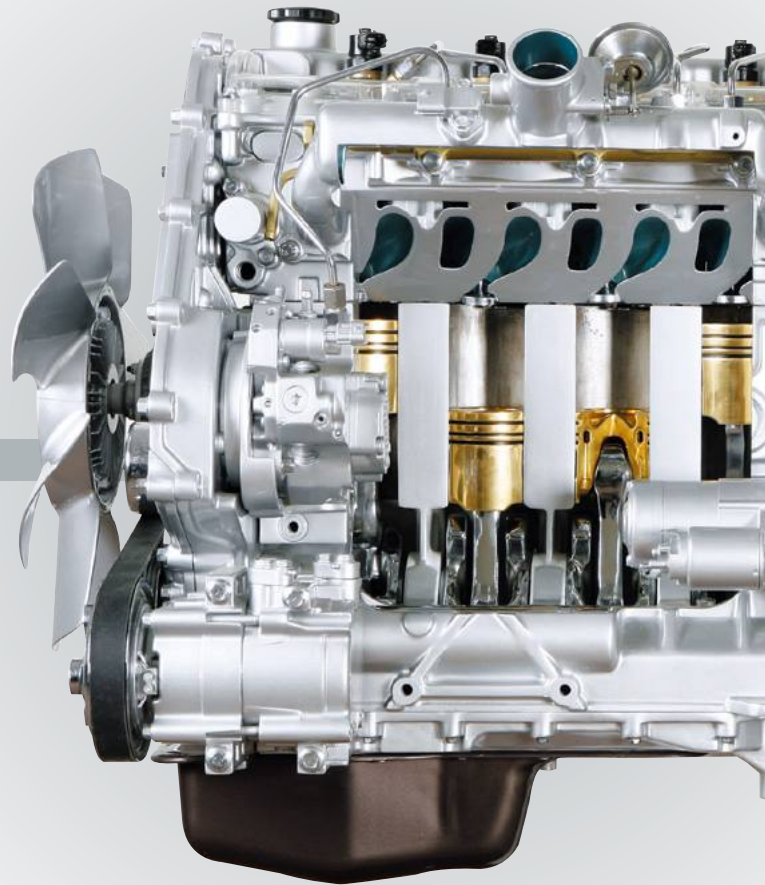
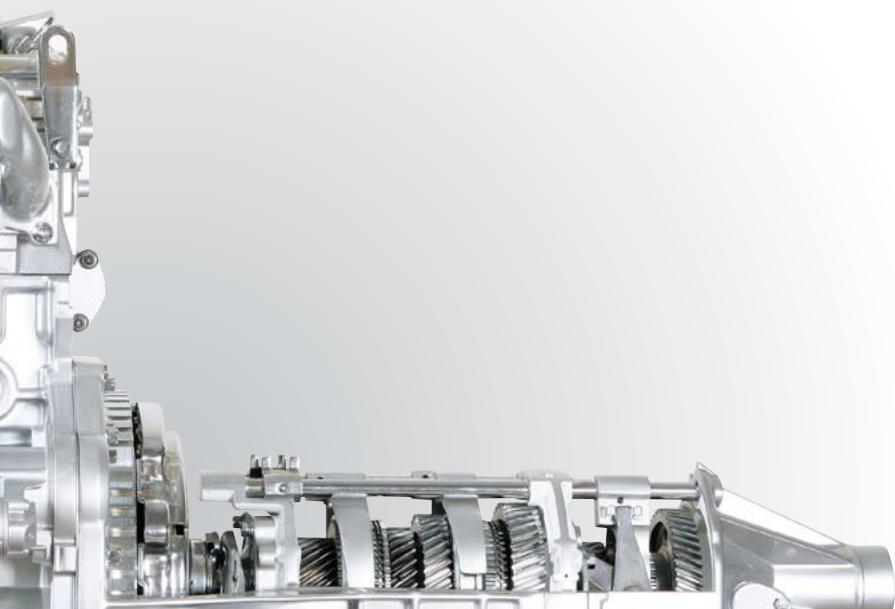


# Powertrain / Vehicle Engineering Solutions

Driving The Future Through Energy Conversion Technology





## Contents

04	Who is TENERGY
10	Achievements
16	Engine design
18	CAE analysis
20	CAE specialty company - TenergySoft
24	Engine test
26	Transmission design & development
28	Vehicle calibration
34	Fuel economy analysis
36	xEV benchmarking and system development
38	Electric and electronics solution
40	Bus fuel saving system
42	Big data management system
46	Vehicle engineering
50	Major clients



## World Best with The Best

Driving the future through leading technology

TENERGY is trying to lead green technology and listen to the voice of clients.

TENERGY is an engineering service provider of automotive industry with utmost professionalism and agility.

We have our special expertise and best technology to make success for our clients.

We offer detail and flexible solutions for powertrain and vehicle development as total programs or selected services.

Strong partnership and engineering perfection are our commitments.

TENERGY is a technical leader in the field of energy conversion and environmental technology.

→ → → TENERGY is ready to support the clients who are thirsty for higher level of engineering to make the green world.



# Suwon R&D center





# Dongtan R&D center



# Suwon R&D center

## Engine dynamometers

Test cell	Dynamometer			Gas analyzer model
	Type	kW	Maker	
T-01	AC	390	Schorch	Horiba 8120
T-02	EC	290	Apicom	Horiba 8120
T-03	AC	200	AVL	Horiba 9100
T-04	Hydraulic	2,500	Schenck	Horiba 9100
T-05	AC	390	Schorch	Horiba 9100
T-06	EC	30	Apicom	Horiba 9100
T-07	AC	390	Schorch	Horiba 7100
T-08	AC	300	D2T	Horiba 7100
T-09	EC	300	Meiden	Horiba 554
T-10	EC	300	Meiden	Horiba 554

## Chassis dynamometers

Test cell	Dynamometer			Capacity (kW)		Emission analyzer
	Type		Maker	Front	Rear	
CD-01	4 WD	Single roll	Onosokki	110	75	AVL AMA 4000 · 2ch analyzer
CD-02	4 WD	Single roll	HORIBA	150	150	HORIBA MEXA-ONE · 3ch analyzer · FTIR



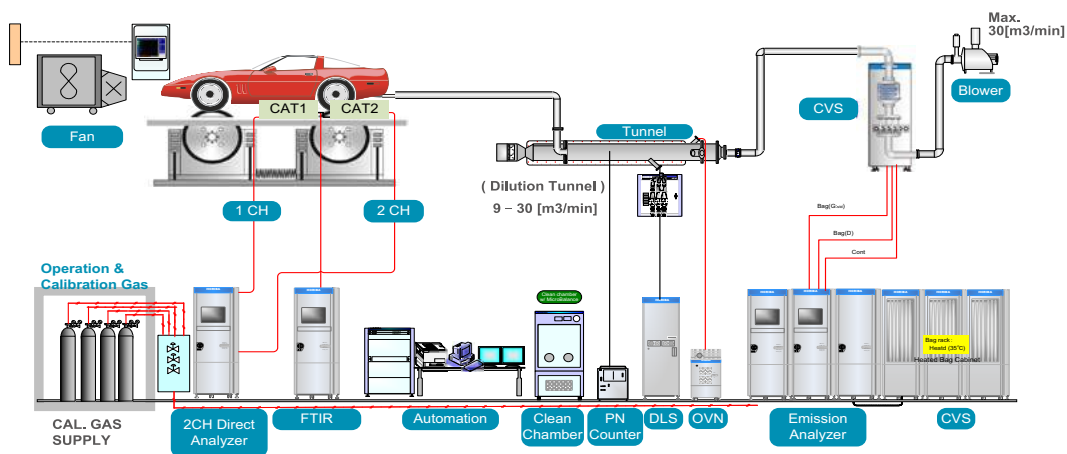
# Dongtan R&D center

## Engine & Transmission dynamometers

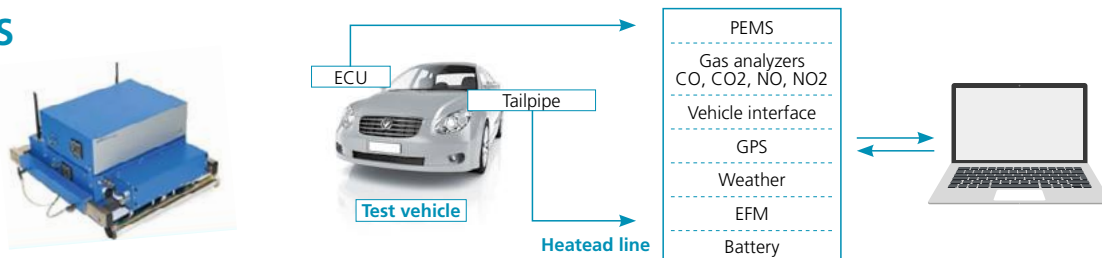
Test cell	Dynamometer			Gas analyzer model
	Type	kW	Maker	
T-01	AC	390	Schorch	TBD
T-02	AC	390	Schorch	TBD
T-03	AC	390	Schorch	Horiba 9100DEGR
T-04	AC	400	AVL	TBD
T-05	AC	220	AVL	Horiba 9130
T-06	AC	350	AVL	Horiba 9130
T-07	AC	390	Schorch	TBD
T-08	AC	350	AVL	Horiba 9100DEGR
T-09	EC	500	SAJ	TBD
T-10	Hydraulic	2,500	Schenck	TBD
T-11	DC	230	Meiden	-

**Cold chamber** (to -30°C, 2 units of vehicles can be tested concurrently)

## Emission test system



## PEMS





# Energy and Environment with a Passion for Green





## Driving the future through leading technology

TENERGY is dedicated to providing clients with an extensive portfolio of leading technology and superior consulting services as well as next generation solutions.

Our design concept is based on achieving what clients want: high power, fuel economy, low cost, compact design and environmentally friendly one. All of the achieved design outputs are validated through innovative and advanced technology method at engine test cells and various rigs under controlled conditions during the development process.

TENERGY provides not only engine development services but also complete power train calibration ones to clients.

Our calibration engineers have vast experiences in engine and transmission applications. In addition, they are familiar with many types of engine management systems from various EMS suppliers. We have the strong belief that TENERGY can make a great breakthrough from the old routine in energy saving and environment protection technology of future engines.

Current demands to save the planet via engine technology through more economical and cleaner engines are growing all over the world every year. TENERGY is ready to support to develop next generation, environmentally friendly Gasoline and Diesel engines. The aim is now to reduce the fuel consumption of engines through innovations, including downsizing, direct injection, variable valve train and new diesel FIE system.



# Achievements

Relatively the history of TENERGY is short, but our development references are great. Furthermore, we have major engine design and development contracts with automakers and industrial makers at this moment.

## Engine development

### A2300T IDI engine

- Cylinder head design
- Mechanical development
- Vehicle cooling system development

### 2400T DI engine

- Design, CAE
- Test & development, SOP support

### D3400T DI engine

- Design, CAE
- Test & development, SOP support

### 2.4L (TCI, TC, NA) CRDi Tier 4 engine

- Combustion development
- Mechanical & durability development
- Engine & DPF calibration

### 2.0/2.4L Euro 5 Gasoline engine

- Design (Concept, definitive & detail design)
- Combustion development
- Mechanical & durability development

### 1.8/2.4L(TC, NA) CRDi Tier 4 engine

- Combustion development
- Mechanical & durability development
- Engine & DPF calibration

### 3.4L TCI CRDi Tier 4 engine

- Mechanical development
- Durability development

### 1.2L NA Gasoline Euro 5 engine

- Design, CAE
- Combustion development
- Functional development

### 1.3L NA Gasoline Euro 4 engine

- Design, CAE
- Combustion development
- Mechanical & durability development

### 1.9/2.5L TCI CRDi Tier 4 engine

- Combustion development
- Mechanical & durability development
- Vehicle calibration with CDPF

### 27L(V-12) TCI CRDi Diesel engine

- Optimization of crank-train system
- Improvement of bearing reliability

### 30L(V-12) TCI CRDi Diesel engine

- Concept, definitive & detail design for 1MW power plant
- PFP 220 bar

### 1.8L Turbo-charged Gasoline Euro 5 engine

- Design, CAE
- Combustion development
- Mechanical & durability development
- Engine & vehicle calibration

### Denso Piezo 2,000 & 2,200bar FIE application to HMC R-engine

- R-Engine base definition
- Denso FIE packaging to R-Engine
- Engine calibration & feasibility test

### 6.6L Dual fuel engine (LPG & Diesel)

- System layout design including EMS system
- Combustion development



**0.033L Gasoline engine**

- Design (Concept, definitive & detail design)
- CAE
- Test & development

**2.0L GDI engine**

- Design (Concept, definitive & detail design)
- Combustion development

**2.0L T-GDI engine**

- 10% performance improvement
- Vehicle calibration ULEV 2 (EURO 5 equivalent)

**2.0L T-GDI engine**

- Design, CAE
- Combustion development
- Engine calibration

**2.7L NA Gasoline Euro 5 engine**

- Design, CAE
- Combustion development
- Mechanical & durability development
- Engine calibration

**125/150cc single cylinder engine**

- Design, CAE
- Combustion development
- Mechanical & durability development
- Engine calibration

**149cc single cylinder engine for CHP**

- Design, CAE
- Combustion development
- Mechanical & durability development

**1.5L NA Gasoline Euro 5 engine**

- Design, CAE
- Combustion development
- Mechanical & durability development

**22L(V-12) TCI CRDi Diesel engine**

- Design, CAE
- Combustion development
- Mechanical & durability development
- Engine calibration

