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How Product Line Engineering Drives Consistency and Control in the Automotive Industry

WHITEPAPER

June 2026

MASTERING COMPLEXITY IN THE SOFTWARE-DEFINED VEHICLE ERA

The automotive industry is at an inflection point

Organizations — whether global OEMs, Tier 1 suppliers, EV startups, or regional mobility partners — have different vehicle architectures, compliance requirements, and market expectations. But in today's rapidly shifting landscape, leaders must also contend with the convergence of electrification, autonomous driving, software-defined vehicles (SDVs), and rising pressure to deliver safe, connected, and compliant vehicles at unprecedented speed and scale.

Vehicles are no longer standalone mechanical products. Today's platforms — whether battery-electric powertrains, ADAS systems, connected cockpits, or over-the-air (OTA) update architectures — are interconnected, digitally enabled, and expected to operate across diverse global markets with maximum adaptability. And while these growing demands point to opportunity, they also expose a critical weakness in how most automotive organizations engineer their systems today.

Despite engineering multiple vehicle architectures, modular systems, and scalable product portfolios, many automotive OEMs and Tier 1 suppliers still approach product development as if each vehicle program were completely unique. The result:

- Engineering teams are forced to re-scope, re-specify, and re-validate common assets — brake control software, E/E architecture configurations, and functional safety documentation across every model line.
- Compliance and traceability are reinvented for each project — whether for ISO 26262 functional safety, ISO 21434 cybersecurity, UNECE WP.29, ASPICE, or SOTIF.
- Interoperability with suppliers and partners is a constant challenge — as Tier 1s, software vendors, and chipmakers each work from different baselines.

