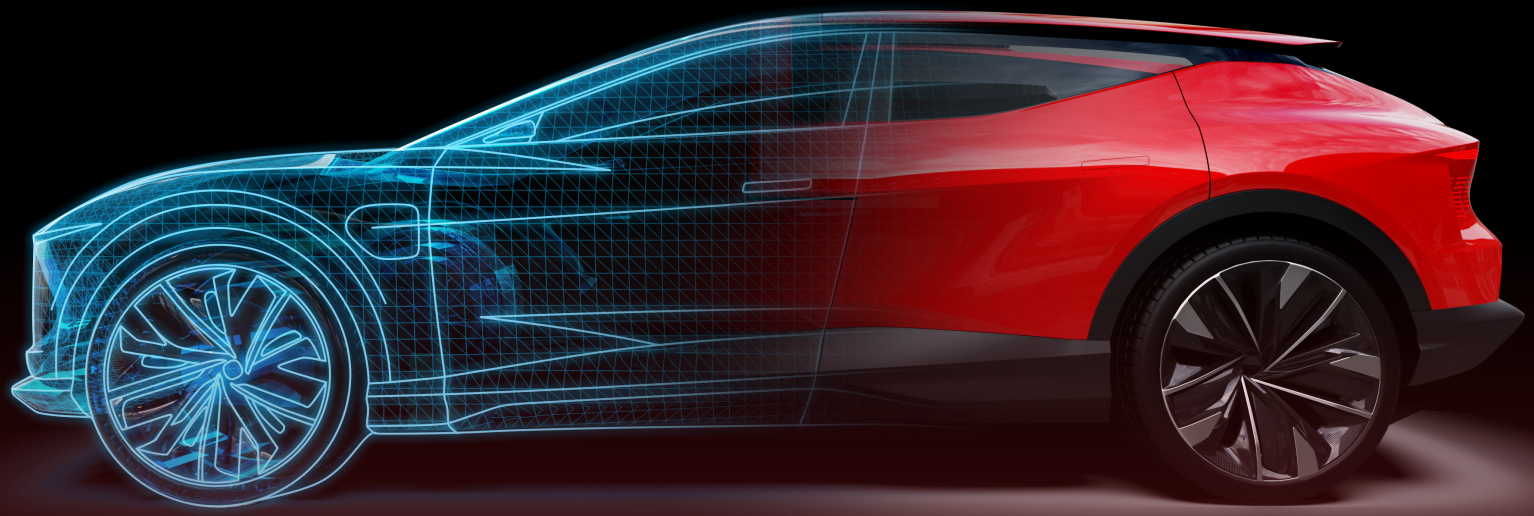


eBOOK

What OTA Update Solutions Must Deliver in the SDV Era

SONATUS

Foreword

In 2012, I was involved in pioneering over-the-air (OTA) software updates for cars while working at a major U.S. telecom operator, supporting connected services for a major automaker. We developed APIs, security architecture, and processes from scratch to deliver Java-based vehicle app updates over the 3G network, marking the first large-scale automotive OTA capability. Initially, we adapted standards from OTA phone updates (OMA-DM), but the industry has since evolved significantly with 4G/5G and software-defined vehicles (SDVs), leading to the development of specialized, automotive-grade software update solutions to meet the unique demands and security requirements of in-vehicle software.

According to the SBD Automotive Connected Car Forecast, 2 out of every 3 cars sold in 2024 in the United States, Europe, and China are OTA-capable, with over 180 million vehicles on the road across the United States, Europe, and China being OTA-capable by the end of the year. This number will increase to nearly 500 million by the end of the decade.

