

CRUISE VEHICLE SYSTEM ANALYSIS

AVL Cruise – Vehicle System and Driveline Analysis

AVL CRUISE is the simulation package that supports every day tasks in vehicle system and driveline analysis throughout all development phases, from concept planning, through to launch and beyond. Its application envelope covers all conventional vehicle powertrains through to highly-advanced HEV systems.

An object-orientated physical model approach makes CRUISE powertrain topologies reflect their real life counterparts. The program offers the flexibility to build up a single system model, which can then be used to meet the requirements of diverse applications in the powertrain and driveline development. Starting with only a few inputs in the early phases, the model matures during the development process according to the continuously increasing simulation needs.

CRUISE offers a streamlined workflow for all kinds of parameter optimization, component matching - guiding the user through to practical and attainable solutions. Due to its structured interfaces and advanced data management, AVL CRUISE has established itself as a data communication and integration tool for different teams.



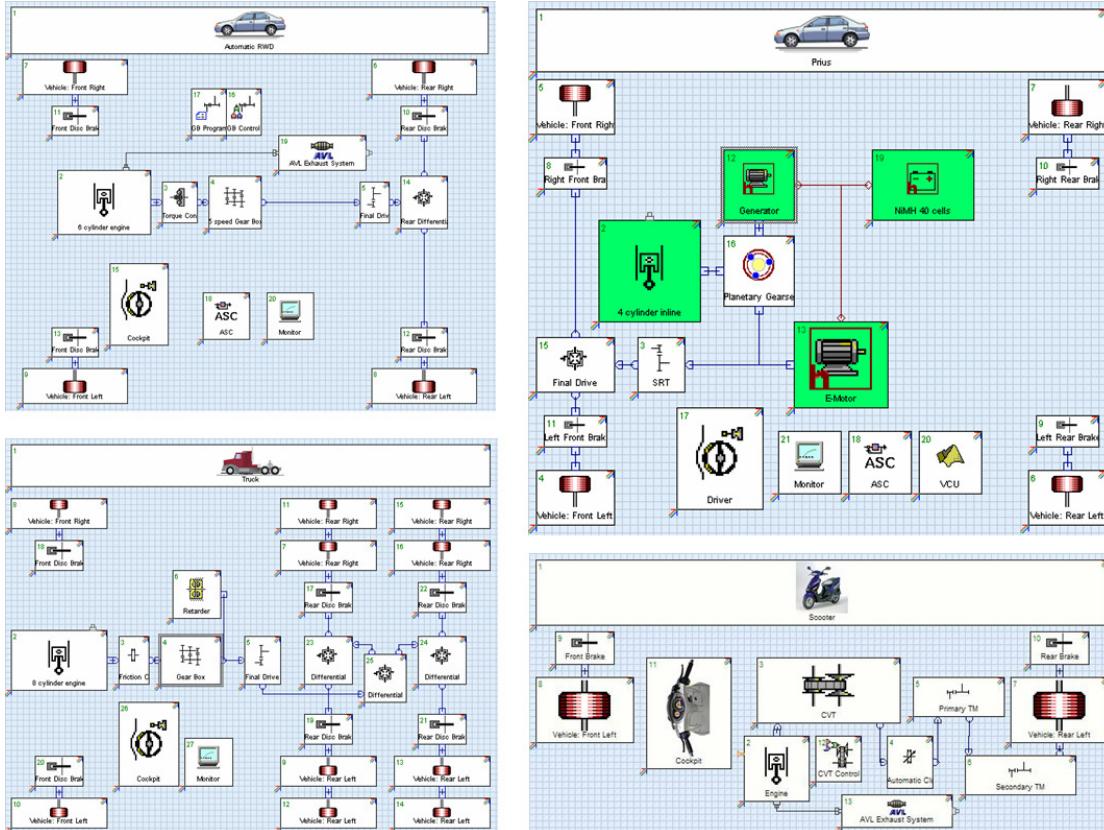
AVL CRUISE Application areas

AVL CRUISE is typically used in powertrain and engine development to optimize the vehicle system including cars, busses, trucks and hybrid vehicles, its components and control strategies with regard to:

- Fuel consumption and emissions for any driving cycle or profile.
- Driving performance for acceleration, hill climbing, traction forces, braking.

AVL CRUISE is also used for tasks like:

- Evaluation of new vehicle concepts such as hybrid powertrain systems.
- Analysis of standard and new gear box layouts like DCT and AMT.
- Analysis of torsional vibrations of elastic drivelines (under dynamic load).
- Drive quality assessment of transient events such as gear shifting and launching.
- Vehicle thermal management.
- Energy flow analysis, analysis of power splits and losses within components.





The workflows in CRUISE are developed for all kinds of parameter optimization, component matching, in order to efficiently find the best balance between fuel economy, performance and drivability:

- Multi-parameter sensitivity analysis of any scalar, characteristic or value within a characteristic or map.
- Overall component variation analysis for finding the right combination of various powertrain components quickly.
- DOE plans can be imported and exported.
- Advanced results representation (variation cubes, trade-off diagrams).
- Significant reduction in manual work for doing driveline studies and the risk of making mistakes.
- Achievement of the best compromise between performance, fuel economy, emissions and drivability in one integrated simulation loop.