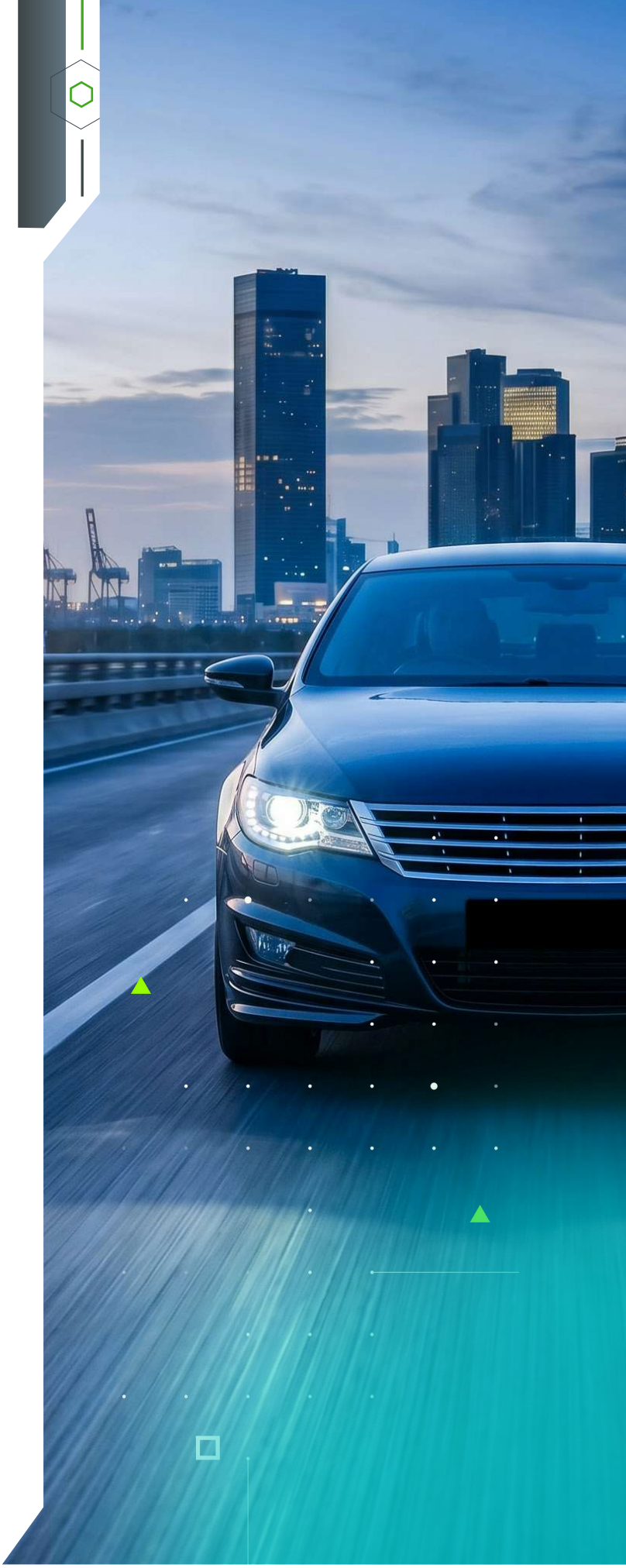
VARIABILITY HAS BECOME A BARRIER TO AGILITY

Every vehicle in the automotive industry is unique, due to different powertrain configurations, regional emissions regulations, market-specific safety requirements, or customer-specified option packages. This variability is essential — but it is also the root cause of duplication, inefficiency, and engineering fatigue. Without a unified strategy to manage variability, reuse becomes a liability rather than an asset. Project teams resort to "clone-and-own" practices, copying past designs and modifying them ad hoc. Over time, this leads to a proliferation of loosely related vehicle variants and software branches that are:

- Hard to manage across global vehicle platforms (e.g., MEB, MQB, TNGA, BEV3)
- Difficult to certify against ISO 26262, ISO 21434, UNECE WP.29, and regional homologation standards
- Expensive to maintain across the vehicle's entire software lifecycle, including OTA updates

Worse yet, every new vehicle program or market-specific derivative triggers a new project — with its own risks, learning curve, and duplication of effort. Talent is spread thin. Institutional knowledge is fragmented. And the organization loses the ability to scale.

For automotive leaders, the implications are clear: Without transformation, engineering becomes a bottleneck to vehicle launch, system development, and market competitiveness.



FEATURE-BASED PRODUCT LINE ENGINEERING

Product Line Engineering (PLE) is not simply an engineering optimization — it is a strategic transformation. Despite increasingly dynamic requirements, regulations, and growing systems complexity, feature-based PLE empowers automotive OEMs and Tier 1 suppliers to engineer entire vehicle product lines — not just isolated one-off programs.

Instead of designing each system variant from the ground up, feature-based PLE creates a controlled, automated process for defining and assembling system configurations from a common, validated asset base.

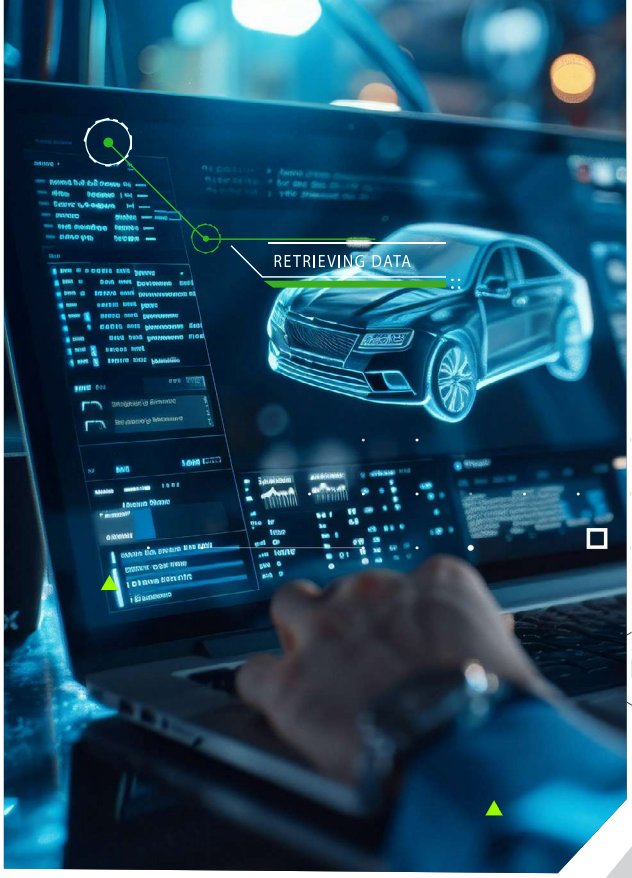
At its core, PTC's feature-based PLE solution, Pure Variants, establishes a model for system engineering, structured around four foundational elements:

SHARED ASSETS

All digital artifacts — embedded software modules, ECU configurations, AUTOSAR components, test cases, documentation, and verification data — are consolidated into a 150% model that includes embedded variation points. These assets represent the reusable core of the product line.