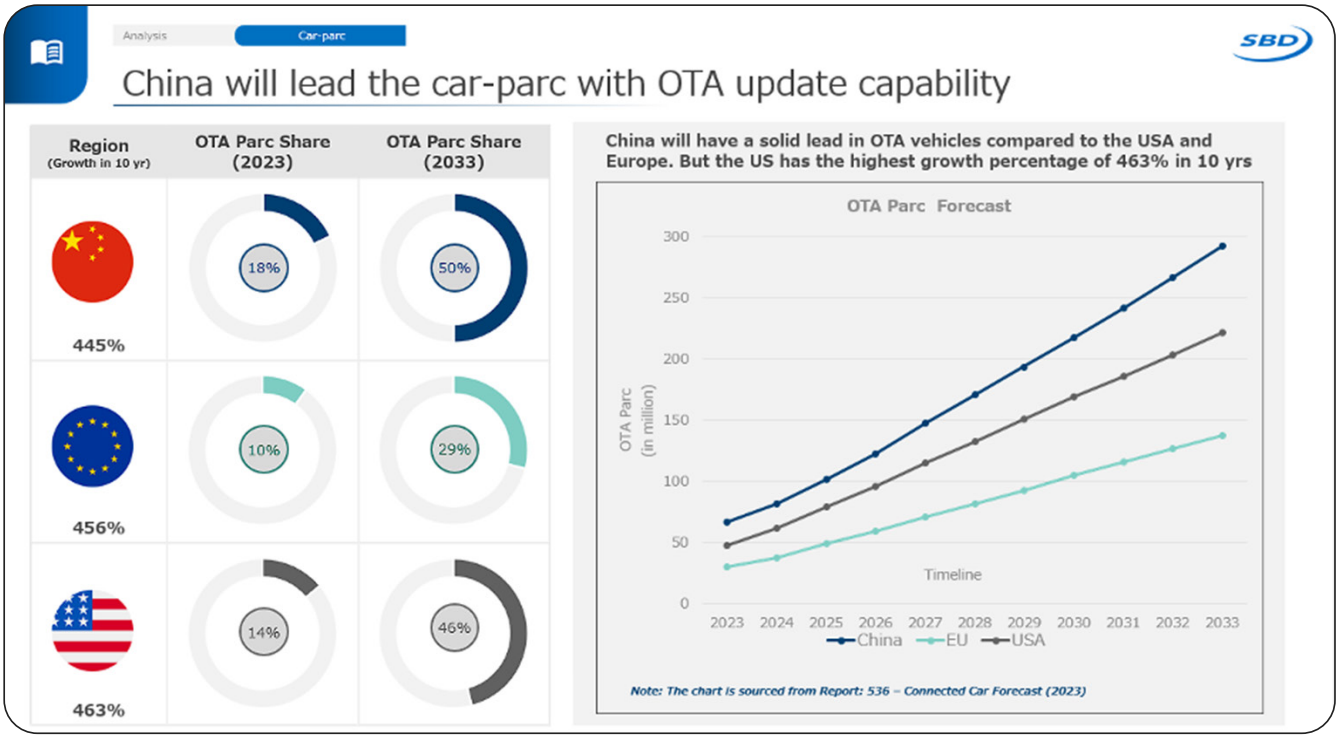


Figure: OTA Car Parc Forecast from SBD Automotive Connected Car Forecast 2023

Automakers will increasingly be relying on well-engineered solution partners like Sonatus for SDV-enabling capabilities such as OTA software updates thanks to stringent regulatory requirements related to cybersecurity and automated driving, specifically for type approval in countries that observe UNECE standards. It's incumbent upon automakers to drive safer, more secure, and more seamless mobility experiences through tactful, responsive use of these capabilities. Well-defined partnerships

between automakers and OTA solution providers will be bolstered by the accelerating shift to zonal electronic architectures and consolidated vehicle software platforms, paving the way for expansive and iterative delivery of new experiences, features, and improvements to car owners.

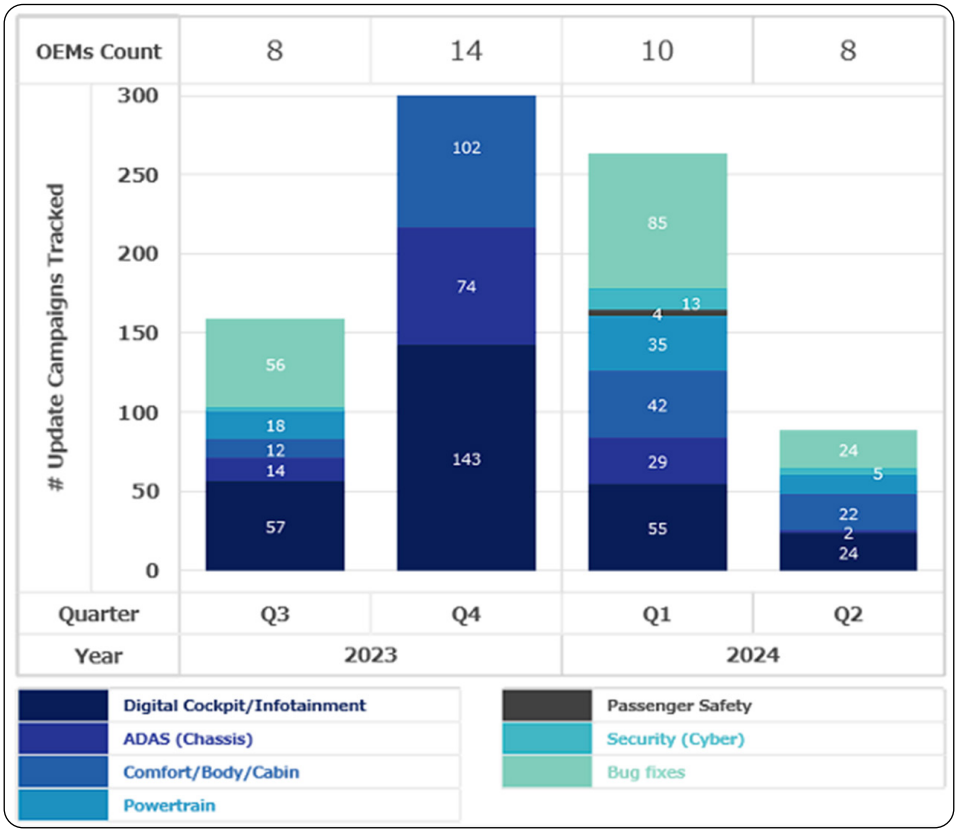


Figure: OTA Update Campaigns '23-'24 - SBD Automotive OTA Tracker Q2 2024 USA Edition