Data management

- Oracle database, with data version control, access rights administration, search and filter options for any CRUISE related data – designed to compliment existing company databases.
- File-based data management of projects and its versions, vehicle models, components, maps, etc., including unique search functionality for CRUISE data stored anywhere on a local disk or in the network.
- Efficient data handling features like import, export and copy-and-paste for all input parameters and results.
- Traceability of data and decisions through the development process.

	table 1			table 2		
	a	b	c	a	b	c
2550.0	14.29	17.592		2550.0	14.29	17.592
3000.0	-4.0	2.73		3000.0	-4.0	2.73
3000.0	-0.5	2.84		3000.0	-0.5	2.84
3000.0	0.0	3.0		3000.0	0.0	3.0
3000.0	0.71	3.552		3000.0	0.71	3.552
3000.0	2.42	5.208		3000.0	2.42	5.208
3000.0	3.97	6.685		3000.0	3.97	6.852
3000.0	5.49	8.412		3000.0	5.49	8.412
3000.0	6.97	10.008		3000.0	6.97	10.008
3000.0	8.41	11.508		3000.0	8.41	11.508
3000.0	8.53	11.508				
3000.0	9.81	13.14		3000.0	9.81	13.14
3000.0	11.29	14.844		3000.0	11.29	14.844
3000.0	14.75	20.916		3000.0	14.75	20.916
3600.0	-4.0	3.22		3600.0	-4.0	3.22
3600.0	-0.5	3.34		3600.0	-0.5	3.34
3600.0	0.0	3.67		3600.0	0.0	3.67
3600.0	0.72	4.44		3600.0	0.72	4.44
3600.0	2.41	6.396		3600.0	2.41	6.396
3600.0	3.97	8.472		3600.0	3.97	8.472
3600.0	7.04	12.18		3600.0	7.04	12.18
3600.0	8.59	14.304		3600.0	8.59	14.304

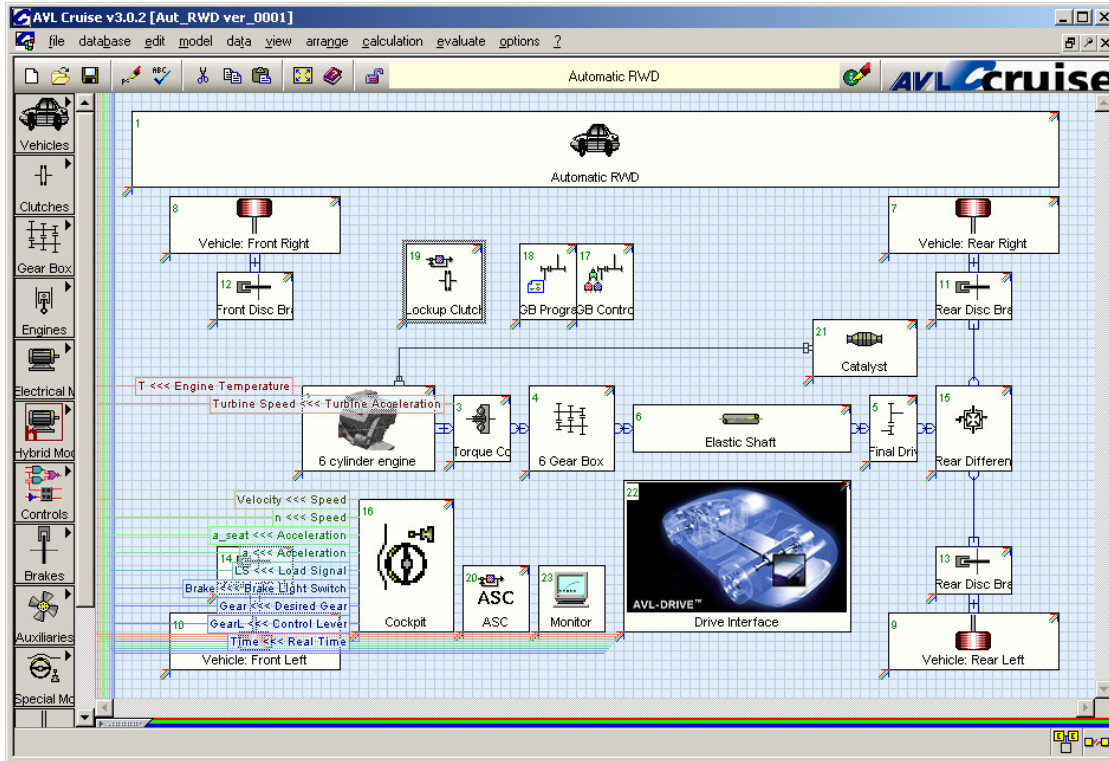


Component and Sub-system Integration

The highly flexible structure of CRUISE enables changing an existing driveline within minutes. Adding hybrid components to a conventional vehicle can be done with a few mouse clicks, using electrical components designed for HEVs. CRUISE can be easily linked with other simulation tools for sub-system integration of vehicle thermal management systems, vehicle control systems, driving dynamics and handling tools, components and sub-system test rigs and HiL systems.

Interfaces to the following tools are currently supported, and tools are being added:

- AVL BOOST (engine thermodynamics, exhaust aftertreatment)
- AVL DRIVE (drivability assessment)
- C, FORTRAN (open DLL interfaces)
- Matlab[®]/Simulink (control systems)
- FLOWMASTER (fluid cycle simulation)
- KULI (fluid cycle simulation)
- AVL InMotion (HiL system, testbed integration, vehicle dynamics, handling)
- IPG CarMaker (HiL system, vehicle dynamics, handling)