**2.4L NA Gasoline Euro 5 engine**

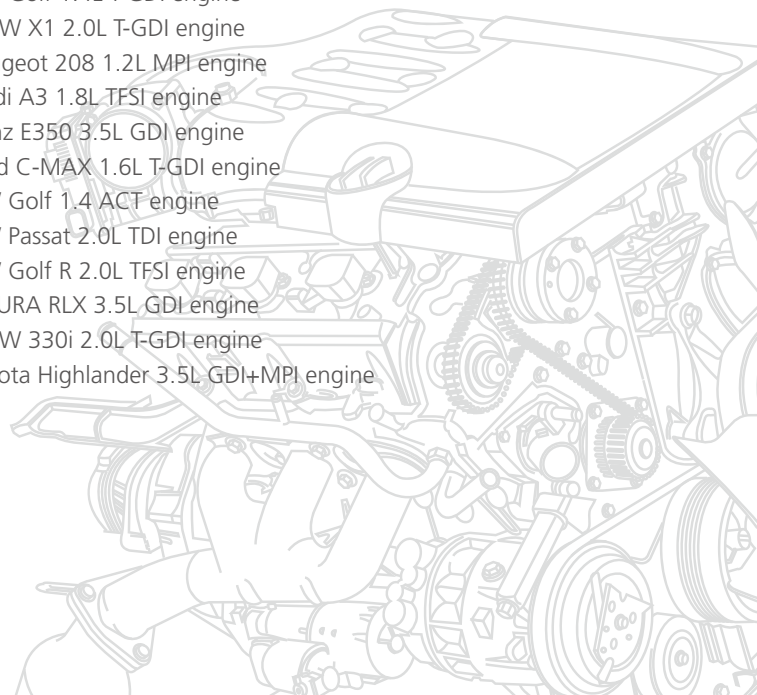
- Design, CAE
- Combustion development
- Mechanical & durability development
- Engine & vehicle calibration

**TENERGY 1.2/1.6L T-GDI engine**

- 1-3 & 1-4 NA & T-GDI family engine
- Design, CAE
- Combustion development

**Engine benchmarking test**

- VW FOX 1.6L flexible fuel engine
- Honda RDX 2.3L TCI engine
- BMW 123d 2.0L Turbo engine
- Audi A6 2.8L GDI engine
- VW Golf 1.4L T-GDI engine
- BMW X1 2.0L T-GDI engine
- Peugeot 208 1.2L MPI engine
- Audi A3 1.8L TFSI engine
- Benz E350 3.5L GDI engine
- Ford C-MAX 1.6L T-GDI engine
- VW Golf 1.4 ACT engine
- VW Passat 2.0L TDI engine
- VW Golf R 2.0L TFSI engine
- ACURA RLX 3.5L GDI engine
- BMW 330i 2.0L T-GDI engine
- Toyota Highlander 3.5L GDI+MPI engine



# Achievements

Relatively the history of TENERGY is short, but our development references are great. Furthermore, we have major engine design and development contracts with automakers and industrial makers at this moment.

## Vehicle EMS calibration

### Diesel vehicle calibration

#### A150 2.0 CRDi calibration

- EURO 5/4 regulation
- Emission / EOBD / CDPF / Drivability calibration

#### C150 2.0 CRDi calibration

- EURO 5/4 regulation
- Emission / EOBD / CDPF / Drivability calibration

#### C211 2.0 CRDi calibration

- EURO 5/4 regulation
- Emission / EOBD / CDPF / Drivability calibration

#### Y295 2.2 CRDi calibration

- EURO 6b regulation
- Emission / EOBD / CDPF / LNT/ Drivability calibration
- RDE monitoring

#### Y400 2.2 CRDi calibration

- EURO 6b/5/4 regulation
- Emission / EOBD / CDPF / LNT / Drivability calibration
- RDE monitoring

#### Q200/201 2.2 CRDi calibration

- EURO 6b/4 regulation
- Emission / EOBD / CDPF / Drivability calibration
- RDE monitoring

### Gasoline vehicle calibration

#### C300 / X150 1.5 T-GDI calibration

- K-SULEV30 regulation
- Emission / KOBD / Drivability calibration

#### X150 1.5 T-GDI calibration

- EURO 6d temp regulation
- Emission / EOBD / Drivability calibration
- GPF / RDE calibration

#### C300 2.0 MPI calibration

- EURO 6b regulation
- Emission / EOBD / Drivability calibration

#### 1.8 T-GDI calibration

- EURO 5 regulation
- Emission / EOBD / Drivability calibration

#### 3.3L MPI calibration

- OBD2 calibration

#### 11L CNG calibration

- EURO 6b regulation
- CNG lean-burn engine OBD logic / calibration

#### 125cc / 250cc Gasoline(single cylinder)

- Emission / OBD / Drivability calibration



## Transmission development

### T-MAT development

- Torque interruption free  
(Manual-based Automatic Transmission)
- Concept & layout design
- Under patent examination

### Manual transmission

- Design, CAE
- Longitudinal 5 speed M/T
- Shift control layout design

### 4WD Transfer case

- Full-time transfer case with high gear and low gear
- Concept & layout design
- Test & development

### A/T calibration

- Calibrating shifting-process control and specific operating modes
- Designing shift points

### Fan clutch development

- CVT type using oil pump
- Electronically controlled
- Fail-safe design

### Reduction gear assembly

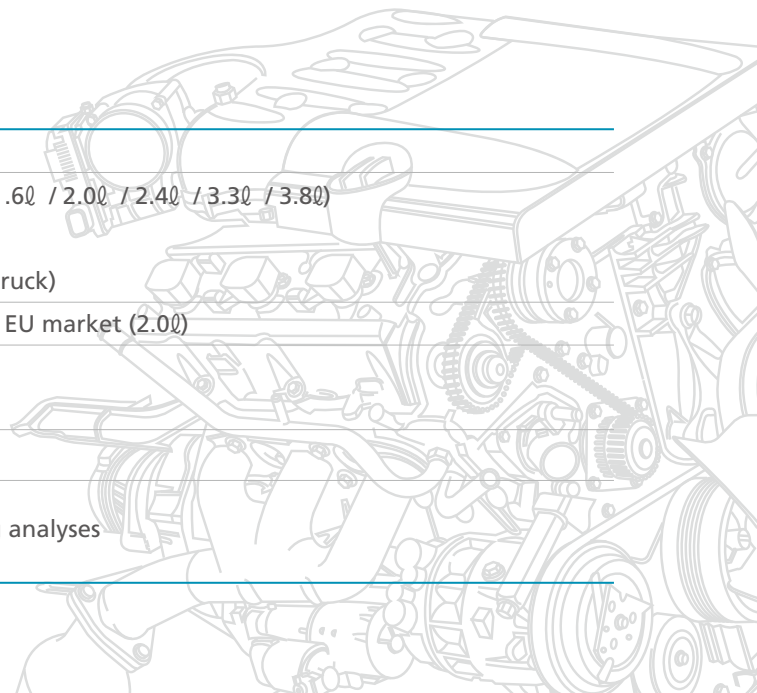
- Design for helicopter drone
- With spur gear & spiral bevel gear
- Assembling and dynamo test

## Energy Flow-Down Method

Great success for development of better FE

7~15% improvement of FTP-75 / NEDC mode F/E

Company	Vehicle program
<b>H</b>	Passenger car (1.1ℓ / 1.5ℓ / 1.6ℓ / 2.0ℓ / 2.4ℓ / 3.3ℓ / 3.8ℓ) Diesel SUV (2.0ℓ, 2.2ℓ) Commercial vehicle (24 ton truck)
<b>G</b>	Diesel SUV for Korean / US / EU market (2.0ℓ)
<b>S</b>	Diesel SUV & Van ( 2.5 / 2.7ℓ) Diesel SUV 2.0ℓ
<b>R</b>	Passenger car (V6 3.5ℓ)
<b>TOYOTA, HONDA, RENAULT, VOLVO, AUDI, etc.</b>	More than 25 benchmarking analyses



# Achievements

Relatively the history of TENERGY is short, but our development references are great. Furthermore, we have major engine design and development contracts with automakers and industrial makers at this moment.

## Vehicle engineering



Saga-R

Persona-R

Iriz

Preve

Integrated engineering  
(Vehicle development)

Exora

New Saga

Savvy



Next Mini bus



Next Van



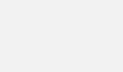
Gaz-on truck



Next Double



Next Single



Frame bus

Integrated engineering  
(Body manufacturing integration)



LADA S/W

LADA VESTA

Integrated engineering  
(Vehicle development)



HEXA

Integrated engineering  
(Vehicle development)



Essentia

Aveo

Sail

D-MAX

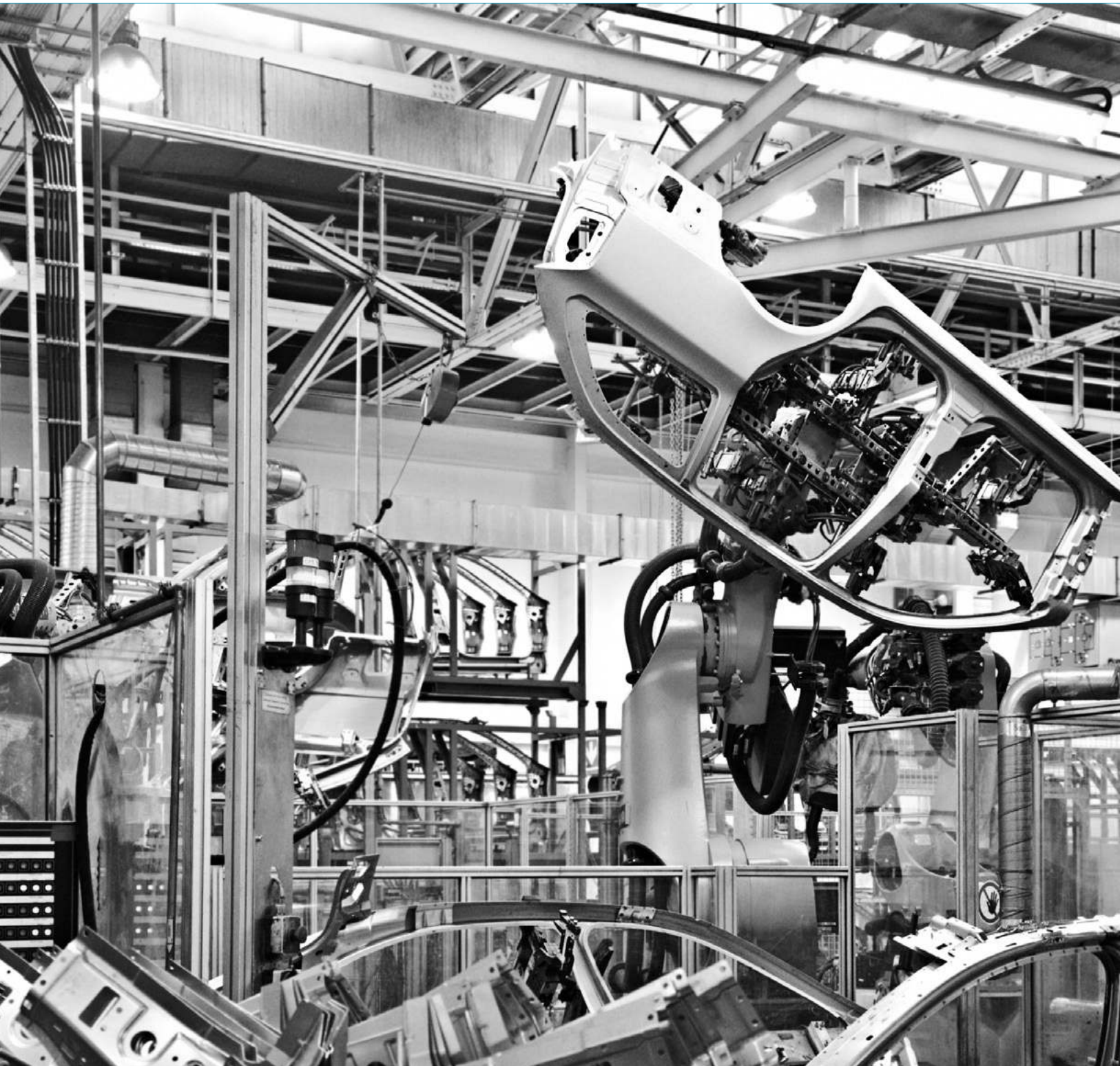
Tool & equipment development  
(Body assembly)



Ling-ao

Tool & equipment development  
(Body assembly)





# Engine Design



A lot of recent new engines have showed new variants and limits in every component and combustion type, which have motivated TENERGY to look into the relative merit of each engine.

The design philosophy of TENERGY is to develop well-researched and test-supported criteria to support the design decisions of future engine by investigating the key considerations of new engine design thoroughly and observing their trends carefully.

Experienced and highly motivated design engineers work on all types of design projects. And they are effectively supported by our experienced CAE, combustion system, mechanics and electronics teams. Furthermore TENERGY design details always take into account our clients' manufacturing boundary conditions and facilities.

