Solutions for Virtual Vehicle Development

The Control Panel for Scenario-Based Validation of Software-Defined Vehicles (SDVs)

VIRTO and one:cx

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1 The Challenge: Structural Limits in SDV Validation

In the development of software-defined vehicles (SDVs), one thing is becoming increasingly clear: validation is turning into a bottleneck. This is not due to the quality of individual tools – quite the opposite. Rather, the validation landscape has grown historically, is tool-centered and fragmented, resulting in a lack of coordinated, cross-domain interaction. This is a structural problem that is becoming increasingly severe.

Typical challenges in the industry are:

- Scenarios are redefined for each test level.
- Vehicle and simulation data exist in isolation in different systems.
- Each department plans and manages its test scope independently.
- Test results from simulation, test bench and test drives are difficult to compare.
- Reusability of tests across test levels and test domains is limited.
- Traceability is severely restricted by decentralized evaluation of test results and test coverage.
- The ability for targeted test control is often lacking for project owners due to manual research.

Given these conditions, the key question – “Where do we actually stand?” – usually cannot be answered satisfactorily.

With SDVs, the situation becomes even more acute: ADAS driving functions are getting more complex, test scopes are growing exponentially and regular over-the-air updates (OTA) are now standard. The real challenge is not test execution, but overarching coordination, consistency and traceability across all test levels – from MIL, SIL, HIL, VIL to the vehicle.

2 The Solution: Scenario-Based Validation

This is exactly where we apply a new perspective: moving away from test-level-specific views of individual functions toward reusable scenarios as a continuous reference across all test levels – controlled by a central "control panel" that coordinates existing tools, services and processes and provides transparency to all stakeholders about overall status at any time.

Scenarios describe expected system behavior independently of the concrete execution environment. Clear rules apply for practical implementation: in scenario-based validation, scenarios are not understood merely as test input, but as central validation objects with clear versioning, quality assurance and reuse across all testing areas.

Scenario-based validation is built on two key components:

- **A semantic foundation** as a central, consistent source for scenarios, vehicle data and models.
- **An orchestration layer** that derives specific test campaigns from that foundation, executes them, consolidates test results and evaluates them in a traceable way.

The combination of VIRTO (IPG Automotive) as the semantic foundation and one:cx (tracetronic) as the orchestration layer provides an integrated system with a clear division of responsibilities.