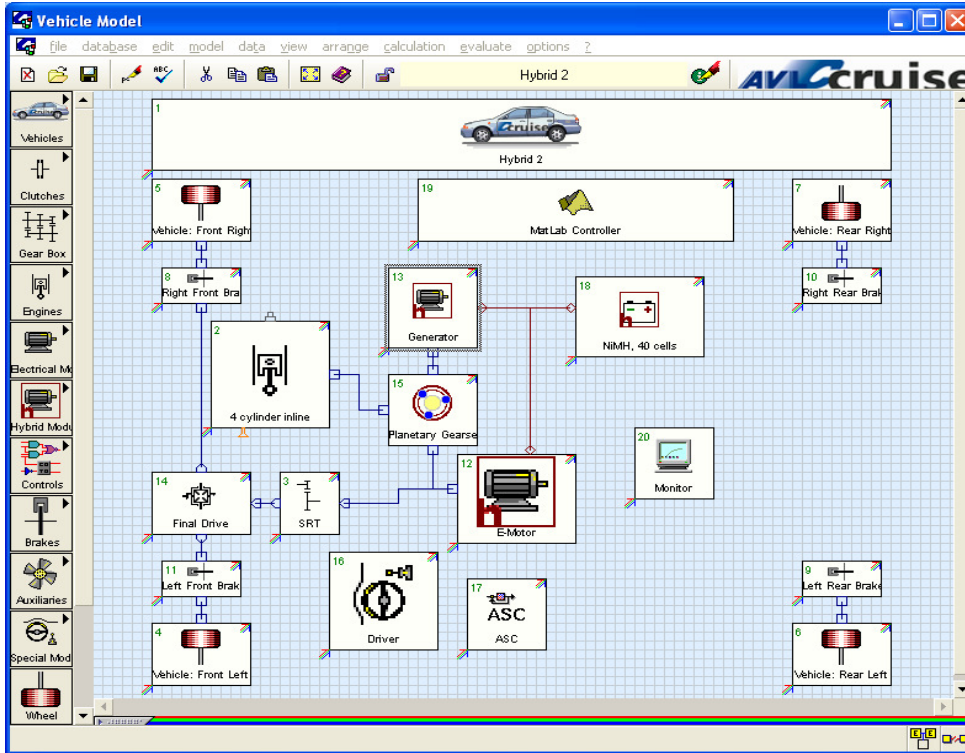


Vehicle Model

In CRUISE, a vehicle model is comprised of different components as it is in reality. This enables the user to model different vehicles, such as motorcycles, passenger cars, trucks, and buses. Additionally, all kinds of drivetrain configurations can be modeled, such as hybrids, twin-engine concepts and sophisticated transmission systems, like DCT and AMT.

The available components in CRUISE cover the whole range of vehicle parts, such as:

- Vehicle and trailers
- Combustion engine, exhaust gas aftertreatment system
- Clutches (friction clutch, hydraulic torque converter, viscous coupling, automatic clutch)
- Transmission elements (multiple step gear box, single ratio transmission, differential gear, planetary gear, double pinion gear, CVT, double clutch transmission)
- Control elements (transmission control, gearbox program, clutch control, clutch program, engine shut-off, cylinder deactivation, start stop automatic, brake control, AMT control – automated manual transmission control, DCT control – double clutch transmission control, CVT control, ASC – anti slip control, PID control)
- Shafts (rigid or torsion-elastic)
- Wheel/tire (including slip and advanced rolling resistance models)
- Electrical components (electric motor, generator, battery, electrical supply)
- Hybrid components (electric machine, super capacitor, DC/DC converter)
- Brakes, Retarder
- Auxiliaries (for applications like: oil pump, air conditioning, power steering)
- Driver
- Environment (wind, road surface, ...)



Depending on the calculation task and the desired accuracy of the results, the complexity (modeling depth) of the vehicle models can be increased from simple to complex continuously in a very efficient way.

The data to be defined is in general the data needed for a dynamic calculation as masses or mass moments of inertia. In addition, data such as dimensions of the parts, transmission ratios, and losses in the different parts can be defined. For the engine different characteristics are needed such as full load characteristic, motoring curve, consumption maps, emission maps, etc.

It is possible to use different model depths for the single components. These model depths mean that different amounts of input data are needed for the calculation. As an example, this means for the Engine: For pure performance calculations, there is no need to input fuel consumption or emission maps. For the calculation of fuel consumption, fuel consumption maps are needed. In this case, steady state measured or calculated fuel consumption map are used. Additional effects such as acceleration enrichment, warm-up enrichment, and turbo-charger response can also be activated. Another example is the definition of the gearbox losses via efficiencies or transmission losses maps, speed, load or even temperature dependent.

