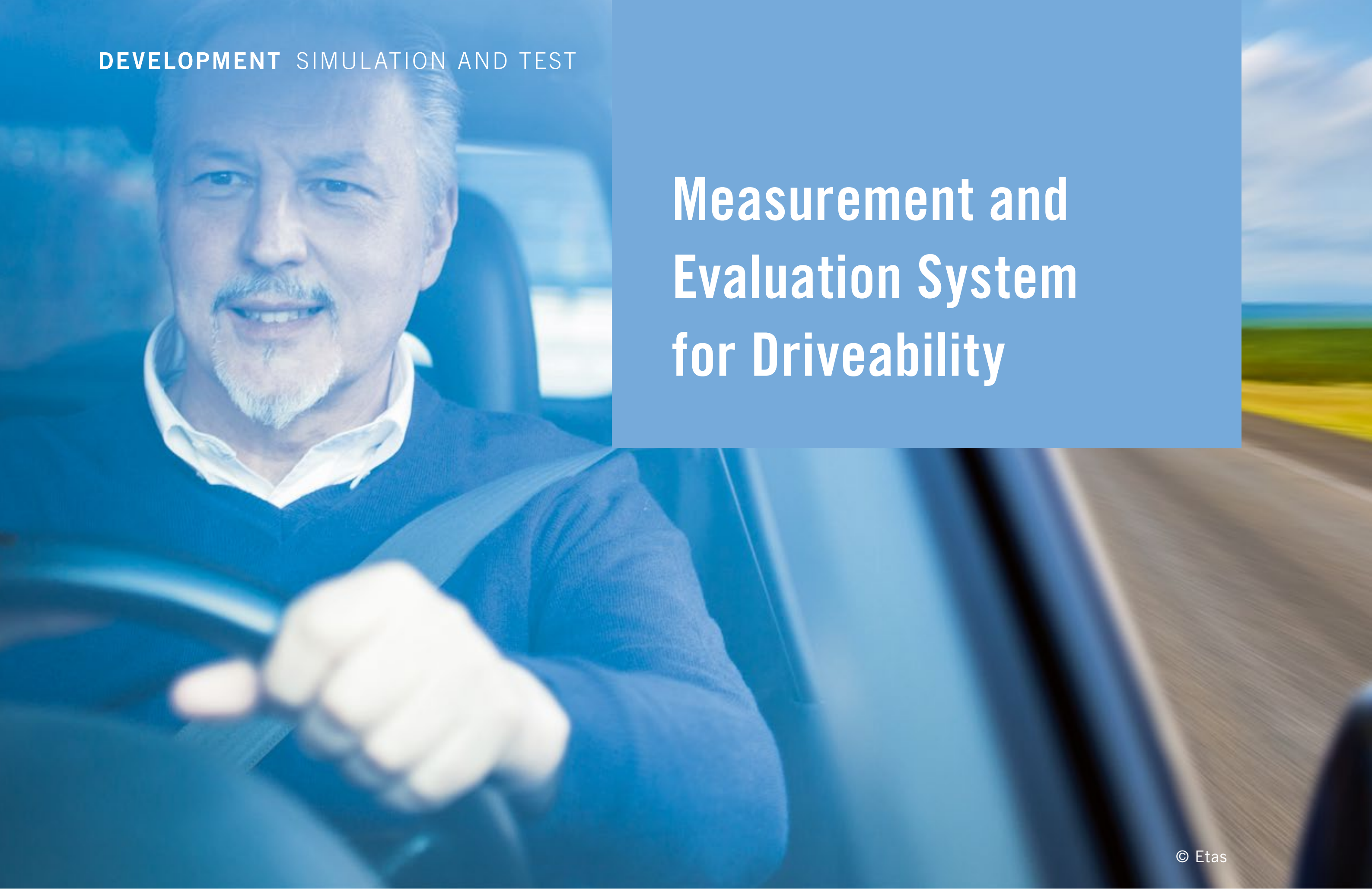
Measurement and Evaluation System for Driveability



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When people buy a car, they expect to get a carefully tuned driving experience that corresponds to their chosen brand. However, the number of test vehicles is limited and they are only available late in the development process. Thus, calibration engineers often have to tune the driving behavior of numerous vehicle variants and models under intense time pressure. Currently, they rely on their expertise and get instincts to carry out this tuning process. Etas, in collaboration with IAV, has developed a measurement and evaluation system based on Inca-Flow that allows engineers to tune even large numbers of vehicles efficiently.