FEATURE CATALOGUE

A structured model that captures the complete set of product features, such as powertrain options (ICE, BEV, PHEV), ADAS capability levels, regional safety and emissions standards, cybersecurity configurations, and connected-car service



packages. This catalogue provides a common vocabulary for managing variability across the entire organization.

VARIANT CONFIGURATION

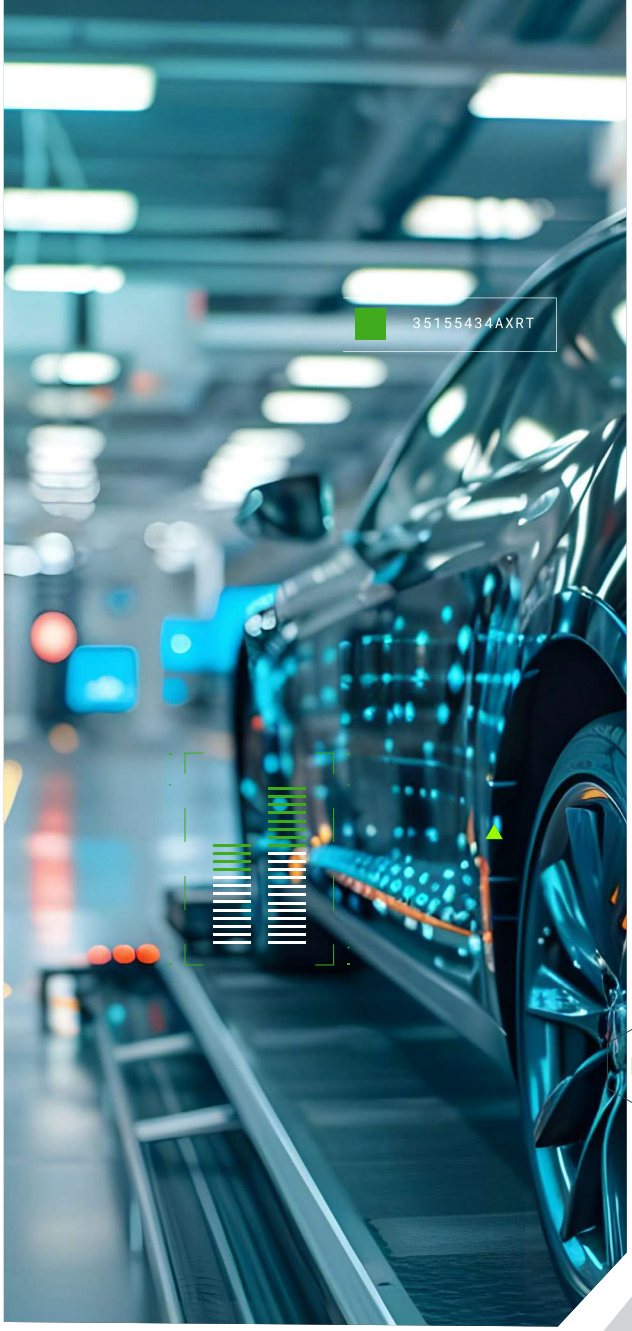
Each individual vehicle variant is described using a product or variant configuration — a precise specification of selected features based on market, regulatory, or customer requirements. This acts as the blueprint for generating tailored configurations.

AUTOMATED VARIANT DERIVATION

This applies selected features to shared assets, automatically producing the correct set of artifacts for a given product variant. This tight integration significantly reduces time, errors, and manual overhead.