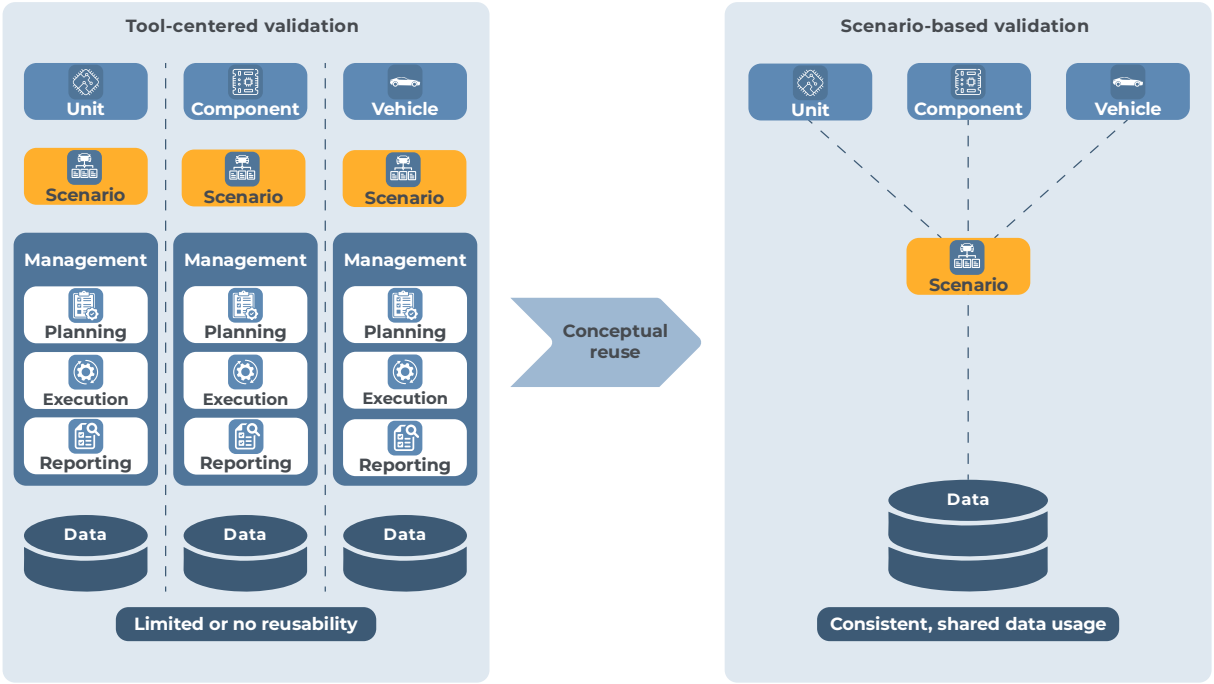

Fig. 01: From tool-centered to scenario-based validation

3 The Architecture: Data Logic Meets Test Logic

What sounds like two separate layers within the overall test ecosystem at first is, in practice, a symbiotic architecture: VIRTO and one:cx act as specialized units with clear interfaces and complementary strengths.

3.1 VIRTO: The semantic foundation

VIRTO serves as the central, unified "single source of truth" for all domain-specific components of virtual vehicle development and connects all stakeholders via a web-based, modular platform with consistent simulation artifacts that are traceable at any time. The solution is specifically designed to simplify and scale complex testing and development processes and to make them accessible to all roles:

- **Scenarios**: VIRTO enables the centralized definition, versioning and quality assurance of all scenarios and test conditions. These can be stored in specialized as well as common standardized formats (e.g. OpenSCENARIO, OpenDRIVE). This ensures that all teams work with the same unambiguous traffic scenarios, significantly increasing comparability and reusability.
- **Vehicle prototypes**: Through an automated build process, virtual prototypes are created with full parameterization and consistency. VIRTO manages all relevant parameter data, controls variants and versions, and thus enables a robust and reproducible vehicle build-up – whether for individual tests or complex development programs.
- **Simulation data**: The platform brings together digital twins of sensors, vehicle components and ECUs (integrated virtually or with real hardware) in one place. This structured collection makes it possible to integrate data sources cleanly and feed them into subsequent development steps – a key advantage given the growing system complexity.
- **Model quality**: VIRTO provides an automated and systematic assessment of scenarios and models. Dependencies and potential weaknesses can be identified early before they enter extensive test chains. In this way, the platform supports consistent frontloading and makes a substantial contribution to increasing the reliability and overall quality of simulation.

All stakeholders – from simulation to test benches and real-world driving tests – access consistent, centrally managed artifacts in VIRTO. Any change to parameters, models or configurations becomes visible immediately and remains fully traceable. This enables scalable, CI/CT-capable development processes, increases the reusability of tests and creates a clearly documented, transparent basis for decisions at every stage of vehicle development.

3.2 one:cx: The control and orchestration layer

While VIRTO defines “what,” one:cx decides on “how,” “when” and “where.” one:cx is an enterprise platform that traceably controls and monitors the entire validation process.

The platform orchestrates planning, execution and tracking of tests across all test levels – from purely virtual simulations (MIL, SIL) to hybrid setups (HIL, VIL) to physical tests on the test bench, in the real vehicle and in the fleet.

This reach makes one:cx the central control instrument: It integrates existing tools, infrastructures and processes across organizations, makes results comparable and consolidated and provides data-driven decision bases for approvals.