OBJECTIVE DESCRIPTIONS OF CALIBRATION CRITERIA

It is certainly a daunting challenge: Carmakers are increasingly calling for a system that would simplify vehicle tuning in the calibration process while simultaneously enabling them to efficiently define the character of the vehicle itself. What is more, they want to create objective descriptions of calibration criteria that engineers had previously determined subjectively.

The reasons for pursuing these goals are many and varied. For one thing, complexity is constantly increasing – and so too are the challenges it creates. The variety of vehicles car manufacturers offer is growing inexorably, with ever more nuanced differences between vehicle variants. As well as multiple different models, there is also a multitude of powertrain configurations to consider, with hybrid concepts that offer different operating modes and types of transmission. Engineers are tasked with defining the specific characteristics of manual transmissions and torque converter automatic transmissions as well as automated manual transmissions, dual clutch transmissions, and continuously variable transmissions. Moreover, the automotive industry is facing ever stricter emissions standards in real-life driving conditions for combustion engines (Real Driving Emissions, RDE) while simultaneously striving to reduce CO_2 emissions in the strict Worldwide Harmonized Light Vehicles Test Procedure (WLTP) cycle. Yet none of these requirements can be allowed to have a negative impact on driveability.

On top of all these challenges, many end customers expect their chosen vehicle to offer a driving experience that meets their own individual needs, and they would ideally like to be able to fine-tune this experience as they see fit. For example, a luxury saloon car accelerates more smoothly and steadily while a sports car responds more spontaneously. There will also be noticeable differences in vehicle start-up and gear change behavior. Each car marque has its own character, and vehicle models may differ substantially from one another even within the same brand.

Calibration engineers tune each type of vehicle in line with these specifications and the technical data prescribed for that model while simultaneously creating the desired level of driveability. Each vehicle's individual character is largely reflected in its longitudinal driving behavior, which is heavily dependent on the powertrain. In addition to the tools previolsy used in vehicle tuning, the engineers' subjective perception has also played a major role.

All these aspects taken together result in very high expenditure on development – and this can no longer be sustained without introducing more efficient tools into the calibration process.

SYSTEM DESCRIPTION

In collaboration with IAV, Etas has developed an objective measurement and evaluation system that meets the decribed needs: the Inca-Flow Engine Driveability Toolbox (EDT) and Transmission Driveability Toolbox (TDT). The system is based on an extensive range of dedicated algorithms for data acquisition and evaluation. The EDT supports calibration engineers in measuring and analyzing driveability in engine ECU calibrations. The TDT performs various functions, including detecting events in the transmission such as upshifts and downshifts. It also enables engineers to evaluate these events based on objective, physical criteria. Featuring software with a familiar user interface, the toolboxes can be put to use in a vehicle in a matter of minutes by combining them with existing Etas measurement hardware such as products from the ES500 series. Instead of requiring their own sensors, the toolboxes simply read vehicle signals from existing bus systems such as CAN (Controller Area Network), FlexRay, and XCP (Universal Measurement and Calibration Protocol). Optionally, an external accelerometer mounted quickly and easily on a seat rail can be used.

The process itself is simple: During driving maneuvers, the measurement and evaluation system records the physical parameters of the powertrain in real time. As a rule, the acceleration and engine speed signals are the best choice for providing reliable evaluation parameters for load changes, pedal use, gearshift sequences and starting. The system evaluates this measurement data and displays the relevant driveability parameters as both numerical and graphical outputs, including comparisons with reference values. It also offers the option of offline evaluation – for example in tandem with colleagues back in the office.