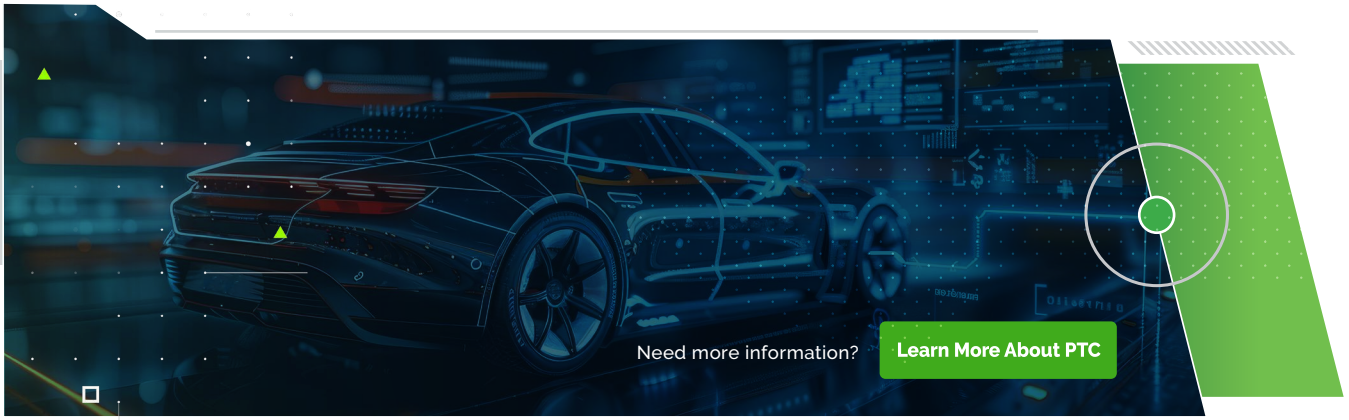
This PLE approach, based on international standards like ISO/IEC 26580:2021, ISO 26262 and ISO/IEC 26550 enables automotive organizations to:

- Move from a reactive, project-based model to a proactive, product-line-centric strategy.
- Strengthen traceability and artifact consistency in support of ISO 26262, ASPICE, and UNECE WP.29 compliance activities.
- Scale across domains and disciplines — from embedded software to mechanical systems to documentation. Once PLE is established, engineers collaborate on evolving the shared asset base and the Feature Catalogue, rather than duplicating work across isolated programs. Changes are governed and propagated systematically, and the creation of new system configurations becomes a variant derivation process — not a new development effort. This shift not only delivers faster, higher-quality results but also creates strategic alignment between engineering, program management, and suppliers, while producing the structured evidence regulators require.