With over 800 individual software update campaigns identified across all OEM brands within the United States between Q3 2023 and Q2 2024 within our OTA Tracker, the OTA-enabled "arms race" is just beginning. I'm looking forward to following the mutual innovation in developing more reliable and capable OTA solutions as OEM solution requirements continue to mature. As the Sonatus team writes here, there is a mutual responsibility to maximize the return on investment in this technology: while the provider must continue to provide safe, secure and reliable infrastructure and campaign management tools, the OEM must have the skills and CI/CD development tools to achieve faster development cycles from concept to car.

Foreword by Alex Oyler, director at SBD Automotive, a global automotive research & consulting firm. Alex spearheaded the first industry report on over-the-air updates in 2016 and the first industry report on SDVs in 2021.

Table of Contents

What OTA Solutions Must Deliver in the Era of SDVs

As the automotive industry shifts towards producing software-defined vehicles (SDVs), the role of over-the-air (OTA) updates is becoming not just important but essential. Unlike vehicles built heretofore, SDVs will be designed to continuously evolve throughout their lifecycle through software updates that enhance vehicle performance and improve the user experience - all without a visit to the dealership. For automakers, this shift means that their OTA solutions must be as robust and flexible as the vehicles they support.

SDVs are platforms for continuous innovation

At the heart of an SDV is greater configurability by decoupling software from hardware to make the shift towards software-led innovations. In SDVs, critical functions such as powertrain control, infotainment, and advanced driver assistance systems (ADAS) are managed by fewer, but more powerful, electronic control units (ECUs). This consolidation simplifies the vehicle's architecture but demands a sophisticated approach to software management.

SDVs are no longer static products; they are continuously updated and upgraded. This paradigm shift means that an OTA solution must address all vehicle domains, providing updates across diverse types of software and hardware configurations. It's no longer just about fixing bugs and firmware changes. Instead, it's about rolling out new features and updating existing ones that will increasingly run on sophisticated containers and hypervisors, while ensuring compatibility with heterogeneous hardware and software configurations across multiple product lines.

Therefore, OTA solutions must be purposely designed to tackle the complex demands of frequent and diverse software updates that will define the era of software-defined vehicles.

Support for vehicle-wide updates and diverse types of software

As more vehicle features and functions become software-defined, an OTA solution must be able to support more vehicle domains and software types. This includes wholesale feature upgrades, bug fixes, minor updates, deployment of AI models, policy and configuration changes, and more. The challenge also lies in the diversity of hardware to which these updates must be applied —from HPCs to ECUs and MCUs. The solution must be capable of managing these complexities while delivering updates seamlessly and efficiently.

To meet these needs, OEMs must embrace OTA solutions that can manage updates using a single-pane-of-glass approach. A unified approach allows for creating comprehensive update packages while carefully managing dependencies and sequencing across the disparate vehicle software bill of materials (BOM) and hardware versions in a fleet. It's about more than just pushing updates; it's about ensuring that each update is delivered in the right order and without disrupting the vehicle's functionality.

Frequent and continuous deployment cycles

The software lifecycle in SDVs is drastically different from traditional vehicles. In the past, vehicle updates were infrequent and often involved a visit to the dealership. Looking ahead, SDVs will need to support a continuous deployment cycle, with updates rolling out on a monthly and even weekly basis. This shift from quarters or years between updates to weeks means that OTA solutions must be operationally efficient, reducing transmission and in-vehicle resource costs while minimizing disruption to the end user.

Integration with continuous integration and continuous deployment (CI/CD) pipelines is critical to realize this new reality. OTA solutions must integrate seamlessly with cloud-native toolchains, enabling automakers to push updates as quickly as they are developed. This requires not just technical capability but also a shift in the operational mindset of automakers, who must now think more like software companies, focusing on increased agility and speed, without compromising safety.

Robust, reliable and secure operations

As SDVs become more software-centric, the stakes for OTA updates are higher than ever. The consequences of a failed update range from a loss of functionality up to serious safety risks and damage to the OEM brand. Therefore, OTA solutions must ensure end-to-end reliability, from the cloud where the updates are managed, to the individual ECUs and sensors in the vehicle.

Predictability is key. Automakers need to uncover potential conflicts and issues before updates are deployed to the greatest extent possible, ensuring that updates are not only successful but also transparent to the user. When issues do occur, faster resolution is essential. This requires a robust operational framework that can quickly diagnose and fix problems, minimizing downtime and protecting vehicle safety.