The core functions of one:cx are:

- **Intelligent test planning and execution:** Intelligent scheduling and automated distribution of test jobs to available virtual and physical test resources, including the cloud. Building on that, process and workflow automation with quality gates and workflows ensures an end-to-end CI/CD pipeline.
- **Central data storage and integration with other tool landscapes**: Central data storage eliminates silos and provides consistent information: test results from SIL, HIL and vehicle scenarios, configurations, requirements from ALM systems, etc. The platform thus creates a trusted data foundation for all stakeholders. Additional tools – e.g. requirements tools, ticket systems or software repositories – are seamlessly integrated.
- **AI agents:** AI services reduce bottlenecks in evaluation and evidence creation. Based on automated workflows and consistent data in one:cx, AI agents support the derivation of test specifications and test cases, cluster and prioritize failure patterns across releases and variants, and detect anomalies and unstable tests. Review and analysis effort is significantly reduced, while approvals remain deterministically safeguarded via quality gates and traceability.

4 The Application: Key Points and Typical Workflows

4.1 Differentiation from traditional toolchains

The following four key elements distinguish this approach from an ordinary toolchain:

- **Scenarios as reference**: Scenarios are the common point of reference for assuring complex software functions across all test levels – from MIL/SIL to HIL to road testing and the fleet. Instead of testing individual functions in isolation, the system checks whether the expected purpose is achieved during a realistic sequence of events.
- **Validation as a controllable, data-driven process**: Changes to scenarios, models or requirements systematically trigger validation needs. Planning and execution can be automated in a cross-level validation model with uniform KPIs. Every test result is traceable: which scenario, which vehicle configuration, which test environment, which requirement? It is all documented in the overall system making the context available, not just the outcome.
- **Scalable, protected collaboration without silos**: All stakeholders work in the same scenario-based validation context with an approach that scales functionally (across all test levels up to the fleet), organizationally (OEMs, suppliers, teams, partners, sites) and technically (available test resources) within a single enterprise platform. Granular rights concepts ensure compliance with strict IP protection, security and compliance requirements. Traceability requirements from ASPICE and ISO 26262 are supported end-to-end and audit-proof.
- **Feedback loops instead of a linear process**: VIRTO and one:cx do not work linearly (requirements → scenarios → tests → results), but in intelligent feedback loops. The result: significantly shorter decision times through real-time transparency, faster feedback when changes occur and continuous optimization for safe, high-quality software.

4.2 Typical workflows from the user perspective

4.2.1 Simulation data input

Whether for scenarios or virtual vehicle prototypes, expert knowledge is required to provide artifacts. Experts enter versioned, quality-assured artifacts with a clearly defined lifecycle into the system, provide them with a standardized usage recommendation and thus create the basis for downstream validation.

4.2.2 Campaign planning and execution

When changes to software, scenarios or models occur in VIRTO, one:cx automatically detects the new validation need and derives the required test campaign from it without manual planning. one:cx orchestrates and optimizes the distribution and execution of test jobs automatically – also in the cloud.

4.2.3 Analysis and feedback

After the tests are completed, the results are available centrally. AI-supported evaluations detect deviations, compare across test levels with historical data, highlight critical differences and thus deliver essential insights for improvement. End-to-end traceability across the entire system makes it possible to trace influences down to individual simulation models and parameters, including metadata such as version status, timestamps, responsibilities and quality ratings.

Target-group-specific dashboards and reports create a transparent, data-based foundation for approvals and further actions.