The driveability parameters relevant for longitudinal driving behavior can be changed even while a calibration test drive is in progress. The Inca-Flow EDT and TDT toolboxes themselves determine the criteria (for example shuffle) based on objective rules and display them directly in the Inca experiment. That enables calibration engineers to shift the driving characteristics in the required direction quickly and efficiently.

The measurement and evaluation system shows its strengths in situations where calibration targets are agreed with binding effect as acceptance criteria in the form of target parameters right at the start of the project. Engineers can then specifically measure these parameters during the calibration test drive and steadily optimize them to achieve the desired result.

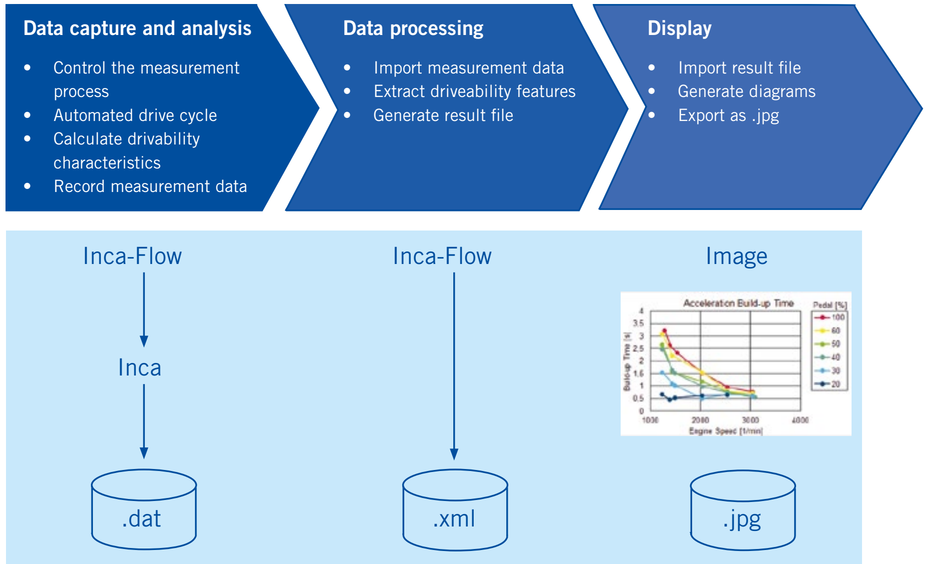

FIGURE 1 EDT tool chain – from the performance of driving maneuvers to the capture and analysis of measurement data and the presentation of results (© Etas)

The toolboxes can be used in the following applications:
- calibrating ECUs in the vehicle and displaying the results online
- specifying target values for the calibration process
- determining and documenting the maturity of a calibration
- test drives
- homologation runs/acceptance tests
- documentation for data version releases
- benchmarks.

The system offers a number of key advantages:
- evaluation of calibration targets with the aid of physical parameters and evaluation indices
- easy auditability of results
- reproducibility
- high flexibility in regard to input signals and signal sources (CAN, FlexRay, XCP, etc.)
- fast installation of the measurement technology in the vehicle within a matter of minutes
- simple operation thanks to smooth integration in existing calibration systems (Inca and Inca-Flow)
- use of existing measuring systems (for example the ES500 series from Etas).

TOOL CHAIN

The system is designed to make life easier for calibration engineers by supporting them through the entire process from the performance of driving maneuvers to the capture and analysis of measurement data and the presentation of results, **FIGURE 1**.

An interface module – for example from the ES500 series – uses an ETK to import measurement data from the ECU via the CAN bus and an analog-digital (AD) converter (for example Etas ES411), **FIGURE 2**. The data is captured and evaluated online simultaneously, allowing Inca to save the calculated driving behavior parameters to the same file. Inca also displays the results, enabling the calibration engineer to operate in a familiar working environment. Where required, the results can be prepared in a graphical format and exported as graphic files once the measurements have been completed.