TENERGY mainly uses Pro-E or CATIA and carries out engine design based on 3D model. Theoretical and numerical analyses are also carried out for every optimization. We surely guarantee our design and development outputs after SOP



## Engine design

- Gasoline engine
- Diesel engine
- Industrial engine
- Hybridization
- 2-stroke engine
- Wankel engine
- Marine engine
- Gen-set engine

## Engine design process

### Concept design

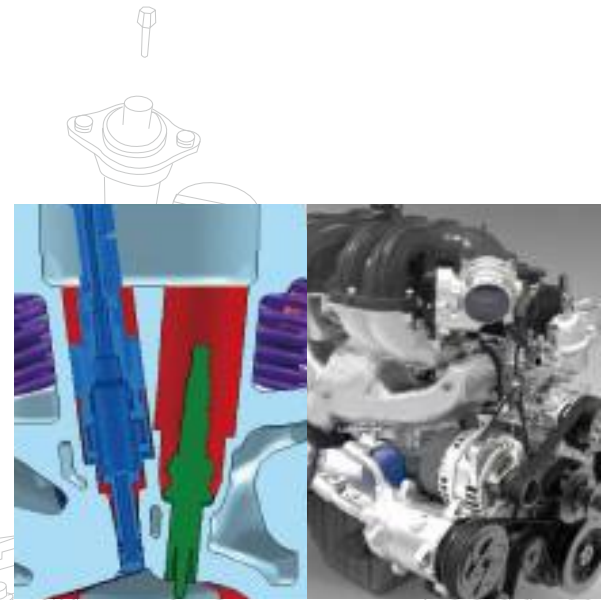
- Performance definition
- Packaging layout
- Front & timing drive layout
- Valve train layout
- Intake & exhaust system layout
- Cooling & lubrication circuit
- Numeric analysis
  - 1D cycle simulation
  - 1D cooling & lubrication
  - Oil film thickness
  - Torsional vibration
  - Crankshaft, conrod
  - Piston & piston pin
  - Bolt tightening
  - Engine balancing

### Definitive design

- Parts & layout design(3D modeling)
- Kinematic / Motion analysis
  - Valve & crank train
- Structural FEA
  - Cylinder block & head
  - Crankshaft, connecting rod
  - Bulkhead & main bearing cap
  - Valve train
- Modal analysis
  - Main structural parts
  - Covers & brackets
- Fatigue life calculation
  - High & low cycle fatigue
- CFD
  - Intake & exhaust ports
  - In-cylinder flow(combustion)
  - Coolant flow
  - Intake & exhaust manifold

### Detail design

- Detail parts design(3D modeling)
- 2D drawings
  - Tolerance
  - Roughness
  - Material
  - Machining
- All information related to production
- Reports
  - Design
  - Analysis





# CAE Analysis

## TENERGY supports all CAE works required in every engine design stage.

In concept design stage, baseline simulations such as gas exchange calculation, numerical analysis of cranktrain and piston assembly including TV, 1-D cooling and lubrication analysis are carried out.

In detail design stage, structural and dynamic analysis of engine major components are carried out. In addition CFD of coolant and exhaust gas flow and NVH analysis of auxiliary parts are performed.

Highly specialized experts with many years of experience in the field of engine development are involved in all CAE works which simulate actual loading conditions as much as possible. Therefore they can offer the optimum solutions for all stages in development process.

TENERGY pays particular attention to CAE works in the scope of development process. CAE works support the whole development process efficiently and enable clients to produce highly qualified engines while achieving shorter development time and lower cost.

---

### Gas exchange with T/C matching

1-D cooling

1-D lubrication

Valve train kinematics

Bearing load analysis

Torsional vibration

CFD In/Ex. port

CFD in-cylinder flow

CFD coolant flow

CFD intake manifold

CFD exhaust manifold

---

### FEA cylinder head & block compound

FEA cylinder block

FEA cylinder head(LCF)

FEA crankshaft

FEA connecting rod

FEA exhaust manifold(HCF & LCF)

FEA brackets

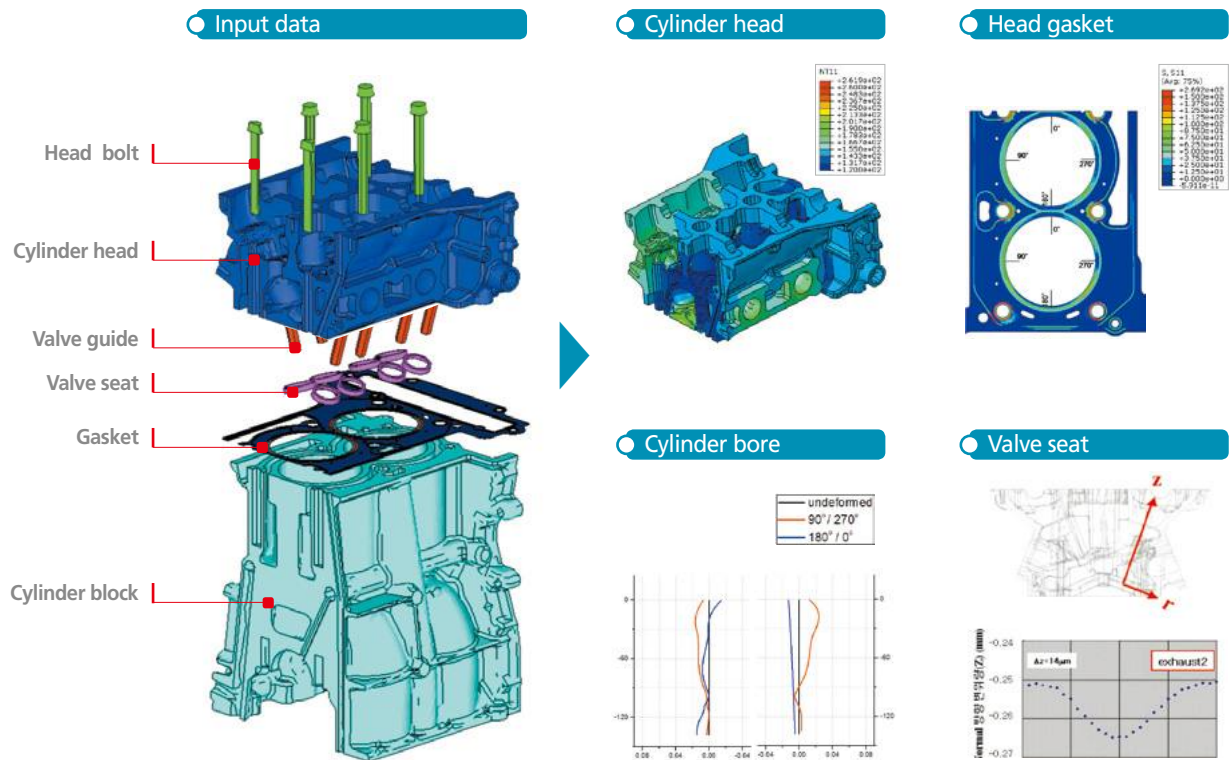
FEA NVH & modal analysis

FEA intake manifold(plastic)

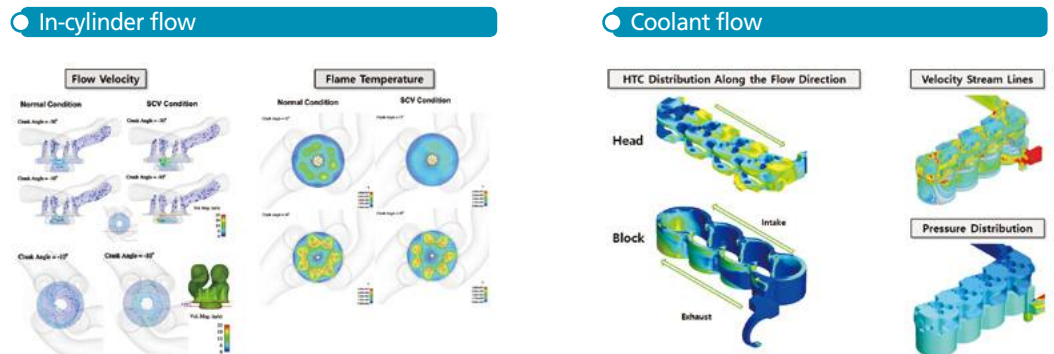
FEA cylinder head cover(plastic)

---

## FE analysis of cylinder block & head compound



## CFD analysis



# CAE Specialty Co. - TenergySoft

The company TenergySoft is a family of TENERGY providing comprehensive CAE consulting services to a variety of customers all over the world.

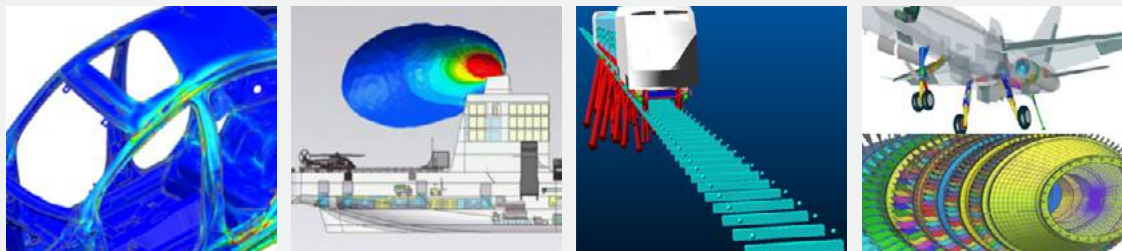
## Business areas



CAE analysis of powertrain	CAE analysis of vehicle	CAE analysis of shipbuilding	CAE analysis of others
Intake & exhaust flow Structural & thermal Noise & vibration - Normal mode & FRF of PT - Whine & rattle noise of TM	Suspension K&C Full vehicle R&H Autonomous driving validation Virtual test validation Crash of bumper & hood	Structural & strength Durability of ship Performance estimation Energy saving device Propeller design	Landing gear drop Composite material Railway derailment Fluid-Structure Interaction(FSI) Heavy equipment

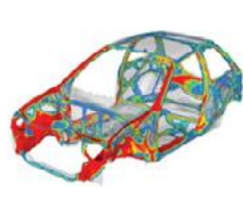
## Application fields

- Structure / Fatigue / Nonlinear
- Multi body dynamics
- NVH / Composite / Optimization
- Fluid dynamics / 1D simulation
- Vehicle driving simulator
- Analysis & test process consulting

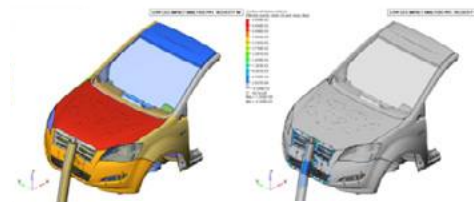




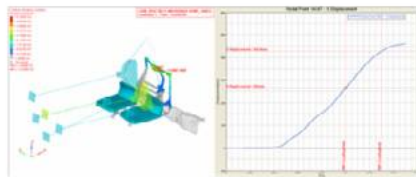
## CAE analysis of chassis & vehicle



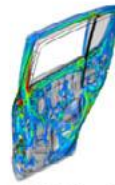
Car body NVH analysis



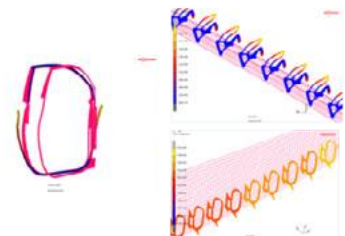
Crash analysis of bumper & hood



Seat belt anchorage analysis

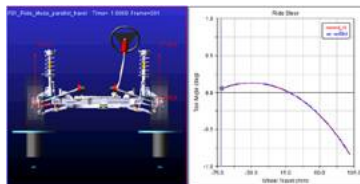


Door NVH analysis

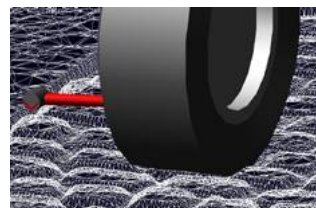
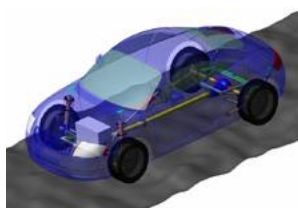
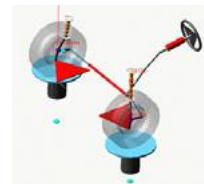
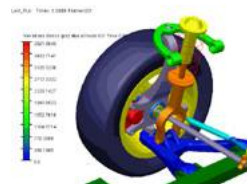


Weather strip analysis

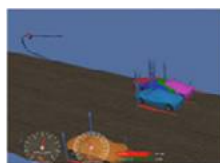
## CAE analysis of chassis & vehicle



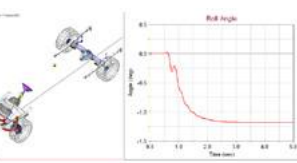
Suspension kinematic analysis



Ride analysis



Max performance

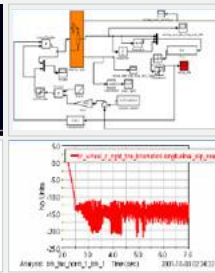
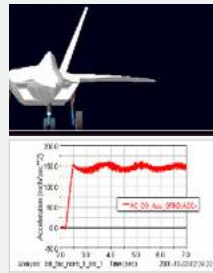
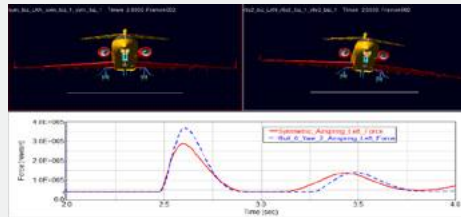