The increased frequency of updates also requires that vehicles can accept them more readily. Making sure that vehicles are in a safe condition to receive the updates will require that OTA solutions can monitor for detailed readiness conditions to reliably find the right windows of opportunity to apply them, including securing user consent when necessary.

Security is another critical aspect. As vehicles become more connected, they become more vulnerable to cyber threats. OTA solutions must include robust end-to-end security measures to prevent tampering, malicious acts, and damage to vehicle systems. This involves not only securing the update process itself but also ensuring that the vehicle's systems are resilient to potential attacks.

Sonatus Updater:
An OTA solution purpose-built for SDVs

Sonatus Updater has been designed from the ground up to address the needs and challenges of OTA software updates for SDVs. Updater is part of the Sonatus Vehicle Platform, a diverse product portfolio designed to accelerate automakers' transition to Software-Defined Vehicles (SDVs). This platform includes Sonatus Foundation, Sonatus Collector, Sonatus Automator, Sonatus Guard, and Sonatus Updater, each serving a unique role: Foundation enables flexible and dynamic vehicle E/E architectures; Collector offers cost-effective and precise data collection; Automator provides no-code feature enhancements to add intelligence to vehicles; Guard proactively detects and mitigates cybersecurity threats; and Updater ensures the success of all software updates from a single-pane-of-glass.

These products can be used independently or as an integrated suite, empowering OEMs to continuously enhance the driving and user experience throughout the lifetime of their vehicles.

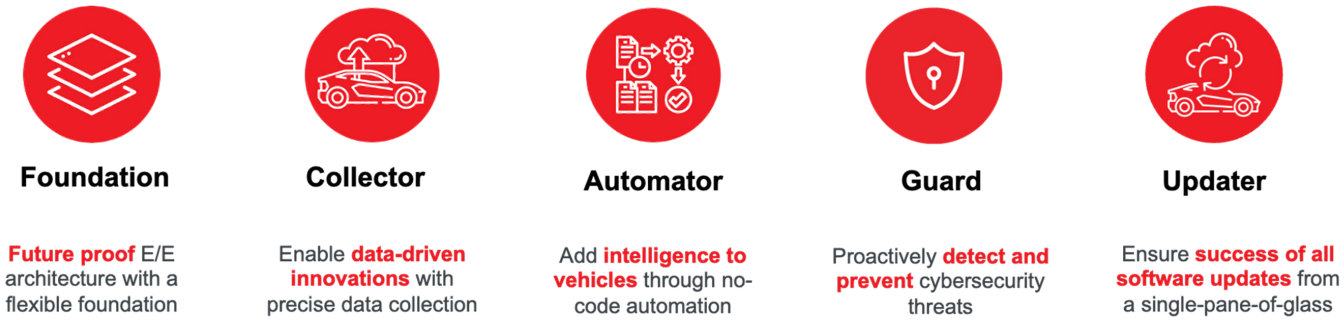


Figure: Sonatus Vehicle Platform product portfolio

Sonatus Foundation, Collector, Automator and Guard leverage lightweight policies that can be quickly created and applied through the Sonatus Command Center, a cloud-based management portal. These policies enable many updates and changes to vehicle software and applications without needing a full OTA process.

Overview of Sonatus Updater

Sonatus Updater serves as the one-stop solution for more substantial updates, managing both lightweight and comprehensive update operations. Combined, Updater and the rest of the Sonatus portfolio provide OEMs the flexibility to employ a range of update methods to keep vehicles continuously updated with the latest innovations and improvements, in pre-production and post-sales.

Sonatus Updater is designed to streamline frequent vehicle updates required for SDVs, with reliability and operational efficiency through the following capabilities.

Single-pane-of-glass operations

Sonatus Updater provides comprehensive management of all vehicle software asset updates, including firmware, network configurations, application policies, edge AI/ML models, containers, and configuration parameters. It delivers A/B updates to ECUs that support it, along with fail-safe rollback, ensuring seamless transitions and reliable software management.