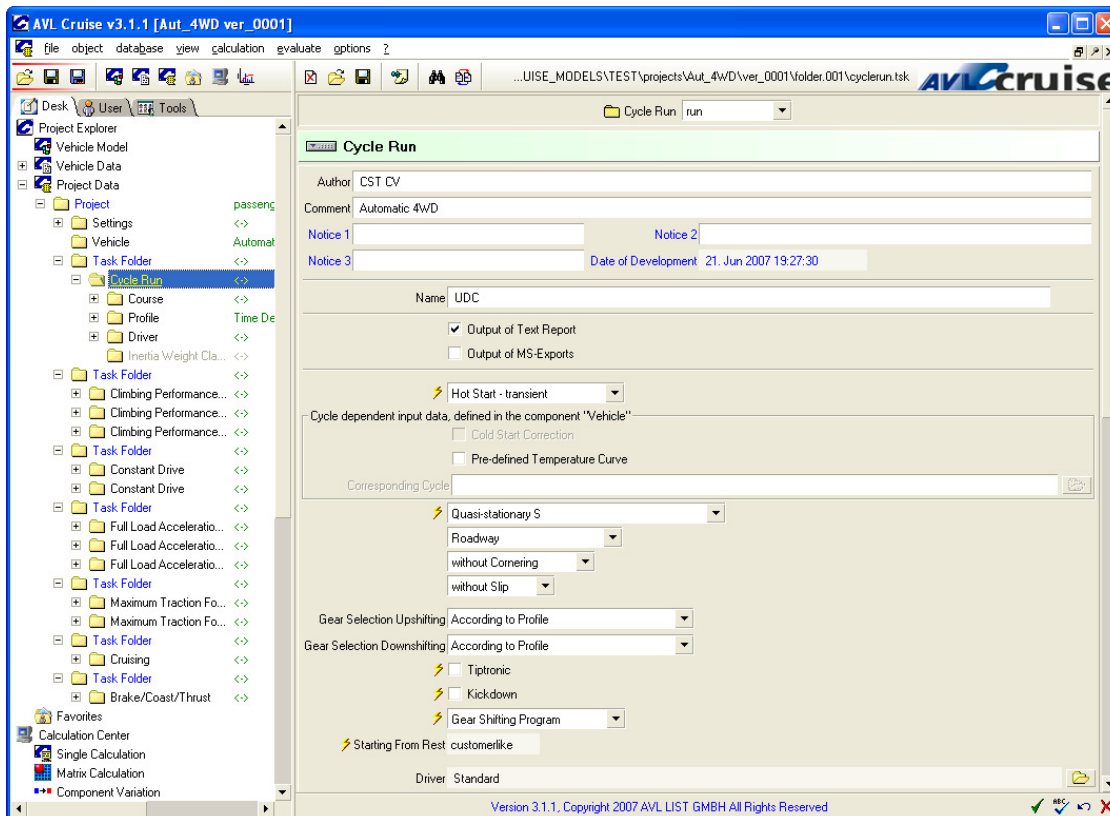


Calculation Tasks and Applications

All standard tasks are provided for the different applications, which were designed especially for use in vehicle analyses. These tasks are:

- Cycle Run: The main goal of this task is the calculation of fuel consumption and emissions on time-based driving cycles. All common driving cycles, time and distance dependent, are predefined (e.g. ECE-R15, EUDC, NEDC, US-city (FTP75), US-highway, Japan 10-15 mode, Artemis). Additional cycles needed for special applications may be defined. E.g., this can be done directly in a table, imported from other sources, or by using the graphical profile editor.
- Climbing Performance: This task is designed for the calculation of the maximum ascending gradients the vehicle can surmount.
- Constant Drive: This task mainly serves for the determination of fuel consumption and emissions at constant velocities. An additional task is the calculation of the current and the theoretical top speed.
- Full and Partial Load Acceleration: This task comprises three sub-tasks:
- Maximum Accelerations in all Gears: Maximum accelerations of the vehicle are computed for the whole engine speed range in all gears.
- Acceleration from Standstill: Vehicle is accelerated from rest to top speed with shifting gears.
- Elasticity: Starting with a definable velocity and a definable gear, the vehicle is accelerated to the defined upper velocity border, with or without shifting gears.
- Maximum Traction Force: This task can be used for the full automatic generation of the Traction Force or Performance Diagrams.
- Cruising: The main goal of this task is the calculation of fuel consumption and emissions on distance based tracks. E.g. the track between two cities can be defined (with speed limit, altitude, etc.) and the overall fuel consumption can be calculated.
- Brake / Coast / Thrust: This task serves for the determination of the braking performance of the vehicle.

With these tasks all necessary applications are covered which are needed during the vehicle development process for the optimization of vehicle powertrains with respect of fuel economy, emissions and driving performance.

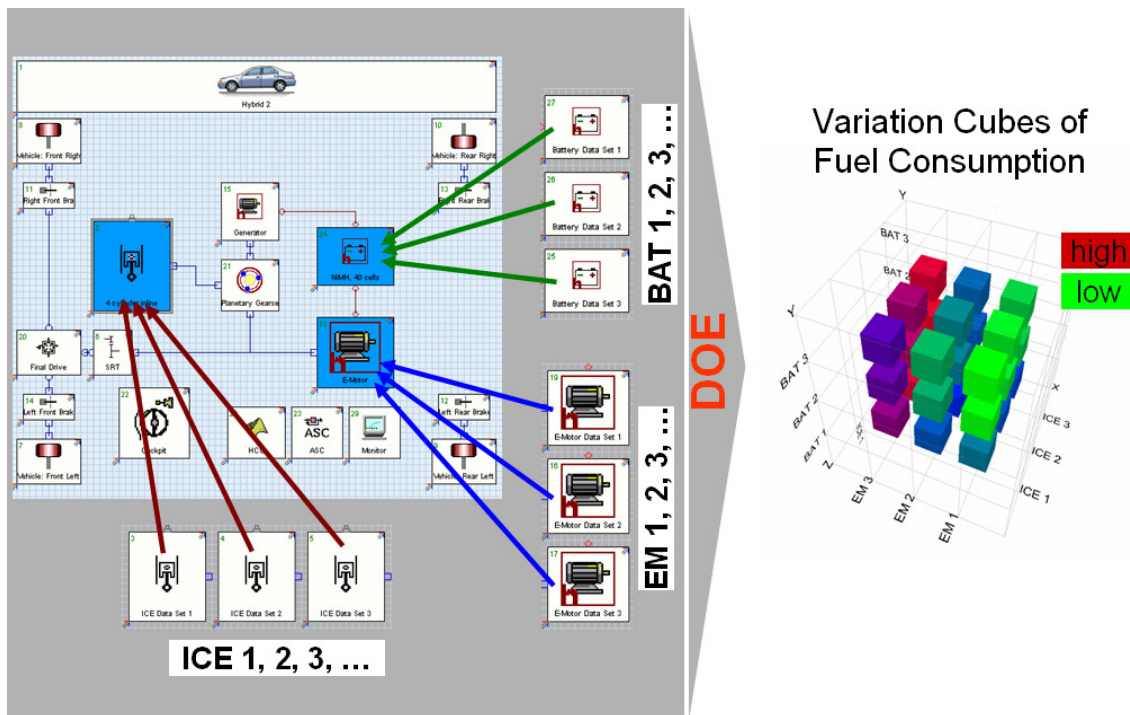




Vehicle System Analysis

Workflows are provided for the analysis and optimization of the vehicle powertrain:

- **Matrix Calculation:** In order to efficiently evaluate the effect of varying the values of input parameters on vehicle performance, consumption and emissions, the matrix calculation method is used. All possible combinations of the varied parameters can be used for the calculation.
- **Component Variation:** Entire components can be specified for variation, not only certain input values like in the Matrix Calculation. The calculation consists of sub-calculations in which components are replaced by components of the same type.



- **DOE Plan for Selection of Variation Cases:** In order to reduce variation cases, it is possible to activate only certain cases by using the 'DOE Plan'.



AVLcruise

Variation DOE Plan

case	Engine Displacement	Curb Weight	Drag Coefficient	Lift Coefficient Front Axle	Lift Coefficient Rear Axle
1	<input checked="" type="checkbox"/> 1 2400	1 1200	1 0.3	1 0.03	1 0.01
2	<input type="checkbox"/> 1 2400	1 1200	1 0.3	1 0.03	2 0.02
3	<input type="checkbox"/> 1 2400	1 1200	1 0.3	2 0.04	1 0.01
4	<input checked="" type="checkbox"/> 1 2400	1 1200	1 0.3	2 0.04	2 0.02
5	<input checked="" type="checkbox"/> 1 2400	1 1200	2 0.5	1 0.03	1 0.01
6	<input type="checkbox"/> 1 2400	1 1200	2 0.5	1 0.03	2 0.02
7	<input type="checkbox"/> 1 2400	1 1200	2 0.5	2 0.04	1 0.01
8	<input checked="" type="checkbox"/> 1 2400	1 1200	2 0.5	2 0.04	2 0.02
9	<input checked="" type="checkbox"/> 1 2400	2 1600	1 0.3	1 0.03	1 0.01
10	<input checked="" type="checkbox"/> 1 2400	2 1600	1 0.3	1 0.03	2 0.02
11	<input type="checkbox"/> 1 2400	2 1600	1 0.3	2 0.04	1 0.01
12	<input checked="" type="checkbox"/> 1 2400	2 1600	1 0.3	2 0.04	2 0.02
13	<input type="checkbox"/> 1 2400	2 1600	2 0.5	1 0.03	1 0.01
14	<input type="checkbox"/> 1 2400	2 1600	2 0.5	1 0.03	2 0.02
15	<input checked="" type="checkbox"/> 1 2400	2 1600	2 0.5	2 0.04	1 0.01
16	<input checked="" type="checkbox"/> 1 2400	2 1600	2 0.5	2 0.04	2 0.02
17	<input type="checkbox"/> 2 2600	1 1200	1 0.3	1 0.03	1 0.01
18	<input type="checkbox"/> 2 2600	1 1200	1 0.3	1 0.03	2 0.02

22 [48] Variations

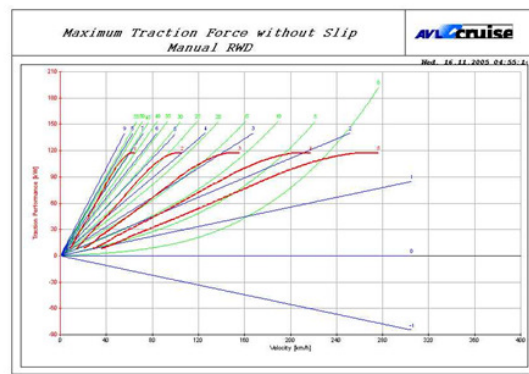
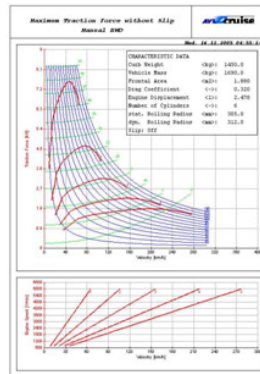
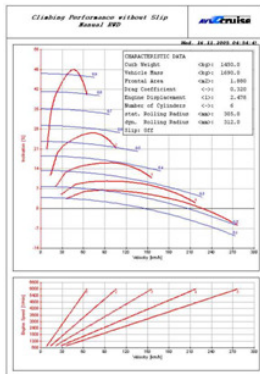
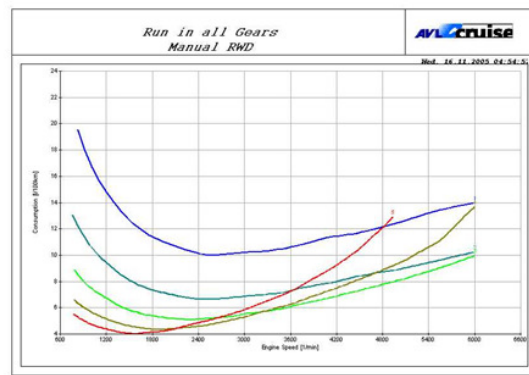
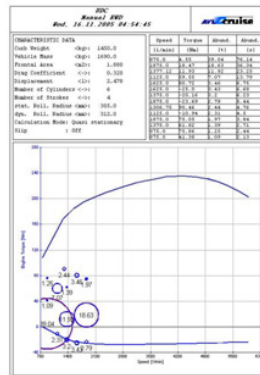
A list of all possible variation cases of the activated variables is shown. The cases of interest can be explicitly select there. The DOE plan can be imported from any external source, like Excel, ASCII editor.