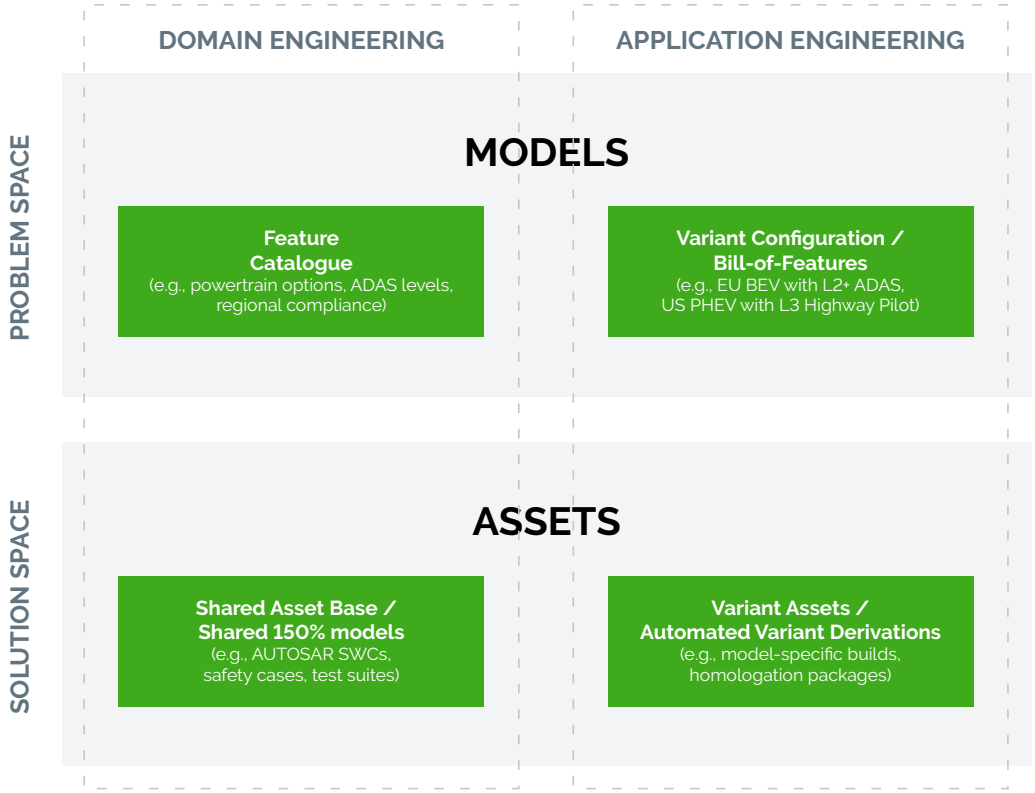


STRATEGIC BENEFITS FOR AUTOMOTIVE

- Faster Time-to-Market: Rapidly configure vehicle variants for new markets, regional regulations, or customer-specific option packages — without configuring from scratch.
- Reduced Risk: Reuse of validated components reduces integration risk — essential for supporting ASPICE process assessments by providing governed, repeatable engineering workflows.
- Improved Quality: Governed changes propagate systematically across affected variants — reducing inconsistency and strengthening traceability.
- Engineering Focus: Free top talent from repetitive tasks and let them drive innovation where it matters — such as next-gen ADAS, AI-powered cockpits, and zonal E/E architectures.
- Stronger Supply Chain Interoperability: Suppliers receive precise, variant-specific work packages derived from the OEM's feature model — reducing ambiguity, rework, and misalignment across the supply chain



PRODUCT LINE ENGINEERING IN A NUTSHELL: SEPARATION OF PROBLEM AND SOLUTION SPACE — ISO 26550



REAL-WORLD SUCCESS CONTEXT: PLE AT SCALE IN AUTOMOTIVE

Leading automotive organizations are recognizing the transformative power of PLE.

THE AUTOMOTIVE PLE IMPERATIVE

Modern vehicle platforms are inherently product-line architectures - built from shared, modular foundations that support dozens of models, configurations, and markets. Yet without systematic variant management, the software and systems layer above these hardware platforms remains fragmented, duplicated, and difficult to certify. Integrated PLE closes this gap by providing a structured, automated approach to managing the variability that sits atop modular vehicle architectures.

"For us, the value proposition of PLE is to improve the quality and consistency of engineering artifacts to address quality problems. To constrain electrical-software system complexity centrally and collaboratively is crucial to avoid pain. End-to-end PLE offers an order of magnitude reduction of manual effort." – Major Automotive OEM.

TIER 1 SUPPLIER ADVANTAGE

For Tier 1 suppliers developing ADAS controllers, battery management systems, or cockpit electronics for multiple OEMs, PLE supports traceability across customer-specific variants — reducing bid-to-delivery time, improving quality, and ensuring compliance across programs.

"Product Line Engineering has fundamentally changed how we manage complexity across our product portfolio. By shifting from variant duplication to a reuse-driven, model-based approach, we can systematically manage variability and maintain consistency across global product lines. This enables our teams to accelerate development, improve cross-domain collaboration, and scale innovation in increasingly software-defined environments – without compromising quality or governance." - A major Tier 1 supplier

SDV-READY ENGINEERING

As vehicles transition to centralized compute architectures and continuous software updates (OTA), PLE ensures that every software variant across every vehicle in the program remains traceable and configurable — a prerequisite for safe, scalable software-defined vehicle operations.

These aren't just digital transformation initiatives — they are competitive advantages.

EXECUTIVE SUMMARY: CONTROL THROUGH CONSISTENCY

In automotive engineering, competitive edge depends on speed to market, cost efficiency, and the ability to ensure compliance at scale across increasingly software-intensive vehicle platforms. Traditional engineering approaches, which are fragmented, manual, and slow, no longer meet the demands of modern programs or the expectations of regulators and consumers.

This whitepaper presents Feature-Based Product Line Engineering (PLE) as a key strategy to meet the demand for increasingly complex automotive systems — by enabling the reuse of engineering assets, reducing duplication, and managing variability across vehicle families and global markets.

Product Line Engineering is not just a development method. It's a transformation of your operating model and a mission-critical enabler for the digital era. Instead of building each system from the ground up, teams work from a validated, governed core, achieving speed, precision, and reuse across the product line. This approach accelerates delivery by aligning engineering, program management, and suppliers through a common feature model. Feature-Based PLE enables true end-to-end reuse — from requirements through design, software, hardware, and testing — empowering teams to rapidly configure, validate, and deliver market-ready vehicle systems that meet evolving customer and regulatory demands.