Handling analysis

# CAE Specialty Co. - TenergySoft

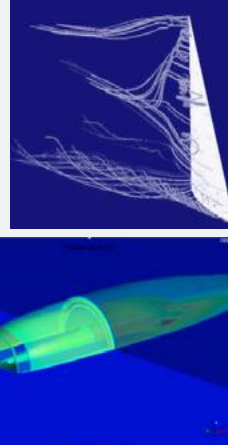
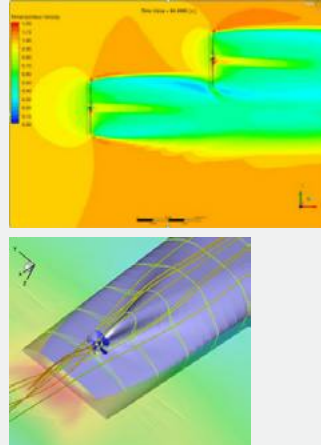
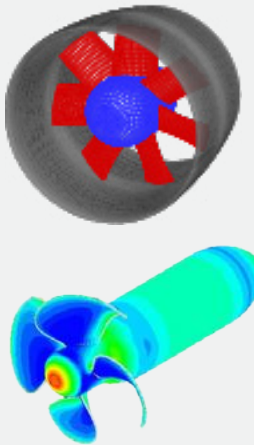
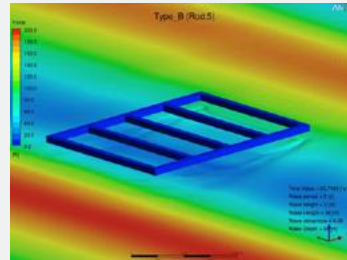
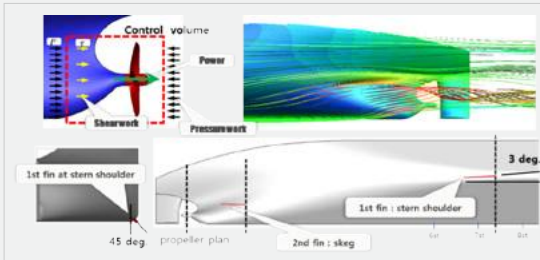
## CAE Analysis of machinery

### Aerospace analysis

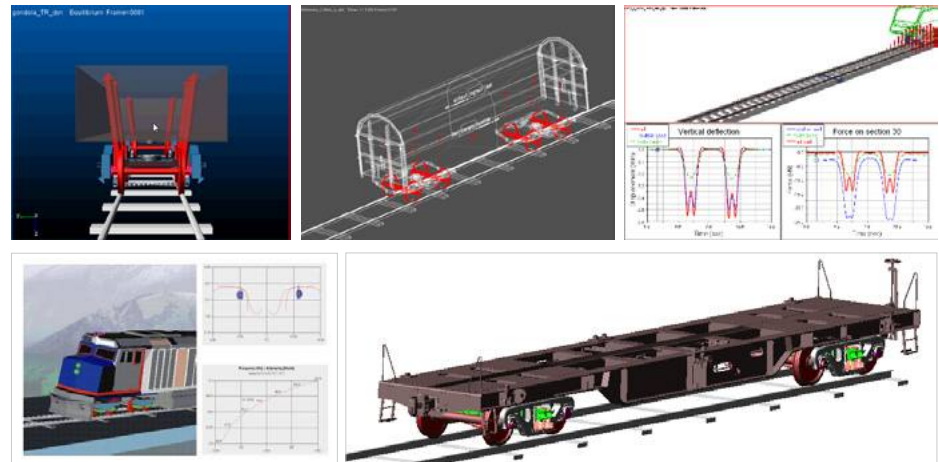


### Shipbuilding analysis

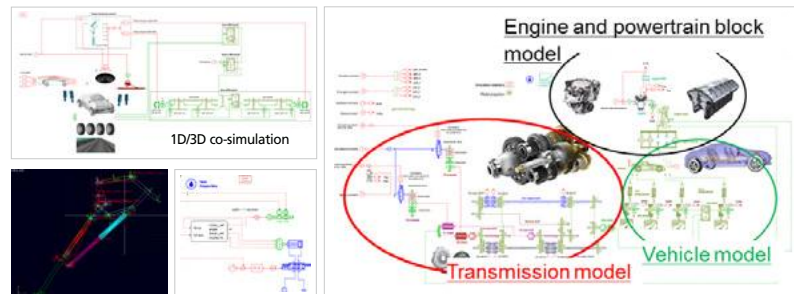
Development of energy saving device / Analysis for performance estimation



## Railway analysis



## System(1D) simulation



## Driving simulator





# Engine Test



**Performance development**

- Combustion system development
- Turbocharger matching
- Port flow development

**Mechanical & functional development**

- Ventilation test
- Heat balance test
- Piston marking test

**Durability test**

- Full load & full speed test
- Thermal shock test

**Benchmarking test**

- Breathing system development
- EGR, particulate filter, LNT, SCR application for emission
- Engine calibration (torque/air model, base maps)

- Oil consumption & blow-by development
- Thermal survey test
- Fatigue test

- Mixed cycle test
- Special purpose test

**Mechanical & functional test**

Telemetry system



Tilting bench



Visualization test



Friction test



Thermal survey test



Cooling system bench



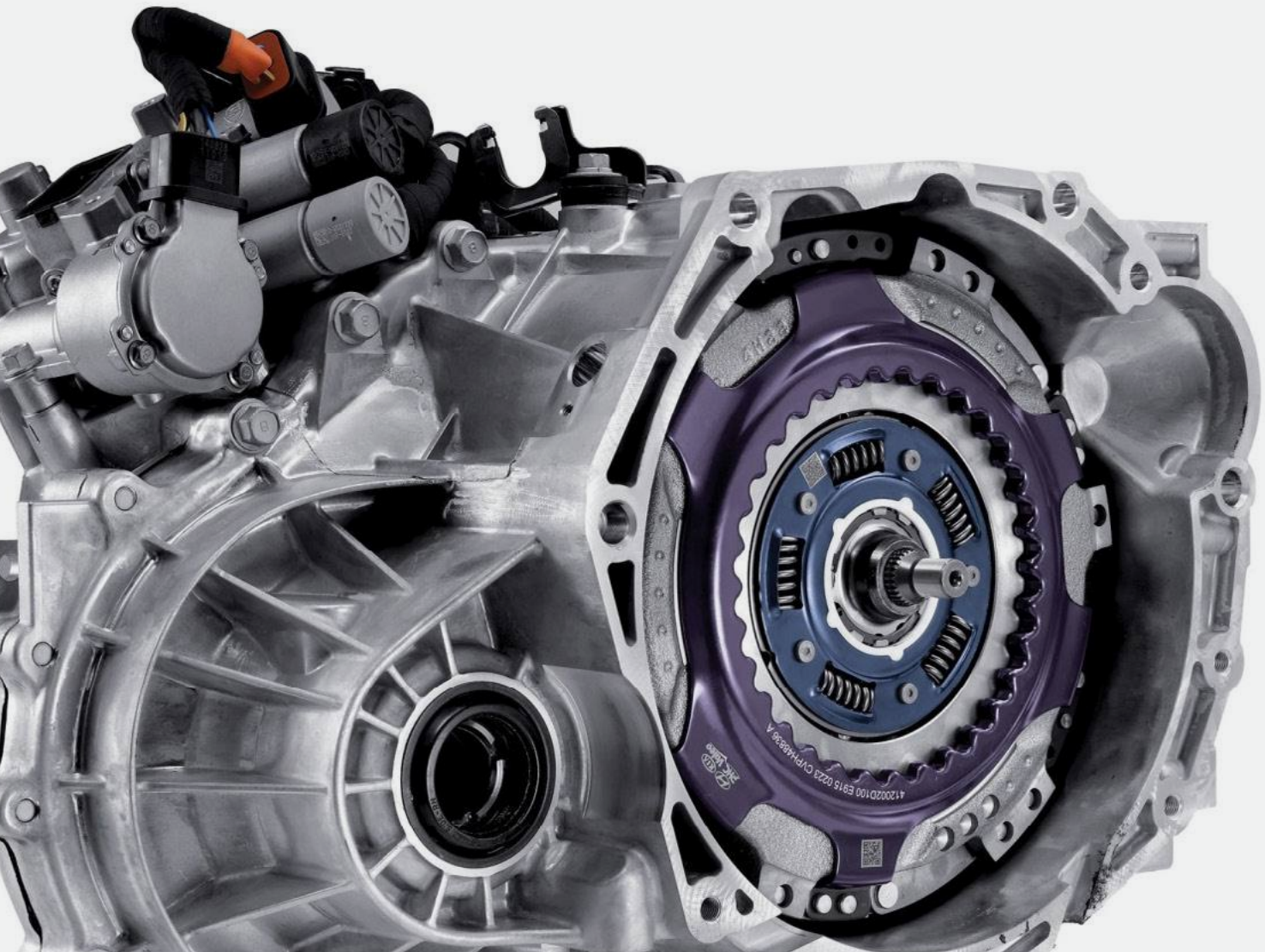
Valve train dynamics



Piston profile measurement



# Transmission Design & Development



## Transmission development

- Compact layout design of manual transmission and DCT
- Multi-speed gearbox for electric vehicles
- Cost-effective design of transfer case for 4WD
- Development of compact AMT which has no torque interruption

## Transmission calibration

Optimal results for dynamics, performance and fuel consumption

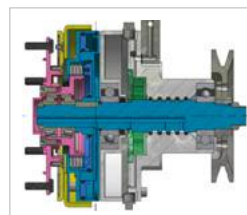
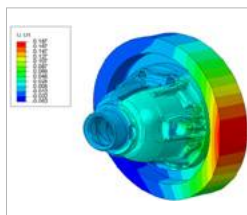
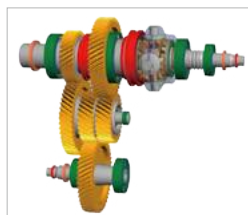
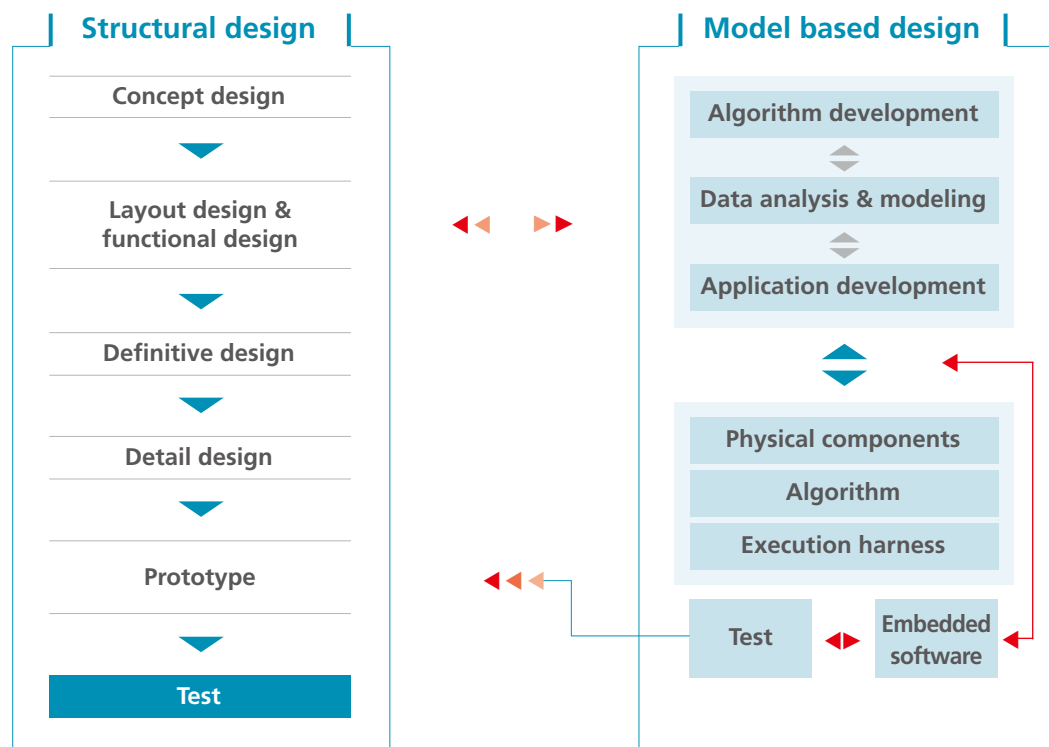
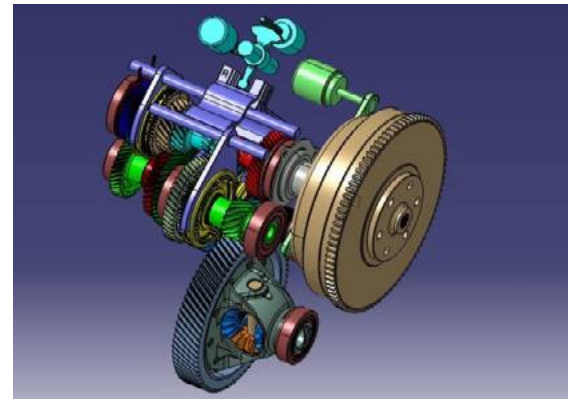
## Prototype development, testing and validation

- Rapid prototyping by 3D printing
- Mechanical and functional rig tests
- Transmission dynamometer for transaxle tests with engine

