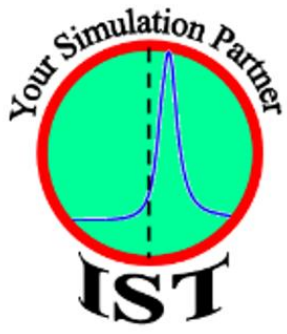
Virtual Valvetrain Model



Kinematic analysis - lift, velocity, acceleration, jerk, follower run-off

Dynamic analysis - spring margin, component force, hertz force and pressure, and dynamic valve lift







Integrated Simulation Technologies

| EV, HEV & Engine Development | Staff Augmentation | Corporate Training |



Thank You

 A2/19, Aditya Breeze Park, Balewadi, Pune-411045, Maharashtra, India  +91-9763909935

 subir.mandal@integratedsimtech.com  www.integratedsimtech.com