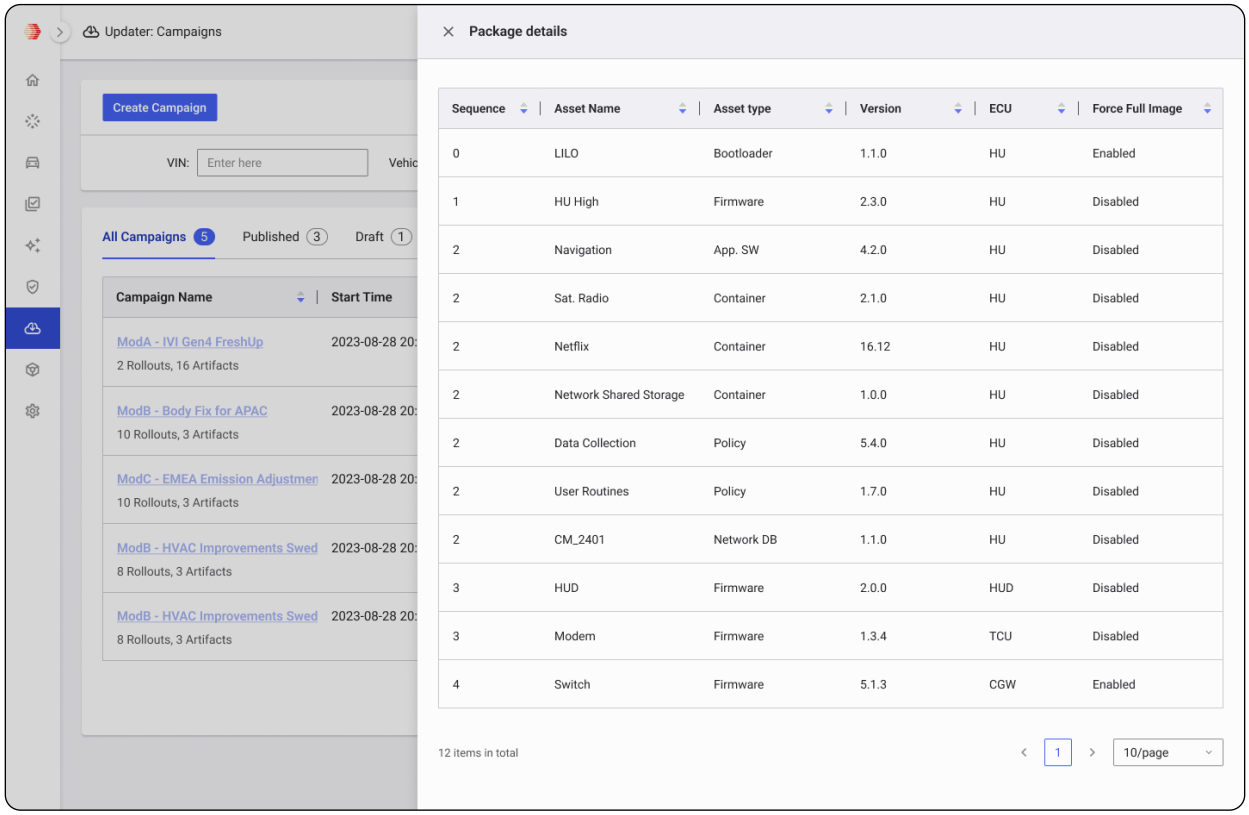


Figure: Single-pane-of-glass operations

Comprehensive and seamless vehicle-wide updates

Updater is designed to handle seamless A/B updates across the vehicle E/E architecture, including for the following key elements.

High-Performance ECUs

SDVs will increasingly be equipped with more capable high-performance ECUs to host various vehicle systems including cockpit controllers, telematics units, ADAS, and central gateways. For such ECUs, Updater supports advanced protocols like DoIP (Diagnostics over Internet Protocol) or SOVD (Service-Oriented Vehicle Diagnostics) to handle complex updates.

Updater's Update Agent facilitates A/B transitions, including support for uboot/bootloader customization for Linux A/B updates.

CAN ECUs

For classic ECUs, such as those controlling doors, body, comfort, and chassis, Updater utilizes UDS (Unified Diagnostic Services) to reliably apply or roll-back updates.

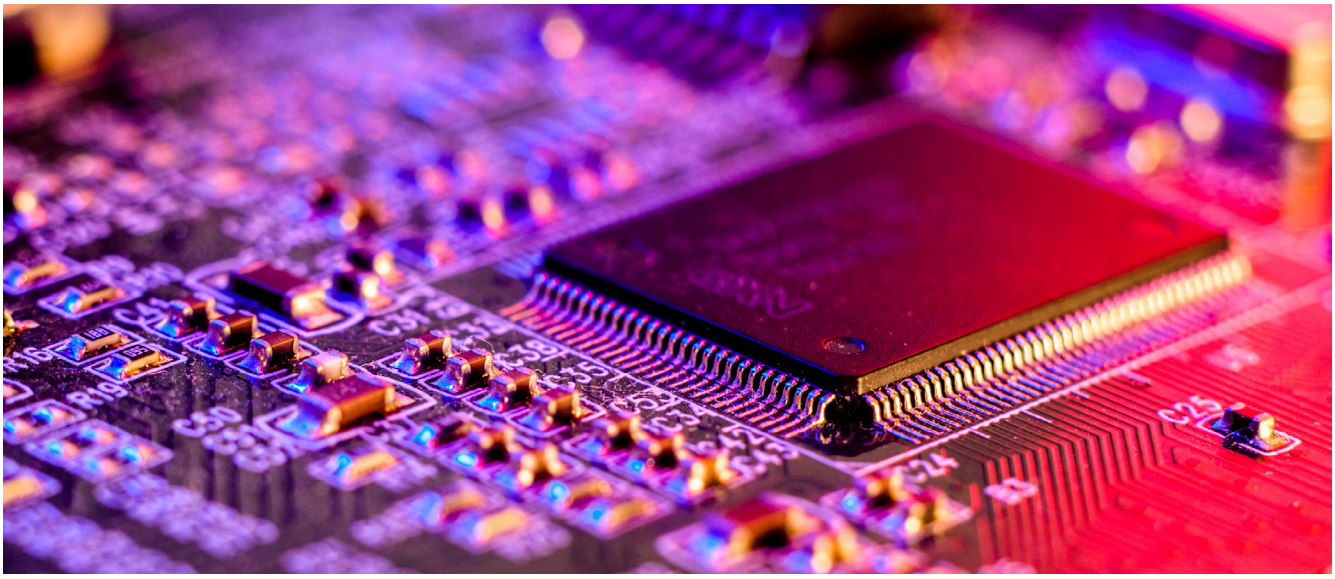
Updater's UDS Update Agent initiates the UDS reprogramming sequence to complete the A/B operation. If A/B updates are not directly supported by the CAN ECU, the UDS Update Agent will invoke reprogramming with the previous image to perform a rollback. This requires CAN ECU suppliers to support UDS reprogramming within the bootloader.