Results Analysis

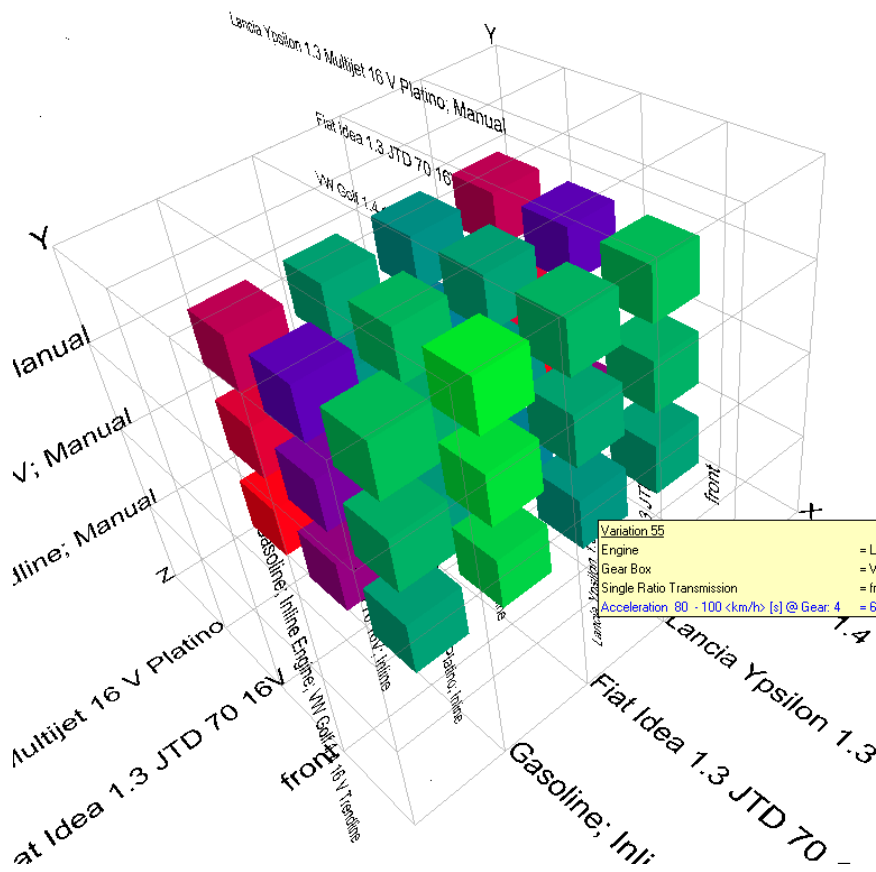
The CRUISE Post-Processor provides different results outputs, which are template-based, which means that the user can standardize the contents and the representation of the results:

- **Text Reports:** These pure text outputs provide an overview on the fuel economy, emissions and performance of the vehicle, like cycle fuel consumption, maximum gradeability, and acceleration times.
- **Component Results:** These diagrams are e.g. time histories (recordings of the simulation run) specifically for the single components. All result outputs for the single components are collected in these diagrams. Curves can be edited in different ways and copied between components and also between different projects to enable easier comparison.
- **Post Processing Diagrams:** These diagrams can contain text as well as diagrams, which offers the possibility to create diagrams for presentations and reports according to the user's needs.