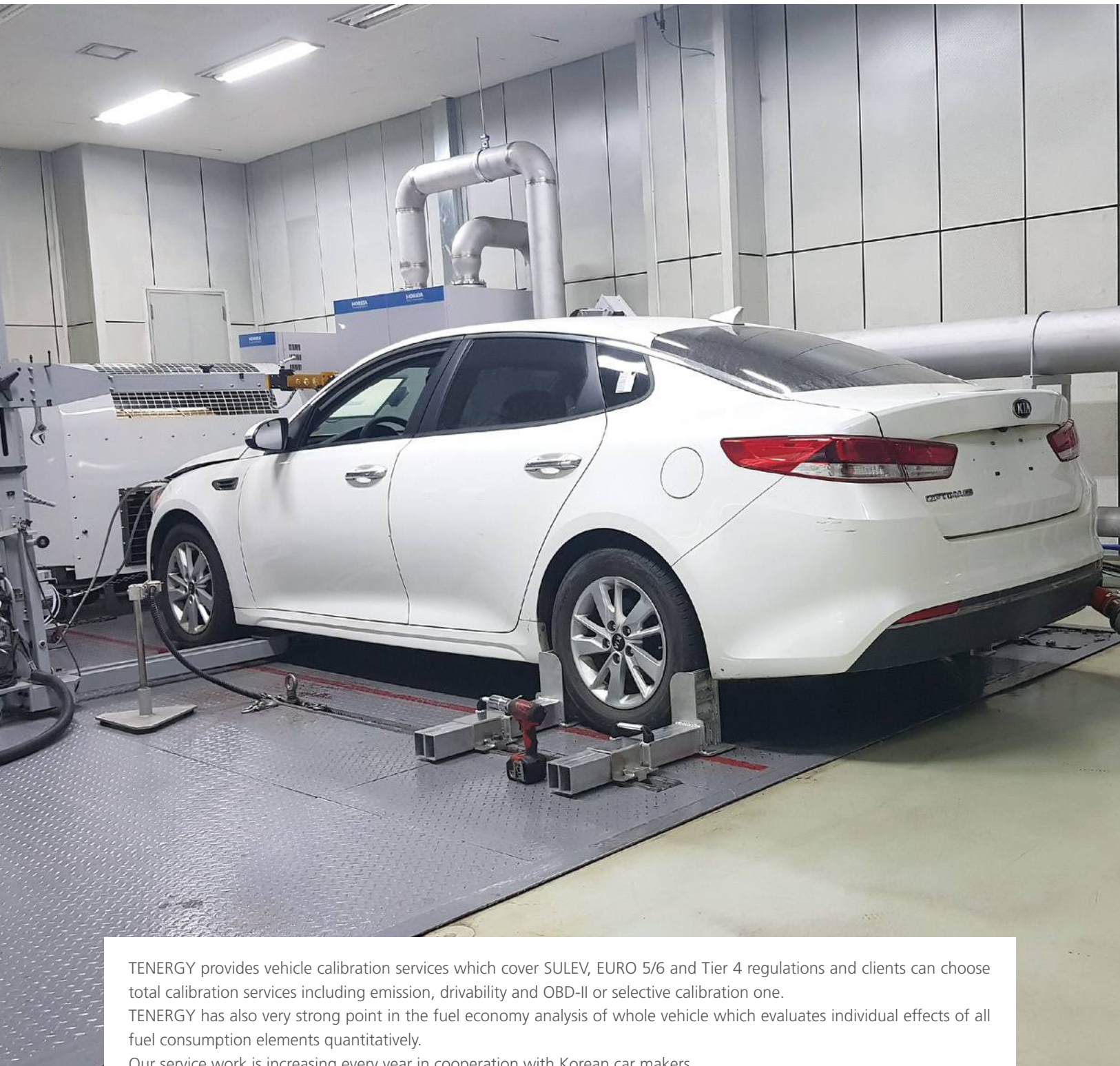


## Transmission development process

We meet the requirements on the functionality and efficiency using an effective and start-to-finish process.



# Vehicle Calibration



TENERGY provides vehicle calibration services which cover SULEV, EURO 5/6 and Tier 4 regulations and clients can choose total calibration services including emission, drivability and OBD-II or selective calibration one. TENERGY has also very strong point in the fuel economy analysis of whole vehicle which evaluates individual effects of all fuel consumption elements quantitatively. Our service work is increasing every year in cooperation with Korean car makers.



### Target vehicle

- Gasoline
- Diesel
- Hybrid
- EV

### Calibration

- Emission
- OBD-II
- Drivability
- After treatment system



### Emission calibration

- SULEV, EURO 6d, China 6b and Tier 4 (Industrial)
- Emission related hardware and component selection
- Optimization of logic and calibration for leaner cold fueling
- UREA-SCR application
- DPF calibration

### OBD-II calibration

- OBD-II, EOBD and KOBD regulation

### Drivability calibration

- Optimum calibration for high drivability index fuel
- Logic development for high drivability index fuel
- Drivability calibration over -30-50° ... ambient temperature

### Fuel economy analysis

- Energy Flow-Down Method

### Vehicle benchmarking

- Emission related hardware, logic and calibration
- Fuel economy related hardware, logic and calibration
- Drivability related logic and calibration

### Development of advanced fuel economy system and logic

### Catalyst bench aging and vehicle durability cycle development correlated with in-use DF



# Vehicle Calibration

## Gasoline SULEV application

### Fast light-off control

- H/W side
- Place the catalyst as close as possible to exhaust manifold
- Increase catalyst cell density
- Calibration side to increase heat flux
- Increase Idle engine speed
- Spark timing calibration
- Waste-gate position open control

### Reduce engine-out raw emissions

#### : optimum catalyst heating point and cold start

- Intake/exhaust VVT control
- Injection strategy calibration
- : SOI, EOI, fuel pressure, split injection calibration

### NOx conversion efficiency increase

- Fuel cut off condition calibration
- Catalyst purge calibration to increase NOx conversion efficiency
- Lambda control calibration with downstream O2 sensor feedback

## Gasoline particulate filter control

### GPF model calibration

- DP soot mass with clean filter model
- Engine out soot model
- Soot burning rate model
- GPF temperature model

### GPF control

- Passive / active regeneration control  
(Lambda, temperature control)
- Fuel cut off condition calibration during regeneration
- Soot mass validation (model vs actual mass)
- Soot burning efficiency test
- Service regeneration strategy
- GPF regeneration strategy (duration, coordinator)
- GPF OBD (efficiency) strategy

### GPF validation test

- GPF failure check through uncontrolled  
burning test (DTI, DTO)
- : CT scanning confirmed
- Environment test (cold, hot, altitude)
- Ash calibration with fleet test

## Diesel SCR control

### SCR model calibration

- Raw NOx, NO/NO2 ratio modeling
- NOx conversion efficiency modeling
- NH3 loading/slip modeling
- SCR temperature model
- SCR efficiency model

### SCR Control

- Heat-up
- NH3 loading target
- Urea dosing schedule
- SCR defrost calibration in cold condition
- Strategy for improvement of emission(RDE, WLTC, NEDC, etc)
- SCR OBD strategy(efficiency, incorrect urea, consumption, etc)

### SCR validation test

- Environment test(cold, hot, altitude)
- Validation of model accuracy
- Robustness of NOx conversion efficiency in real driving

## Diesel particulate filter control

### DPF model calibration

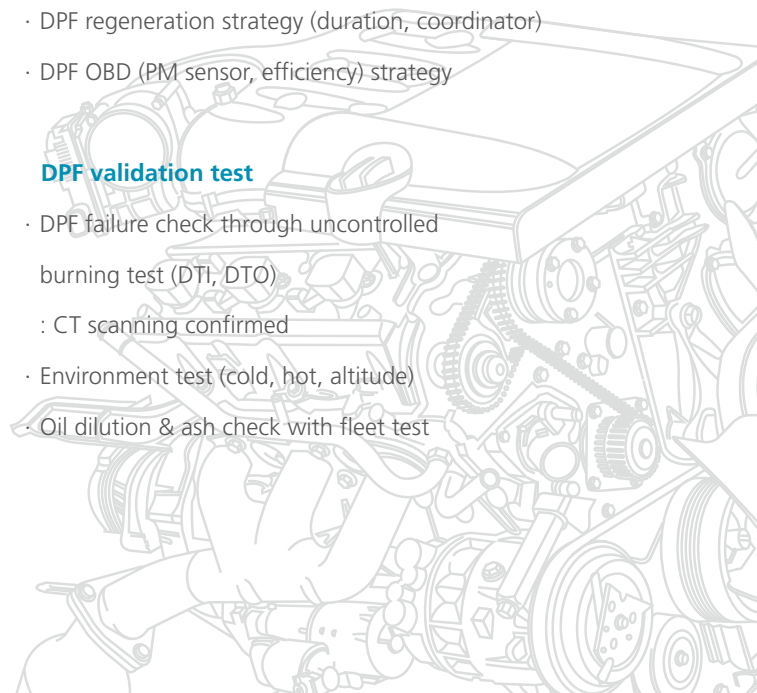
- DP soot mass with clean filter model
- Engine out soot model
- Soot burning rate model
- DPF temperature model

### DPF control

- Heat-up / active regeneration control  
(air control, post injection control)
- Open & closed loop temperature control
- Transient condition check and calibration
- Soot mass validation (model vs actual mass)
- Soot burning efficiency test
- Service regeneration strategy
- DPF regeneration strategy (duration, coordinator)
- DPF OBD (PM sensor, efficiency) strategy

### DPF validation test

- DPF failure check through uncontrolled burning test (DTI, DTO)  
: CT scanning confirmed
- Environment test (cold, hot, altitude)
- Oil dilution & ash check with fleet test



# Vehicle Calibration

## Diesel EURO 7 / China 6

### Additional challenge for better fuel consumption

- Thermal management
  - Integrated thermal management 3-way valve control(block, radiator, heater)
  - Split cooling circuit
  - Optimized temperature of each part
- Weight reduction
  - Aluminum cylinder block
- Friction reduction
  - Piston & ring design optimization
  - Crankshaft balance weight optimization
  - Variable oil pump integrated with vacuum pump
  - Timing belt instead of chain system
  - Camcarrier-camshaft module
  - Crank offset
  - Roller rocker arm
  - Switchable water pump or electrically controlled thermostat

### After treatment system

- SCR system will be in multiple locations and the total size will be larger
- Urea injection will be multi-point injection.
- DPF would not need active regeneration any more, only passive type would be enough.
- Electrically heated catalyst could be used for cold start emission.

### Combustion system

- With enhanced SCR system, engine development could be focused only on better thermal efficiency and on reducing PM, no longer on reducing NOx emission as before.
- Compression ratio would be raised to around 18 from current 15~16.
- EGR would be used limitedly or the system even may be deleted.
- High swirl would be required less than before, therefore port could be optimized for more flow.

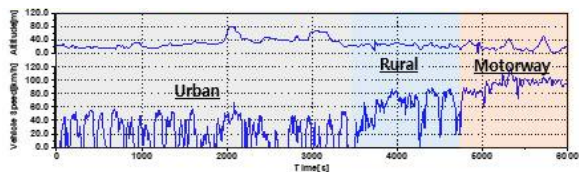
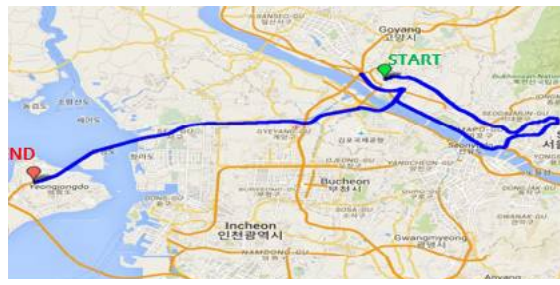
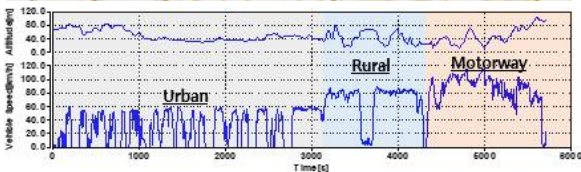
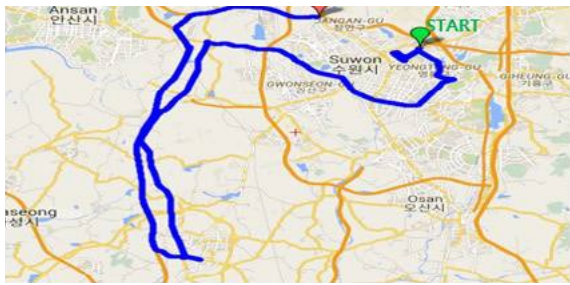
### Electrification

- 48V mild hybrid system will used.(P0~P2)
- EHC could be effective by 48V system



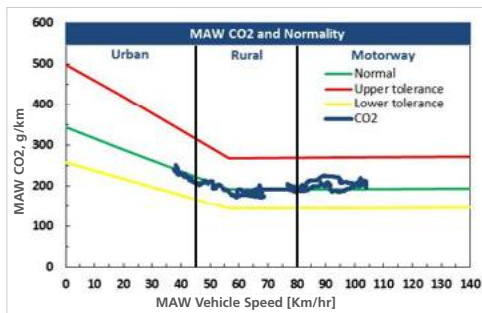
## RDE test route

Route	Trip duration [min]	Average vehicle speed[km/h]			Distance[km]		
		Urban	Rural	Motorway	Urban	Rural	Motorway
RDE criteria	90~120	-	-	-	>16	>16	>16
TENERGY	94.6	28.6	79.3	100.7	27.42	32.19	22.23
NIER #2	100.3	23.9	77	99.7	26.88	24.25	25.03



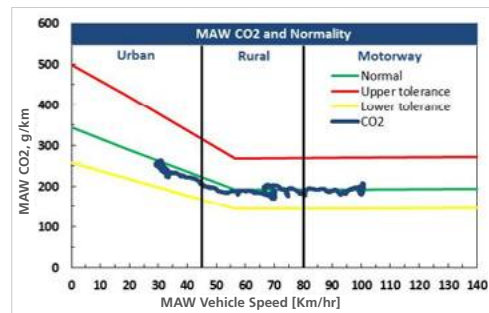
## RDE test evaluation

Dynamic condition @ MAW: meet the RDE criteria



TENERGY route

Window No.			
TENERGY route	Urban	1332	24.59%
	Rural	1541	49.27%
	Motorway	1050	26.14%