Ethernet Switches

For Ethernet Switches, Sonatus Network Manager offers A/B update support for firmware across all major switch vendors, including NXP, Marvell, Broadcom, and Realtek.

Containers

Additionally, for application and container updates, the Sonatus Container Update Agent manages both the old and new container images, enabling smooth A/B transitions and robust update processes for containerized applications.



Dynamic policy updates

In addition to firmware and container settings, policy updates for the other Sonatus products adopted by OEMs can be also managed by Updater. Policies to set zonal/network configurations, data collection procedures, cross-domain software orchestration workflows, and cybersecurity measures. These updates are lightweight in size - measuring in the tens of kilobytes - and can be installed in near real-time to make changes more dynamically.

Support for edge AI/ML models

SDVs will also serve as intelligent edge devices running various AI/ML models to track and improve vehicle performance, vehicle health and customer experiences. In addition to the allocation of compute resources, these models will require access to various vehicle signals and systems through the creation of data pipelines. Updater can be used to deploy policies to set up such pipelines in addition to the allocation of computing resources.

User-defined fail-safe thresholds

Additionally, OEM's OTA operations administrators can define failsafe thresholds. Updates that fail these thresholds are automatically rolled back. Some examples of thresholds include -

- As soon as one ECU fails, rollback all ECUs involved in the update
- Define rolling updates in batches of one, 10, 100, 1000, etc., in which failures beyond the set threshold percentage will pause further updates until the cause of failures are resolved.

Predictable, reliable and secure operations

As software updates become increasingly mission critical to SDVs, it is paramount that OTA operations have a high degree of predictability and security. Updater offers the following capabilities to achieve this.

End-to-end traceability and debugging

The Sonatus Updater provides automotive OEMs with unparalleled, step-by-step traceability into the Over-the-Air (OTA) update process, from the cloud all the way down to individual Electronic Control Units (ECUs). Updater's step-by-step visibility and advanced debugging capabilities allows OEMs to proactively find, troubleshoot, and fix potential issues up to 70% more efficiently.

Troubleshoot and resolve OTA failures up to 70% faster using end-to-end traceability

Complete visibility throughout the update lifecycle

With Sonatus Updater, OEMs gain complete transparency into every stage of the OTA update process. The solution captures detailed telemetry data, providing a comprehensive overview of update progress, process duration, failure reasons, and rollback events. This enables manufacturers to pinpoint exactly where issues arise and understand the root causes of any anomalies.