This efficient process enables fast parameterization. It also ensures that the results are not affected by fatigue or subjective perceptions of the calibration engineer. Taken together, these two advantages ensure that the calibration work always meets the desired goal, even when performed by different teams at different times or in different locations.

As well as using the engine and transmission driveability toolboxes as independent functions within Inca-Flow, users also have the option of embedding the toolboxes' driving behavior analyses in a list of driving maneuvers specified by Inca-Flow itself. This can be scaled all the way up to fully automated optimization of the parameters relevant to driving behavior. It can be used directly in the vehicle and also integrated in a model-in-the-loop environment (Inca-Flow MiL Connector).

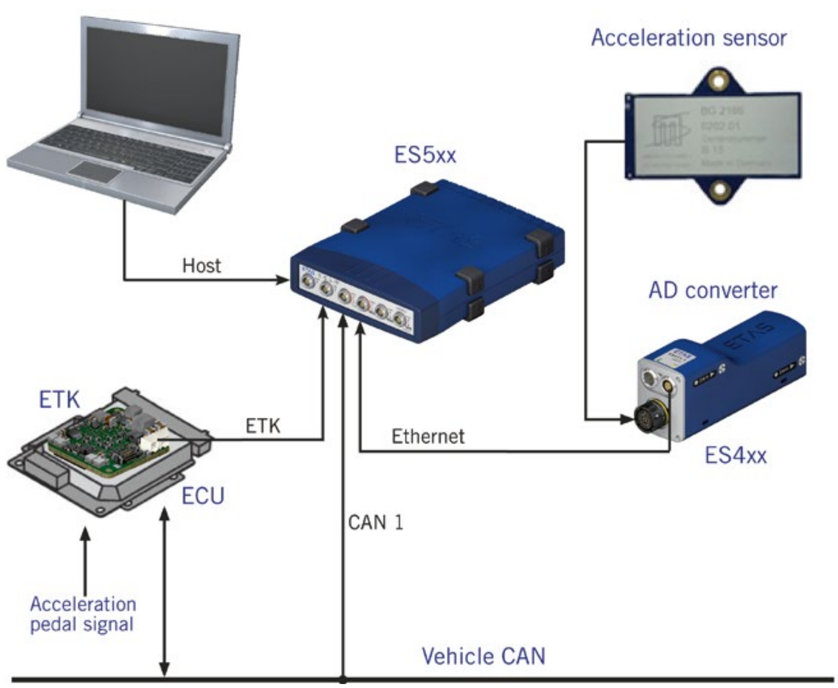

FIGURE 2 Configuration of the measurement system (© Etas)