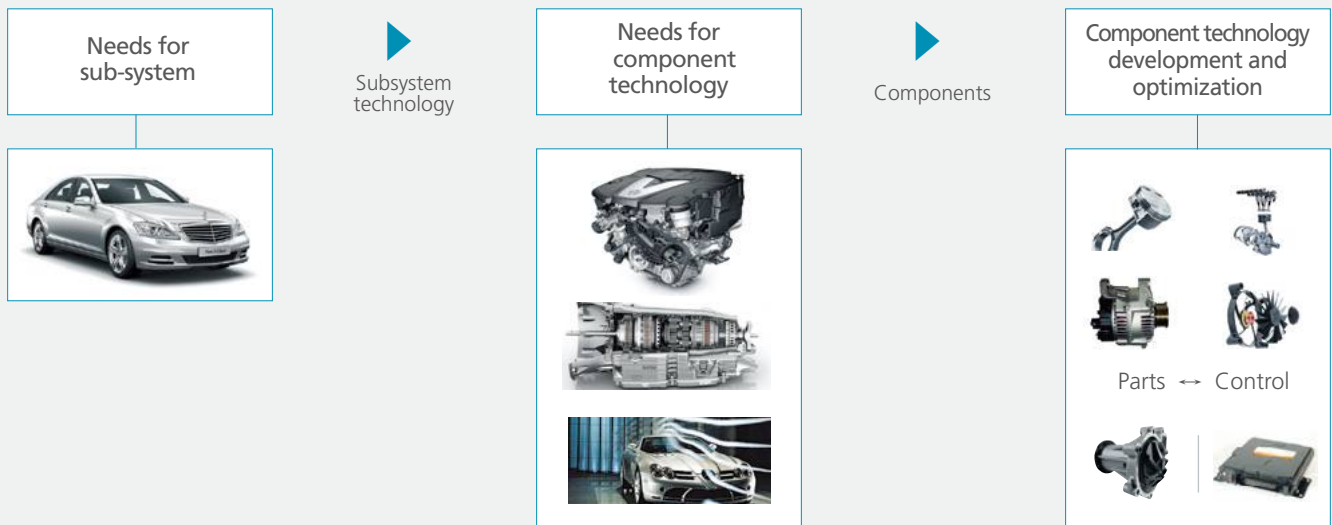
NIER#2 route

Window No.			
NIER#2 RDE	Urban	1911	26.99%
	Rural	1153	29.69%
	Motorway	793	20.32%

# Fuel Economy Analysis

## Principle of Energy Flow-Down Method

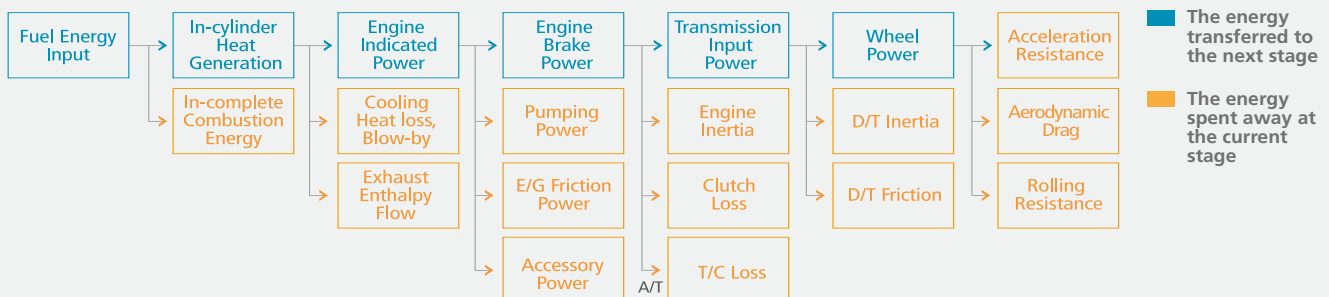
To improve fuel economy of your car, understanding of engine + T/M + vehicle interaction and control strategy (ECU, TCU) are very Important



## Benefits of Energy Flow-Down Method

- Energy Flow-Down Method can analyze the fuel consumption and contribution of each component and ECU/TCU control data through systematic approach.
- Client can have the whole view for the quantitative fuel consumption and contribution of each component.
- Client can recognize the weak and strong points against target vehicle.
- Client can understand how top maker optimizes every component and control data to improve fuel economy.
- Client can make catch-up plan of short, mid, long term in the most efficient cost.

$$\dot{m}_f Q_{LHV,f} = \dot{Q}_{in-comb} + \dot{Q}_{cool} + \dot{Q}_{exh} + P_{pumping} + P_{ef} + P_{accessory} + P_{ei} + P_{tcl(A/T)} + P_{dcl(A/T)} + P_{dtf} + P_{dti} + P_R + P_A + P_{vi} + \dot{Q}_{etc}$$



## How we do, What you can get!

Measurement items	Results	Recommendation
<ul style="list-style-type: none"> <li>· Combustion pressure</li> <li>· Ignition signal</li> <li>· Engine speed</li> <li>· Vehicle speed</li> <li>· Manifold absolute pressure</li> <li>· Air /Fuel ratio</li> <li>· Battery voltage &amp; current</li> <li>· Alternator current</li> <li>· Cooling fan current</li> <li>· Brake pedal signal</li> <li>· Accelerator pedal signal</li> <li>· Throttle angle signal</li> <li>· Coolant temperature</li> <li>· Engine oil temperature</li> <li>· Injection pulse</li> <li>· Fuel rail pressure</li> <li>· Fuel temperature</li> <li>· Exhaust gas temperature</li> <li>· Turbine rpm</li> <li>· Output shaft rpm</li> <li>· Engine inertia @ lift</li> <li>· Drivetrain friction @ lift</li> <li>· Drivetrain inertia @ lift</li> <li>· Engine friction @ bench</li> <li>· Torque converter characteristics @ MAD</li> <li>· Injector characteristics @ rig</li> <li>· Power steering friction @ rig</li> <li>· Each gear driving resistance @ test load (if necessary)</li> <li>· Shift pattern &amp; lockup area @ MAD</li> </ul>	<ul style="list-style-type: none"> <li>· Indicated thermal efficiency</li> <li>· Incomplete combustion loss</li> <li>· Pumping loss</li> <li>· Engine friction loss</li> <li>· Alternator loss</li> <li>· Power steering loss</li> <li>· Engine inertia loss</li> <li>· Torque converter base loss</li> <li>· Torque converter slip loss</li> <li>· Braking loss</li> <li>· Drive train friction loss</li> <li>· Drive train inertia loss</li> <li>· Clutch loss</li> <li>· Vehicle inertia loss</li> <li>· Rolling resistance loss (f0)</li> <li>· Aerodynamic resistance loss (f2)</li> <li>· Pilot/Main injection timing (diesel)</li> <li>· Spark timing (gasoline)</li> <li>· Idle RPM</li> <li>· Total fuel cut time</li> <li>· Total cycle number</li> <li>· Cooling fan loss</li> <li>· Total part load full lockup time</li> <li>· Part load speed ratio distribution</li> <li>· Total driving time at each gear</li> <li>· Shift pattern</li> <li>· Energy management system logic</li> <li>· Neutral control logic</li> <li>· Deceleration lockup logic</li> <li>· Ne elevation logic</li> </ul>	<ul style="list-style-type: none"> <li>· Logic &amp; calibration strategy</li> <li>· Engine hardware strategy               <ul style="list-style-type: none"> <li>- Friction improvement</li> <li>- System application strategy (Intake CVVT, Dual CVVT, Turbo, GDI, etc.)</li> </ul> </li> <li>· Characteristic of engine (BSFC, mechanical friction, pumping friction, engine inertia)</li> <li>· Transmission hardware strategy</li> <li>· Shift pattern &amp; lockup zone strategy</li> <li>· Torque converter selection strategy</li> <li>· Gear ratio selection strategy</li> <li>· Transmission related loss (Drivetrain friction loss, slip loss, fuel consumption at each gear)</li> <li>· Vehicle thermal management strategy</li> <li>· Vehicel electrical load strategy</li> <li>· Vehicle energy save strategy</li> <li>· Rolling resistance reduction strategy</li> <li>· Aerodynamic resistance reduction strategy</li> </ul>



# xEV Benchmarking and System Development



## xEV benchmarking

- Key data measurement via CAN analysis through CAN network reverse engineering
- Analysis of system control strategy and thermal management system for improvement
- Data for fuel efficiency, battery SOC, cell temperature, available power, voltage, current, cooling & heating...etc.

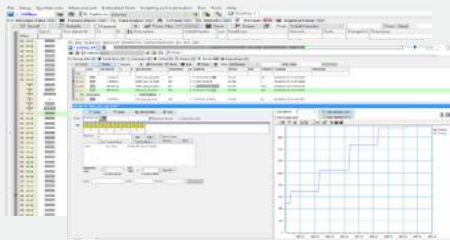
Sensor installation



Logging devices connection



Sensors & vehicle data logging

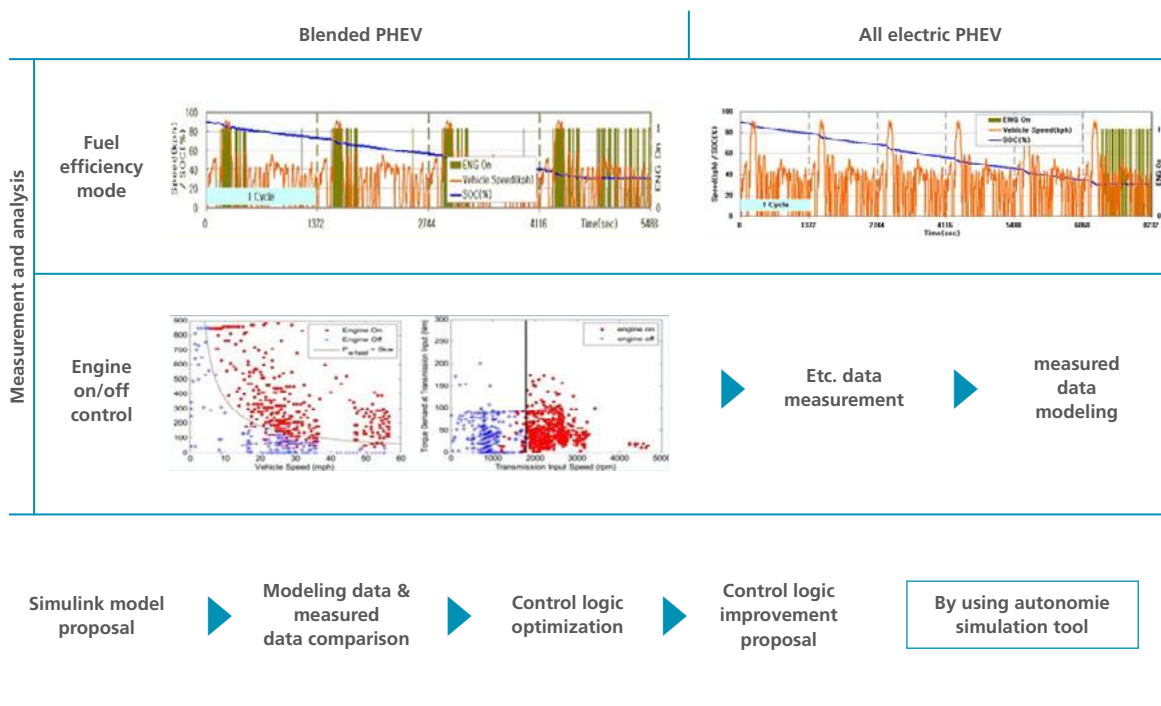


Test result & analysis



## System planning for system configuration and specification

- System concept design through simulation and analysis about fuel efficient, SOC, cell temperature, voltage, current, engine torque, engine on/off pattern, cooling & heating, etc.
- Proposal for system improvement



## System test and validation

- System bench test to validate system performance and control strategy
- System/Component performance
  - Fuel efficiency
  - Performance
- Controller reliability
  - Design verification
  - Fail safe evaluation

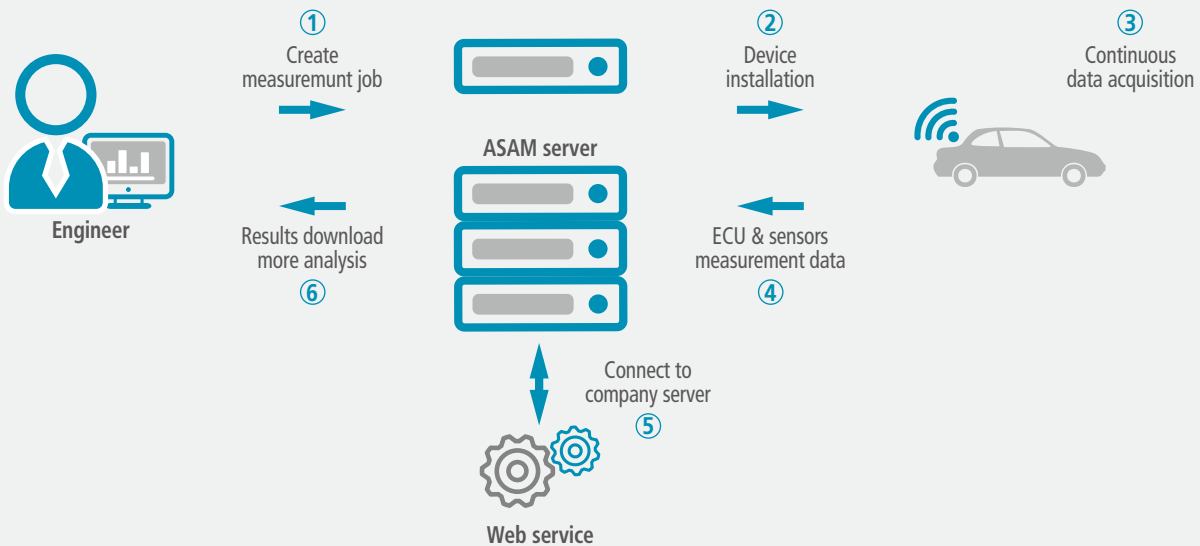
# Electric & Electronics Solution

## Analysis system for mobile data loggers with web interface

For testing and optimizing their utility vehicles, most OEM operate a fleet of vehicles equipped with measurement systems.