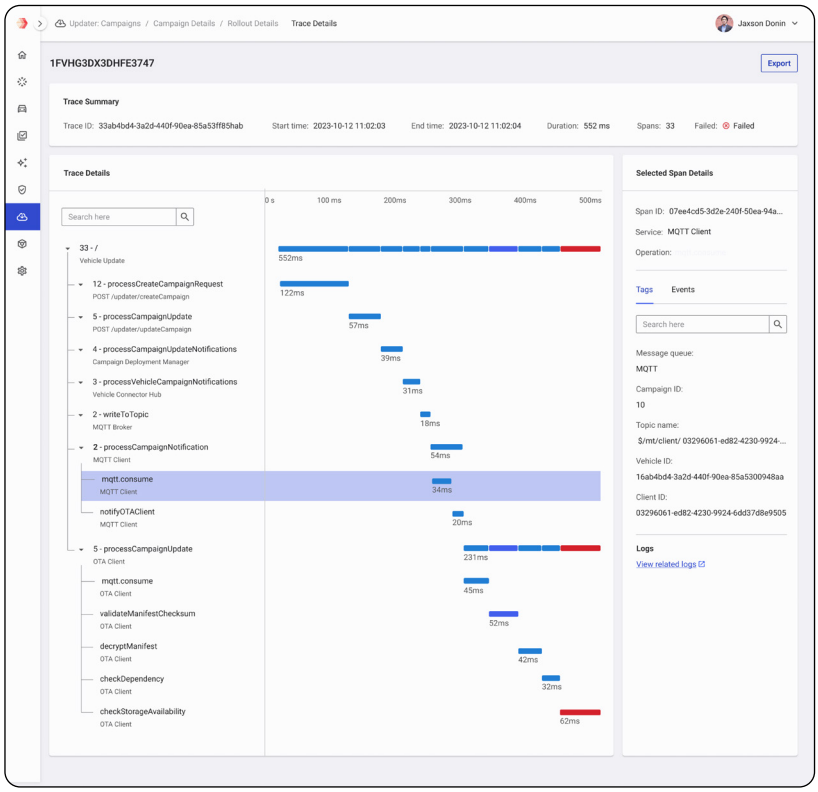


Figure: End-to-end traceability

Advanced data correlation

Sonatus Updater utilizes a powerful TraceID mechanism to group and correlate all relevant data points, offering a unified view of OTA campaigns from start to finish. By leveraging TraceID, OEMs can connect the dots between multiple events, services, and processes, making it easier to detect patterns and potential bottlenecks, diagnose problems, and implement fixes quickly.

Granular insights for proactive troubleshooting

The solution offers granular insights into event detail metrics, such as processes, services, events, and tags, enabling OEMs to delve deep into the specifics of each OTA update event. This level of detail empowers technical teams to conduct thorough analyses and make informed decisions to improve the performance and rate of success of update campaigns.

Seamless integration with vehicle data

Sonatus Updater seamlessly integrates with vehicle data and log traces, allowing for effortless deployment and data analysis. By combining this with detailed telemetry, OEMs can monitor the entire OTA process in real time, ensuring that any deviations from expected behavior are identified and addressed promptly.

Customizable alerts for real-time monitoring

To further enhance the monitoring and management capabilities, Sonatus Updater features customizable alerts that notify stakeholders in real-time of critical events or deviations from expected OTA update behavior. This ensures that any potential issues are flagged immediately, allowing for swift corrective actions to improve update performance.

Cloud-based simulated dry-runs

Updater allows OEMs to perform cloud-based simulated dry-runs of OTA update campaigns on digital twins that mirror the exact software and hardware specifications of each vehicle. This feature enables OEMs to preemptively identify and resolve potential issues, ensuring smoother and more reliable OTA deployments of the actual update process.

Simulation of OTA update process

Updater simulates the OTA update process against actual vehicle configurations in the cloud to detect potential issues and bottlenecks before deployment. By running these simulations on digital twins, OEMs can test updates without risking actual vehicles, minimizing disruption and ensuring a seamless update experience.

Cost and resource estimation

Sonatus Updater provides detailed estimations of the total cost of the OTA campaign, including total bandwidth consumption, bandwidth required per vehicle, installation times, and estimated completion dates. This foresight allows OEMs to plan resources effectively by determining the expected cost of updates over cellular networks to determine if a less costly approach over Wi-Fi is more desirable in certain cases.