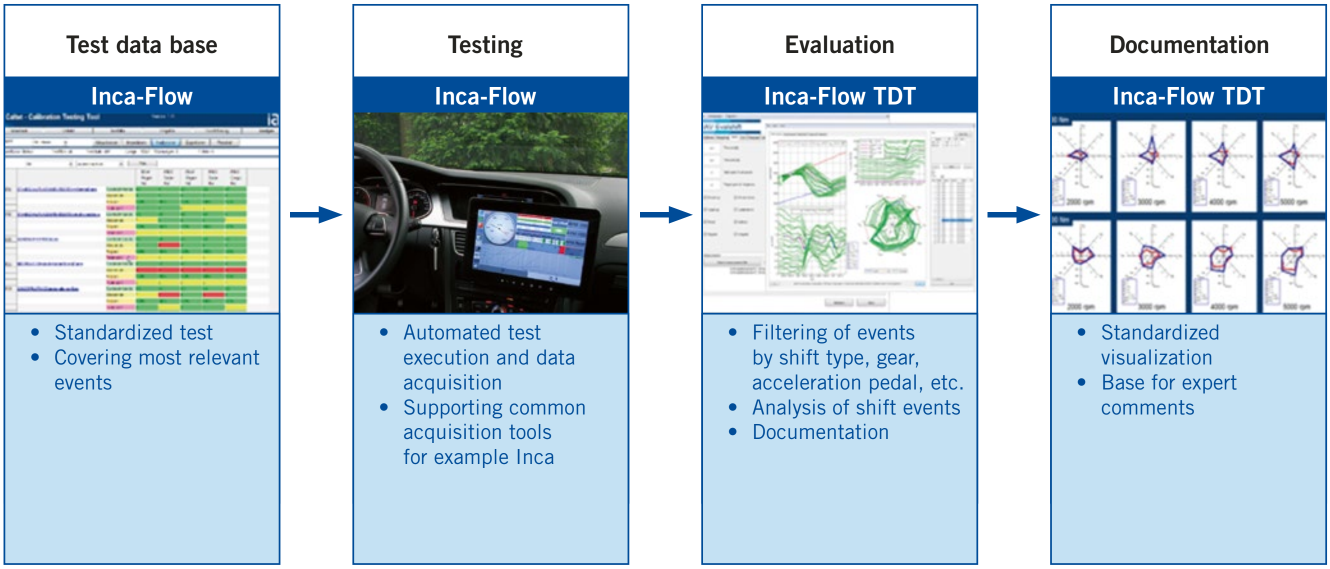

FIGURE 3 Steps in process for calibrating driving behavior (© Etas)

BRIEF DESCRIPTION OF KEY PARAMETERS

The main characteristics can be defined as follows:

- Load Change (EDT): Load change is defined by the four parameters response time, time to acceleration/deceleration, jerk and shuffle. The response time is the amount of time that elapses between depressing the accelerator pedal and reaching a defined acceleration threshold (phase 1). The time to acceleration/deceleration is the time that elapses between accelerator pedal depression and acceleration zero crossing (phase 2). Jerk refers to the filtered gradients of vehicle acceleration (phase 3). The fourth parameter, shuffle, corresponds to the averaged amplitude values of vehicle longitudinal vibration (phase 4). In addition, acceleration build-up time defines the effects of the air system channel on the acceleration curve, for instance by a turbocharger.
- Pedal Application (EDT): When the vehicle is moving off, the maximum achievable vehicle acceleration depends on the accelerator pedal position. This parameter defines how accurately a desired acceleration can be applied. The algorithm determines the maximum acceleration for a certain pedal position. A series of measurements taken over different pedal positions yields the characteristic correlation.
- Gearshift Sequences (TDT): Depending on the type of gearshift (power/coast, upshift/downshift and freewheel/stationary), various different characteristic acceleration curves are produced based on the transmission concept in each case. Essentially, there is a trade-off between shift time and comfort or dynamic handling and comfort, **FIGURE 3**. Based on signal curves, algorithms are used to detect the various types of gearshift and to determine typical driveability-relevant criteria such as shuffle, deviation from an ideally comfortable acceleration curve and peak-to-peak acceleration values, as well as speed criteria such as overshooting and cumulative clutch friction work.
- Starting Launch (TDT): Much like the situation with gearshifts, there is also a conflict of objectives when it comes to starting the vehicle, in this case a trade-off between a good response time and a high level of comfort. Once again, calculations are made of physical criteria and deviations from ideal-typical speed and acceleration curves. There are certain parallels between the control system for starting the vehicle with wet and dry clutches and the controller for converter lock-up clutches and separating clutches used in hybrid powertrains. Implementations of evaluation algorithms are included for these and other types of events.

SUMMARY

The Inca-Flow Engine Driveability Toolbox (EDT) and Transmission Driveability Toolbox (TDT) are powerful tools for efficient vehicle tuning. One of their key benefits is the ability to replace calibration criteria that were previously determined on a subjective basis with objectively measured values. That makes the tuning process simpler and faster and makes it easier to draw comparisons. As a result, the system successfully addresses the growing demand for a method of processing numerous different variants and models within a short timeframe with a strictly limited number of test vehicles.