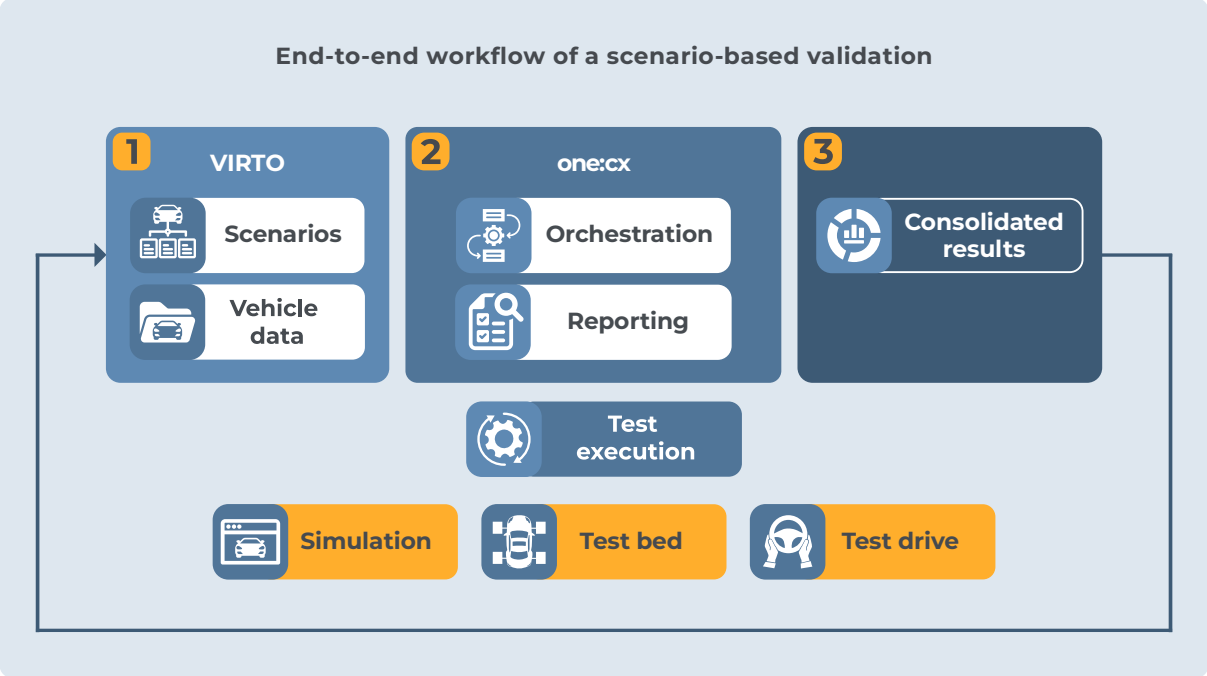

Fig. 02: End-to-end workflow of a scenario-based validation

5 Conclusion: Validation as a Strategic Success Factor

The combination of VIRTO and one:cx no longer makes validation a reactive bottleneck, but a controllable, transparent part of development. Semantic consistency is linked with intelligent control and orchestration. Manual coordination is replaced by automated processes and data becomes knowledge – systematic, traceable and continuous.

Short-term benefits	Mid-term benefits	Long-term benefits
Structured processes through a unified scenario base and standardized workflows	Significant risk reduction through systematic validation and less rework	Automatic knowledge transfer by preserving validation knowledge for follow-up projects
Immediate transparency on status, coverage and anomalies	Collaboration: smooth cooperation across teams, locations and partners	Reusable assets: standards, libraries, best practices – easily extendable
Efficiency by avoiding redundant tests and reducing manual effort	Faster time to market through optimized validation processes	Platform synergies: every new project benefits from all previous ones – shorter setup times, higher quality

Table 1: Tangible benefits

The truly groundbreaking potential unfolds over time. Each project feeds knowledge into the platform. As usage increases, the value and informative power of scenarios, data and test results grow. This creates the basis for advanced analyses, automated gap identification and, in the longer term, data-driven extensions of validation coverage. Validation thus becomes faster, safer and more efficient with every project.

The collaboration between IPG Automotive and tracetronic does not create yet another validation tool, but a consistent operating model for software-defined vehicles. Together, one:cx and VIRTO form the control center that makes it possible to manage the growing complexity of modern vehicle software in a structured way.

6 About the Companies

6.1 IPG Automotive

As a technology leader, IPG Automotive develops innovative simulation solutions for virtual vehicle development. With VIRTO, IPG Automotive provides a modular platform for building, managing and validating virtual vehicle prototypes.

6.2 tracetronic

tracetronic is a specialist for test automation in the automotive industry. With one:cx, tracetronic provides a cloud-native CI/CD platform for end-to-end validation of software-defined vehicles – from the first line of code to the over-the-air update.