Several hundred signals related to the vehicle's operation are recorded over an entire shift: temperatures, pressures, rotation speeds, brake pedal operations, accelerations and shifting operations as well as a large number of controller parameters.

Several gigabyte of raw data is collected per vehicle and shift and automatically transmitted to a central server.



### Pre-configuration for measurement

The main software configures vehicle state variables from control units and measurement devices to vehicle data logger. The results can be stored in itself or sent to web server.

### Individual analysis for measurement data

For the analysis of measurement data, we can offer configurable analysis tool which can be easily adapted to the specific requirements without any programming work.

### Overview in the web portal

All information and data for the test drives can be found in the company intranet via a clearly arranged web dashboard independent of time, location, and platform and can be used for analyses.



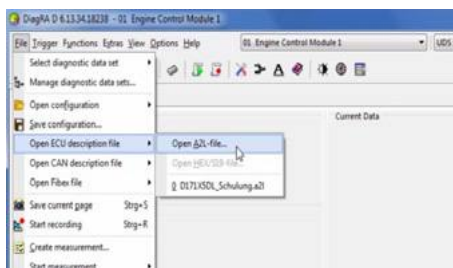
## Hardware key features

- LCD screen
- 6 High speed CAN/CAN FD channels
- 1 single wire CAN channel
- 1 fault tolerant CAN channel
- 2 local interconnect network (LIN) channel
- 100 Mbps Ethernet connectivity
- Wi-Fi enabled
- USB connectivity
- On-board media storage
- Can be powered by USB, the vehicle, or 12V power adapter (included)



## Application software

### T- FDMS (Fleet Data Management)



- Supports CCP as well as XCP on CAN as well as UDP and data acquisition on raw CAN. CAN DBC and A2L files provide the parameter data descriptions.
- Parameterization of measurement sequences in batch mode (measurement channels, trigger conditions). Program closes after a specified number of recordings initiated by trigger.

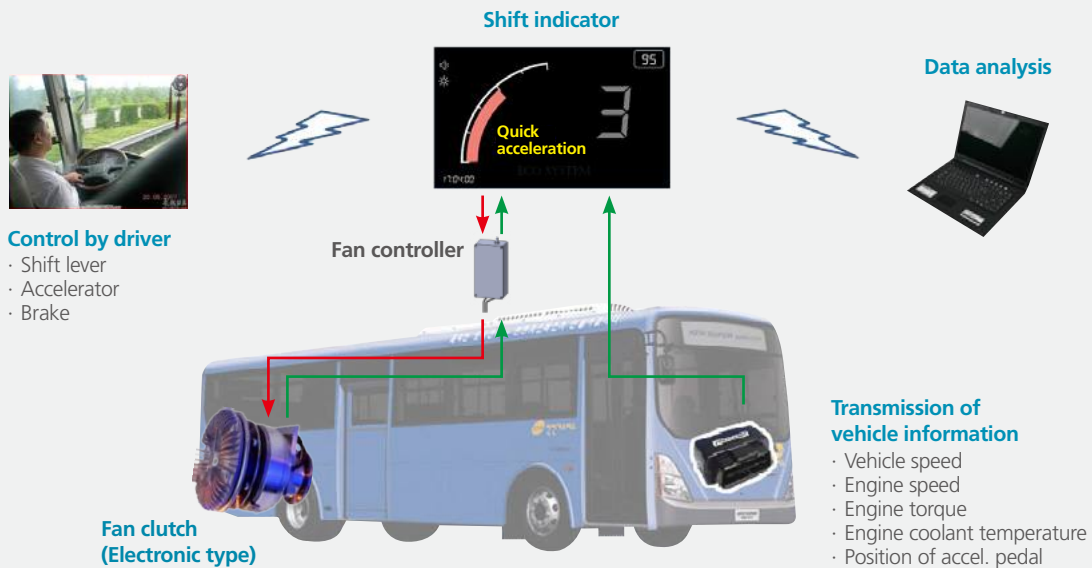
### T- APIS (Assembled Parts Inspection)



- Abnormality check for the main sensors of ECU.
- Inspection for the parts & assemblies from ECU CAN data analysis in the end of lines. (ex. boost pump, EGR valve...etc.)
- Improving the quality of mass-produced vehicles.

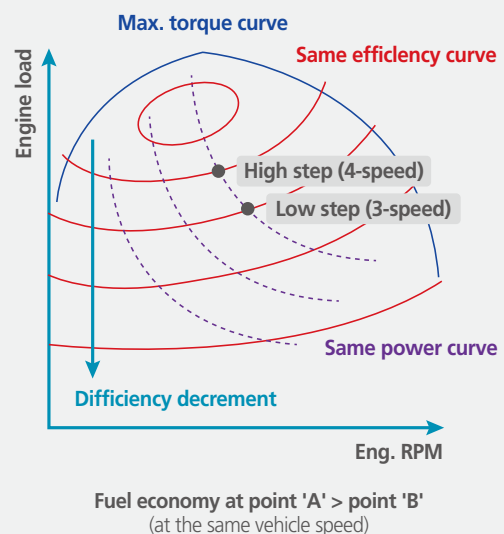
# Bus Fuel Saving System

## How to improve FE (Fuel Economy)



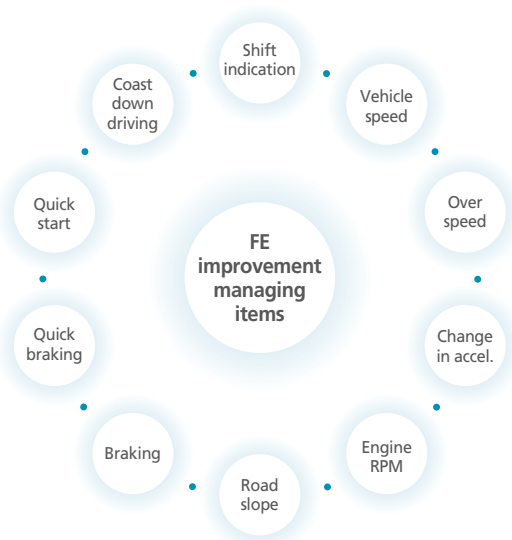
## Shift indicator principle

- Fuel economy can be maximized in case that vehicle is driven in the area of engine highest efficiency.
- Shifting point, optimized in terms of fuel economy is indicated to the driver.
- Quick acceleration and deceleration are especially managed in consideration of passenger's safety.
- Driving pattern can be managed by scoring system



## Scoring system

### Main items of driving score management



### Consideration in driving score calculation

- FE improvement driving indication by operation at optimized (in terms of FE improvement) point depending on route and road condition (road slope, number of passenger)
- Optimization for driving pattern by distance between bus stops
- Accomplishment of FE target higher than the fixed level and the proposal of FE improvement direction by use of the scoring system of FE driving level
- Regulation to be reinforced in order to prohibit bus driver from quick start and braking in consideration of passenger's safety

### Seoul city bus program

about 15%

No. of bus joined in the program	7,500 units
Business type	ESCO (Energy Service Company) investment business TENERGY, as an ESCO, defrayed the program investment cost No burden of investment cost to other parties
Program start	2014. 08 ~
Fuel ratio improvement	about 15%

### Daegu city bus program

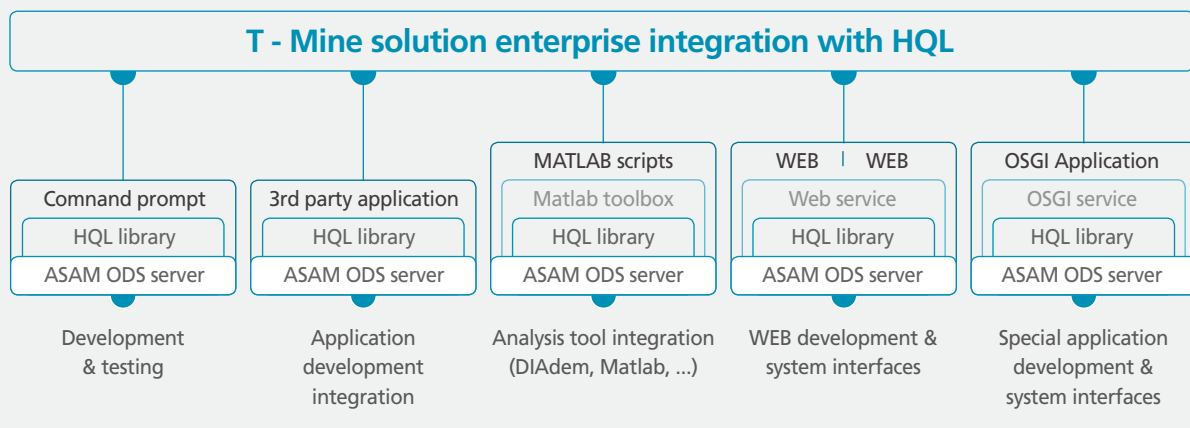
about 12%

No. of bus joined in the program	1,600 units
Business type	ESCO (Energy Service Company)
Program start	2018. 08 ~
Fuel ratio improvement	about 12%

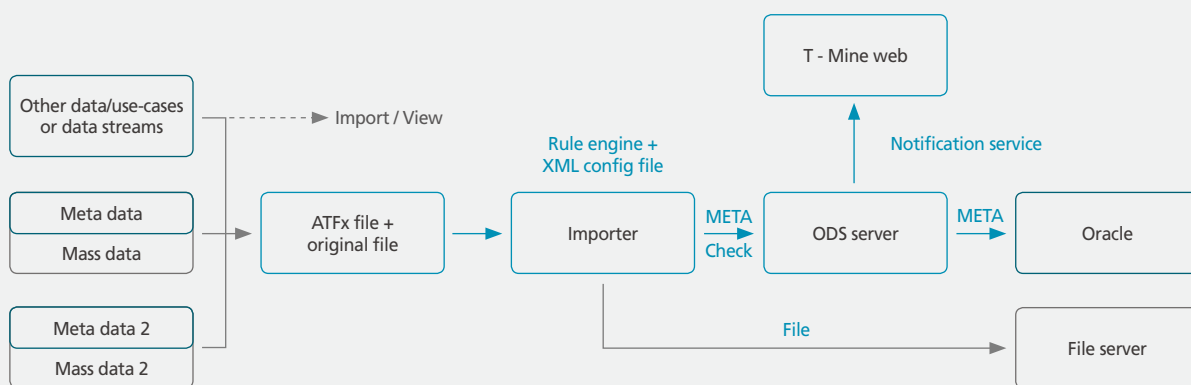


# Big Data Management System

## Big data analysis & management for increasing test data



The efficient performance of tests becomes increasingly important in vehicle development. Especially in global acting enterprises a powerful management system is required that overcomes rigid departmental boundaries and gets the complexity of the test processes under control. The major strength of ASAM ODS, compared to non-standardized data storage solutions, is that data access is independent of the IT architecture. Besides, the data model of the database is highly adaptable and well-defined for different application scenarios.

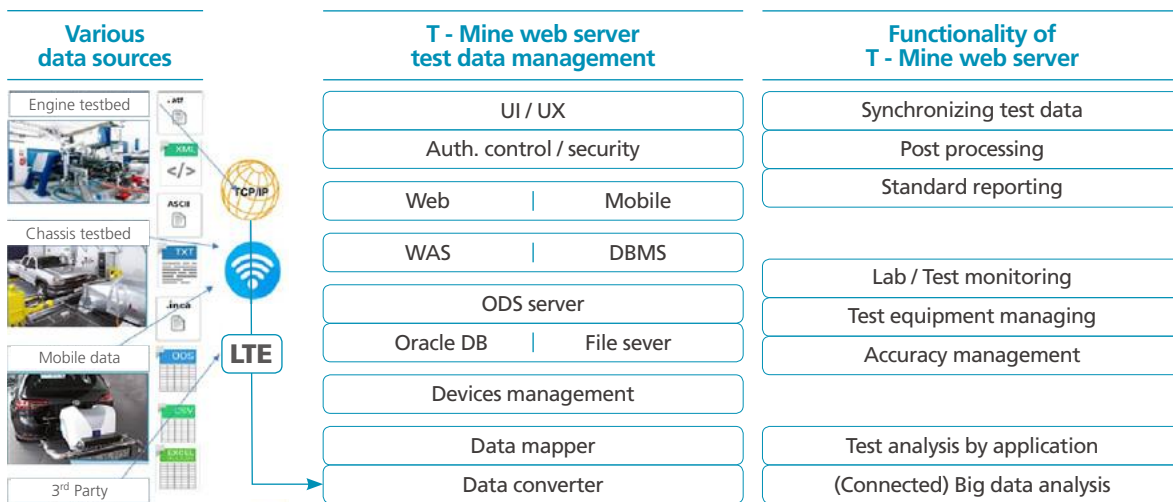


## Overview in the web portal

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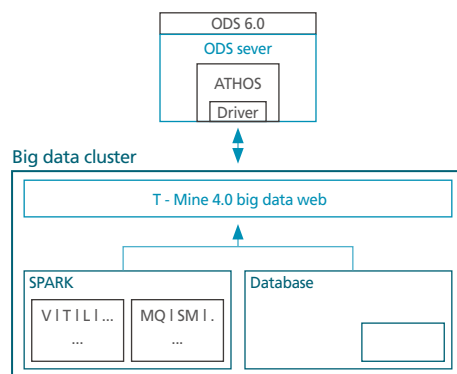
## T – Mine Web Server

for ASAM ODS data management



## T – Mine 4.0 Big data Web server

for Big data analysis from measurement data



- Provides an extension for T - Mine ODS server, which is suited for accessing and processing measurement data stored in Parquet files. In its latest technology proposal for big data, ASAM has recommended this format as appropriate for storing mass data.