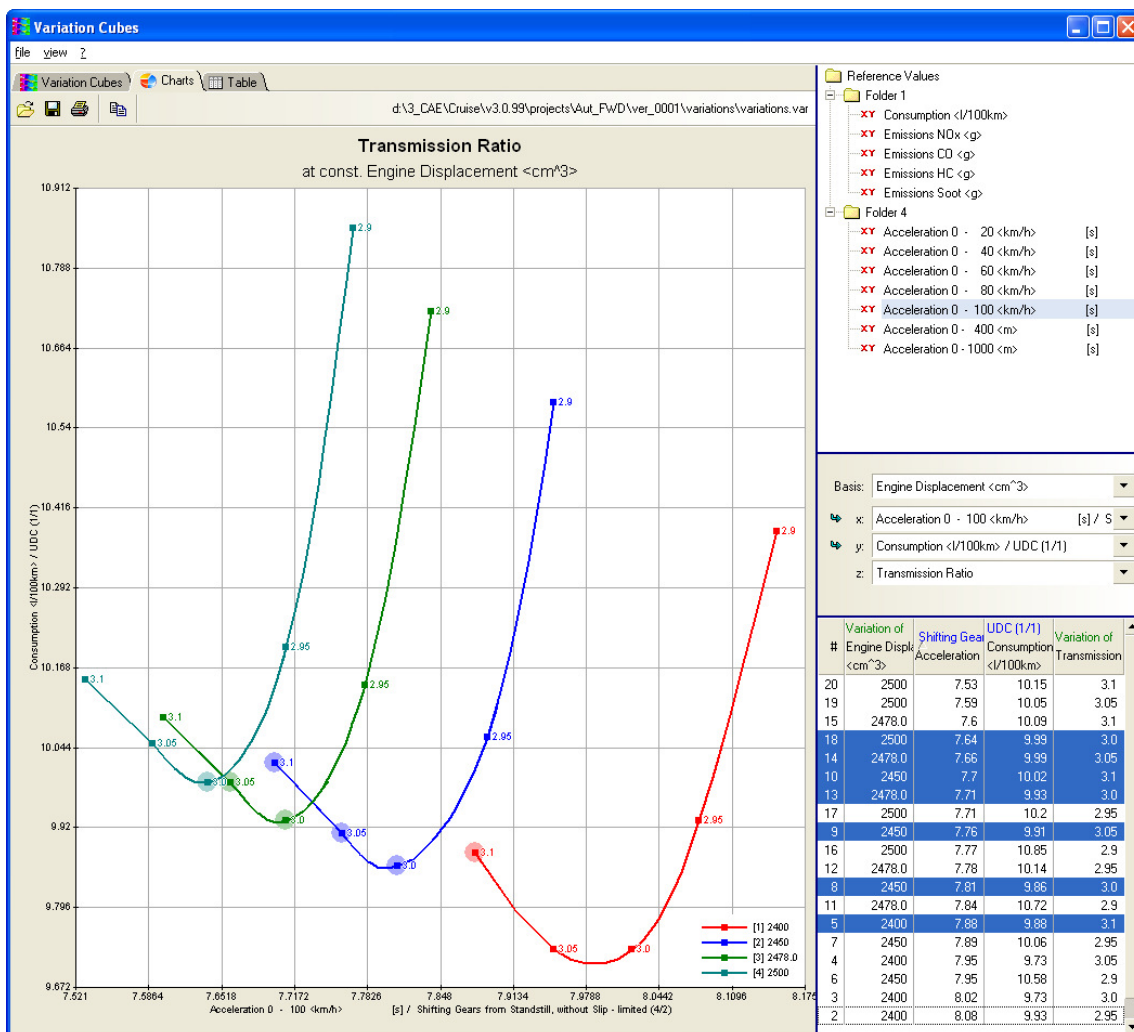


- Variation Cubes – Results of Parameter Studies: Representation of Matrix Calculation and Component Variation results (Variation Cubes), which give a quick overview on the results of all parameter or components combinations.



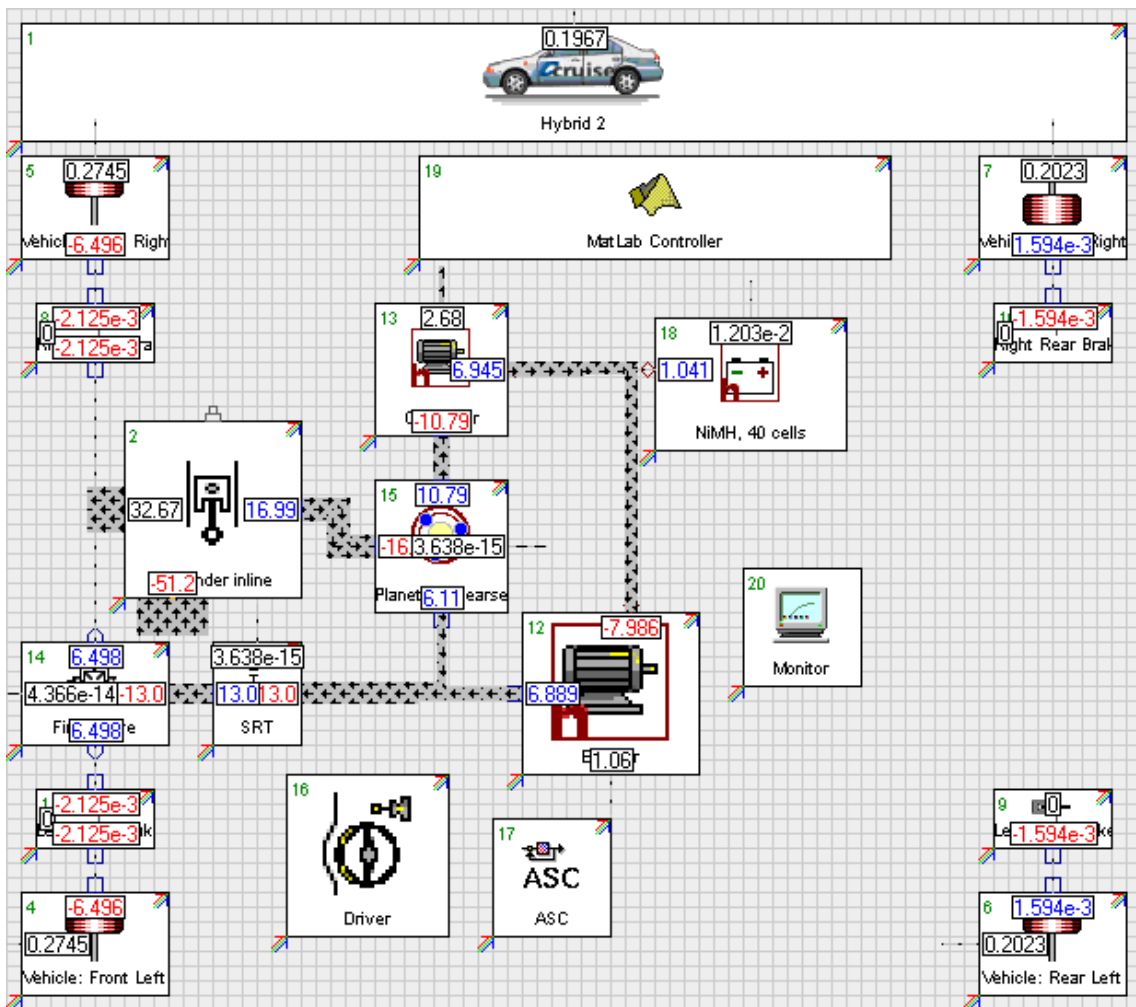


- Combined Results Chart:** Together with the Matrix Calculation or Component Variation, an option called 'Charts' can be used. For two different, often contradictory results (on the axis of the diagram) of one or different calculation tasks, the parameter combinations can be represented. For example, the tradeoff between the fuel consumption from the task 'Cycle Run' and the acceleration time from the task 'Full load Acceleration' is shown for all calculated combinations of engine displacements and final drive ratios ('Axle Hook Chart').