By adopting PLE, automotive manufacturers gain:

- Greater agility to respond to new market requirements, regional regulations, or customer-specific configurations — without engineering from scratch
- Strategic reuse across vehicle platforms and variants, cutting costs and saving engineering hours
- Accelerated time-to-launch through automated configuration of vehicle derivatives
- Strengthened traceability and governed change management that supports ISO 26262, ASPICE, and UNECE WP.29 audit readiness.
- A unified digital foundation that supports MBSE, PLM/ALM, and software-defined vehicle initiatives

Feature-based PLE empowers platform-centric engineering teams to turn complexity into control and variability into value. It helps organizations scale innovation, ensure compliance and adapt to evolving requirements – without compromise. Powered by PTC's integrated digital engineering solutions, PLE becomes a force multiplier — driving faster launches, improved margins, and greater confidence across every vehicle program. From next-generation EV platforms to advanced ADAS systems, PLE ensures that every variant is delivered right the first time.

Start your journey today. Your next vehicle program begins with consistency and control. Talk to our experts to find out how PLE from PTC helps automotive leaders scale with confidence.

ptc.com/en/industries/automotive

Sources & References

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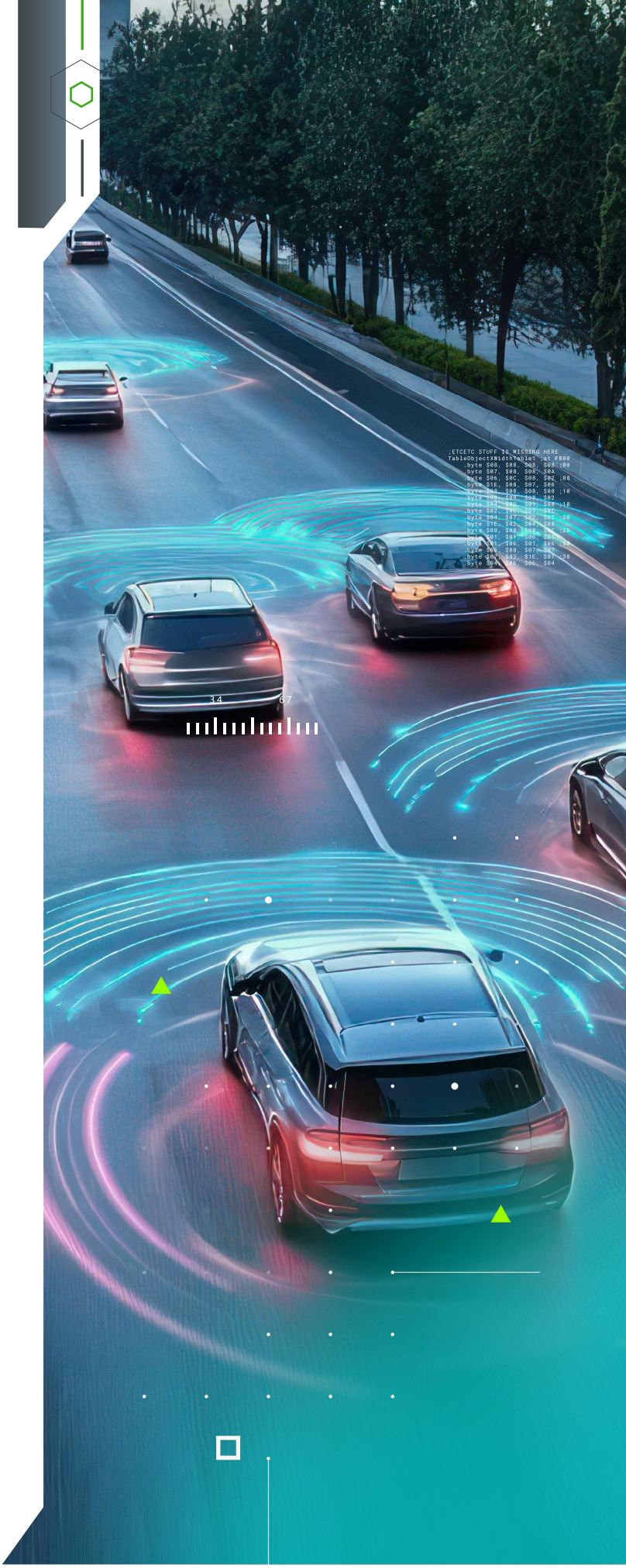

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