- The flexibility of the solution from customer's requirements for processing and analyzing large amounts of measurement data.



Analysis and result file generation / export on 200 measurements or 212.000.000 samples

# Gas Engine Development (LPI, CNG, Biogas)

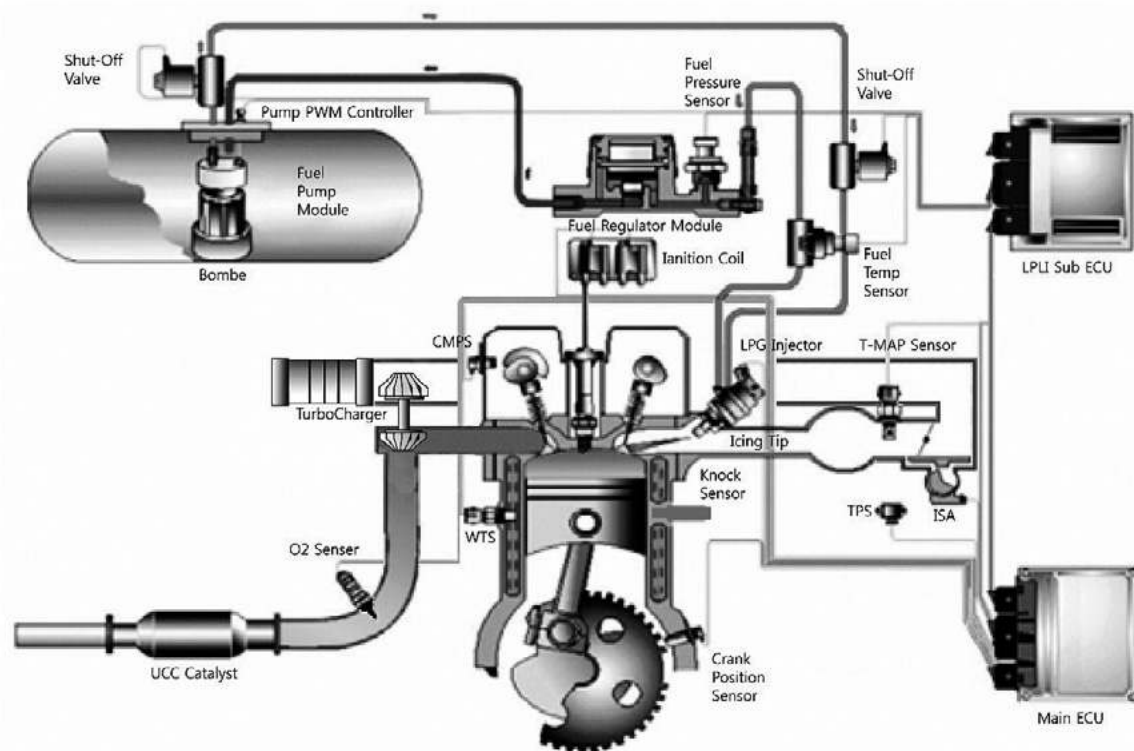
As the importance of the environment grows Korean government started to support diesel engine retrofit to LPI or CNG one with a subsidy from the middle of 2000s.

TENERGY has a outstanding technology in LPI, CNG and Biogas engine applications on the basis of plentiful expertise of mass production engine development and vehicle application. TENERGY offers the best engine performance and fuel economy through knock sensor application and minimizes field claim through systematic vehicle calibration of emission and drivability.

## TENERGY reference of LPI engine

- Improvement of engine power by 10~20%
- Reduction of exhaust emission by more than 50% to meet EURO 6 / ULEV standards

### TENERGY LPI engine system





# Powertrain Benchmarking

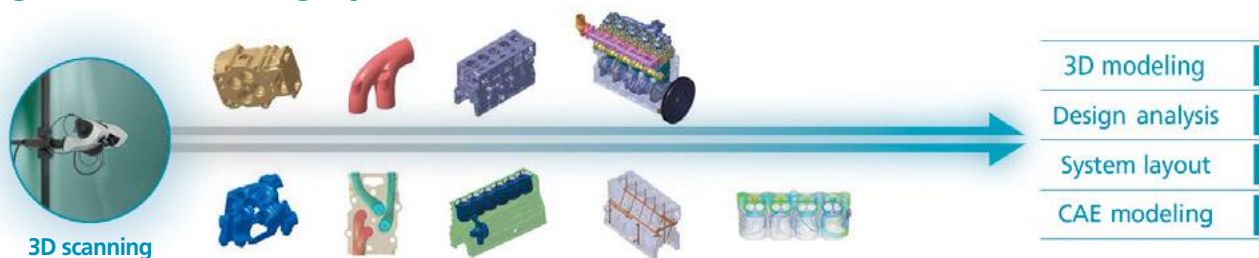
## Gasoline engine test

Items	Details
Full load performance	1000-6500 rpm (250 step)
Part load performance	BSFC, BSHC, BSCO, BSNOx at 23 specified points
Whole range data logging	BSFC, BSHC, BSCO, BSNOx, A/F, spark timing, exhaust temperatures, valve overlap, waste gate control, exhaust pressures, intake pressures at 1000-6500 rpm (500 rpm & 1bar step)
Motoring friction	1000-6000 rpm (500 rpm step)
Smoke (for GDI)	WOT (1000-6000 rpm) at 30°C/50°C/90°C coolant temperatures
Performance with variable hardware states	Full load and part load performance with intake OCV removal, exhaust OCV removal and VVL low
Combustion pressure	Full load, 23 specified part load points and idle
Oil dilution (for GDI engine)	1. WOT at 2000 rpm (coolant 50°C, 1hr) 2. 10bar at 2500 rpm (coolant 50°C, 1hr) 3. 5bar at 2500 rpm (coolant 50°C, 1hr) 4. WOT at 1000 rpm (coolant 50°C, 1hr)

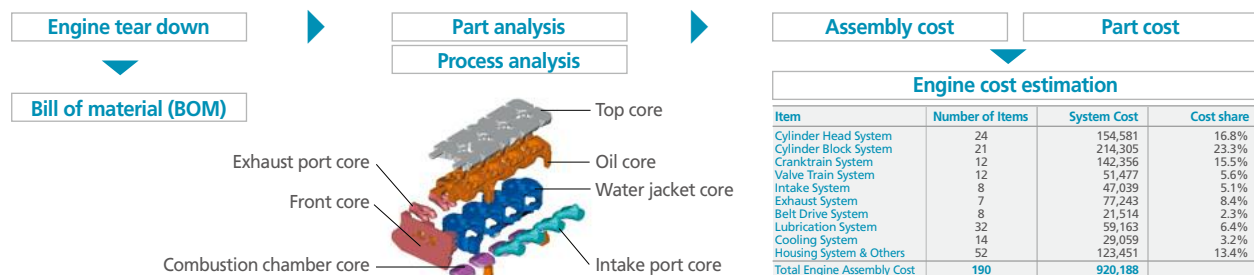
## Diesel engine test

Items	Details
Full load performance	Power, torque, smoke(FSN), noise, BSFC, BSHC, BSCO, BSNOx, EGR rate, boost pressure, main injection timing, pilot injection timing, rail pressure, intake temperatures, intake pressures, exhaust temperatures, exhaust pressures (including before DOC and after DPF) at 1000-4500 (250 step)
Whole range data logging	The same items as above at 1000-4500 rpm (250 rpm, 1bar steps)
Motoring friction	1000-4500 rpm (500 rpm step)
NVH	Whole range (combustion analyzer)

## Design benchmarking by 3D scan



## Benchmarking by cost analysis



# Vehicle Engineering

The vehicle engineering of TENERGY provides various engineering services for vehicle development from vehicle design to the development of various equipment for vehicle production based on engineering know-how and program management capability. The outstanding vehicle engineering capabilities of TENERGY ensure that customers have a successful vehicle launching.

## Vehicle design & validation

TENERGY covers the whole range of vehicle design and validation including prototype for test & validation.

Through close collaboration with styling, manufacturing engineering and P/T engineering, TENERGY creates competitive vehicle in terms of performance, cost, fuel efficiency, etc.

### Body design

- Body structure & BIW
- Exterior trim
- Door & moving



### Chassis design

- Front & rear suspension
- Brake & steering system
- Heat & fluid

### Vehicle package

- Layout & key dimension
- Ergonomics & legal
- Digital mock-up

### Prototype for T&D

- Proto BIW / Vehicle
- Mule car & cubic Jig
- Off-tool prototype



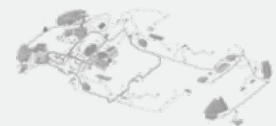
### Interior design

- IP & console
- Interior trim & HVAC
- Seat & restraints



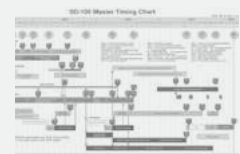
### Electrical design

- Lamp & switch
- Wiring harness
- Electric & electronics



### Eng. Management

- Cost / Weight management
- Issue troubleshooting
- Design qualification



### Test & validation

- Test support
- Validation (Virtual / Real)
- Homologation support



## Simultaneous engineering (SE)

As major virtual validation with CAE, TENERGY provides SE service based on the engineering capability covering the entire area of the vehicle manufacturing. By this SE, TENERGY helps to make optimal vehicle design suitable for vehicle production and proposes the process plan with optimized productivity.

### Press SE

- Panel formability & matching
- Material optimization
- Die operation flow
- Checking fixture



### Body SE

- Weldability & gun access
- MCP / MCS & tolerance
- Line automation & duct location
- Cycle time & process flow



### Paint SE

- Anti-corrosion
- ELPO access & fluid drainage
- Dipping & oven
- Water & dust proof

### General assembly SE

- Assembly tolerance
- Workability & tool access
- Line balance & logistics
- Visibility & handling & error proof



### Injection SE

- Plastic formability
- Raw material & flow
- Hazardous substances
- Part quality & checking fixture



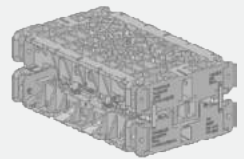
# Vehicle Engineering

## Tool & equipment development

With SE, TENERGY provides the development service of tool & equipment for vehicle production. The engineering capability of TENERGY leads the whole tool & equipment development phase from design to completion of installation and commissioning for the majority of vehicle manufacturing process, and supplies the best quality tool & equipment within the timeframe required by customers.

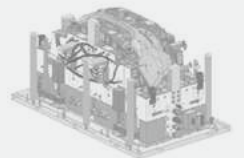
### Press die

- Press die
- HPF (Hot Press Forming) die
- Checking fixture



### Injection mold

- Injection mold
- Checking fixture



### Body assembly

- Welding jig & fixture
- Welding robot system
- Moving system (conveyor, etc.)



### General assembly

- Moving system (conveyor, etc.)
- Automation line
- Pallet & AS/RS





# Major Clients

## Domestic (Korea)

### Automotive OEMs



### Agricultural / Industrial



### Others

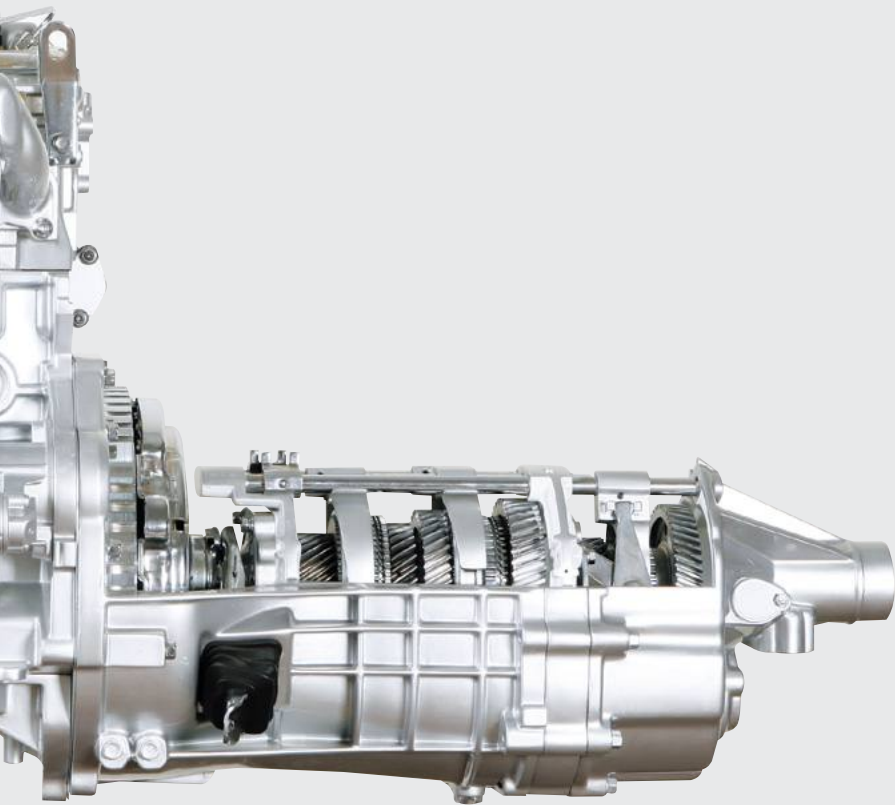


## Overseas

### Automotive OEMs







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