- Direct Data Export to MS Excel: The user can select the data he wants and directly export it to MS Excel, where it can be further processed.
- Energy Flow Graphics: An unique animation shows the simulation results of each component, such as:
 - Power <kW>
 - Energy Stored (e.g. inertia, battery charge)<kJ>
 - Cumulated Energy <kJ>
 - Speed – Velocity <rpm – km/h>
 - Torque – Force <Nm – N>
 - Current <A>
 - Voltage <V>

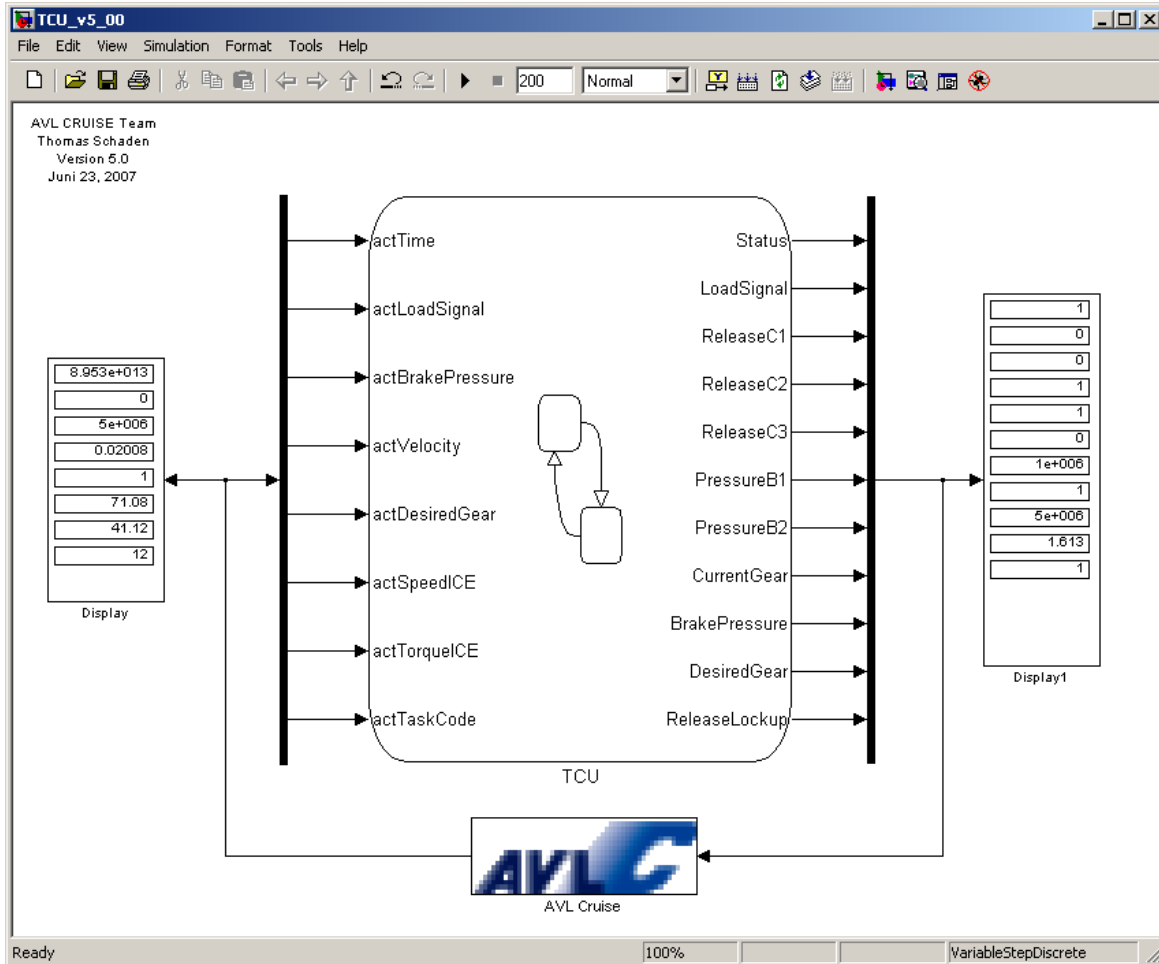




System Integration

AVL CRUISE offers through interfaces the ability of external user-defined controls as well as couplings to other tools used for various applications:

- Black Box (Component for user defined control algorithms written in C or Fortran)
- Interfaces to Matlab/Simulink
- Interface to AVL BOOST (engine cycle simulation)
- Interfaces to Flowmaster and KULI (for vehicle thermal management system simulation)
- Interface to MS Excel
- Interface to AVL DRIVE (evaluation of the drivability of CRUISE results)
- CRUISE Interface: A dynamic link library of CRUISE (DLL), which enables the integration of CRUISE in any arbitrary software. An example is the link of CRUISE to Matlab/Simulink via s-function.





CRUISE RT (RealTime)

The CRUISE fixed step solvers and an optimized CRUISE Kernel enable the calculation of CRUISE models in real time mode.

The CRUISE Kernel (Interface DLL), in addition to the PC platform, is also available for Linux RT and can be integrated into HIL systems, like AVL InMotion™.

It is possible to realize ‘virtual test driving’ at the test bed, including lateral dynamics and drivability analysis. The real engine and/or powertrain can be embedded in the real-time virtual vehicle environment. In this case CRUISE is the detailed driveline model within the test system, which is simulating all parts of the powertrain, which are not real.