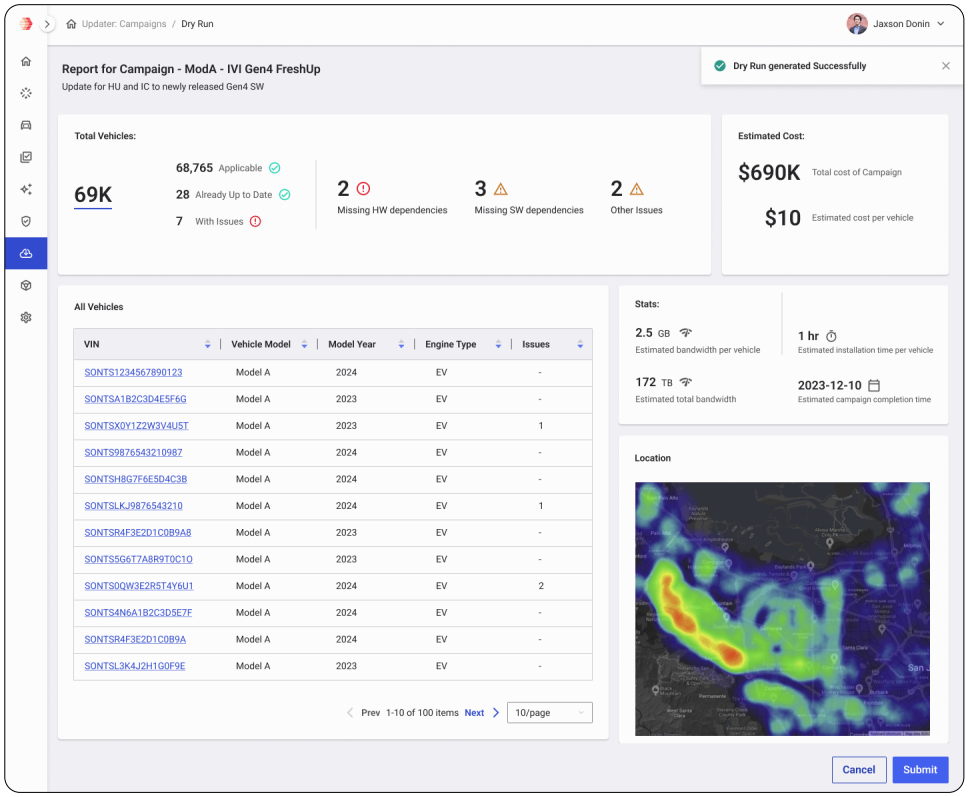


Figure: Cloud-based simulated dry run

Compatibility analysis

By analyzing potential compatibility issues with specific hardware and software configurations, the simulated dry runs help OEMs identify vehicles that might encounter problems during updates. This enables targeted remediation efforts and reduces the risk of update failures.

Detailed reports and insights

The simulations generate comprehensive reports and insights, offering OEMs valuable data for decision-making and planning. These reports include detailed metrics on update performance, potential failure points, and recommended actions to improve the deployment strategy.

Proactive remediation suggestions

Based on the outcomes of the simulations, Sonatus Updater suggests remediation actions, such as deploying pre-campaigns to address identified issues like missing prerequisites or creating service tickets for further investigation. This proactive approach ensures that OEMs can address potential problems before they impact the actual deployment, enhancing the overall effectiveness and reliability of OTA updates.

In summary, the cloud-based simulated dry-runs offered by Sonatus Updater allow OEMs to meticulously plan and refine OTA campaigns, reducing risks and improving operational efficiency.

Dependency management

As vehicle software Bills of Materials (BOMs) become increasingly complex, managing dependencies across different makes, models, years, trims, and hardware versions has become a significant challenge for OEMs. This complexity, if not handled properly, can lead to errors and update failures. Sonatus Updater addresses these challenges through a sophisticated approach that simplifies dependency management, and uses intelligent sequencing, and advanced pre-condition rules to ensure success.

Simplified dependency management

Sonatus Updater creates digital twins of vehicles by executing UDS (Unified Diagnostic Services) commands to gather detailed hardware and software versions of each vehicle, effectively creating a digital representation of each vehicle in the cloud. These digital twins enable cross-functional hardware and software dependency checks, ensuring that each update is compatible with the specific configurations of target vehicles, thereby significantly reducing update failures.

Intelligent artifact sequencing

Updater includes an advanced artifact sequencing capability that allows OEMs to control how software assets are installed and updated, within a single package and across multiple packages. This intelligent sequencing ensures that updates occur in the correct order, preventing conflicts and ensuring a smooth update process.

Advanced pre-condition rules

Updater offers a powerful precondition rules engine that lets OEMs define specific states or conditions under which updates can be applied. These rules go beyond basic vehicle states like ignition on or off, allowing for precisely defined triggers based on unique vehicle conditions. Conditions such as the vehicle's degree of incline, remaining battery charge, door locked/unlocked, windows up/down, and any combination of such vehicle states. This level of control enables OEMs to execute updates in a precise, predictable manner, tailored to unique vehicle make, model and trim.

Overall, Sonatus Updater's combination of dependency management, artifact sequencing, and fine-grained pre-condition rules provides OEMs with a robust framework for managing OTA updates, ensuring a high level of precision, predictability, and success in the update process.

Cybersecurity and safety

With the benefits of over-the-air software updates come the risks of cybersecurity tampering and intrusion. In addition to strict controls over operations through role-based access and control (RBAC), Updater complies with the following standards and practices to ensure integrity and safety of vehicle OTA updates.

UNECE R155

Updater complies with the R155 requirement to work with Cybersecurity Management Systems (CSMS) to ensure cybersecurity risks can be detected and mitigated to protect the integrity of vehicle updates. Updater supports the following to meet the compliance requirements.

- Management of cybersecurity risks related to OTA updates, across the vehicle's lifecycle.
- Continuous risk assessments to ensure OTA updates do not introduce cybersecurity vulnerabilities.
- Uses security measures like encryption and digital signatures to prevent unauthorized access and tampering.
- Provides mechanisms to detect and respond to cybersecurity incidents related to OTA updates.
- Continuous monitoring to address new cybersecurity threats through OTA updates.

UNECE R156

Updater complies with the requirements of R156 to establish a Software Update Management System (SUMS) to ensure updates are safe, secure, and effective.

- Updater allows OEMs to manage software integrity, version control, and update procedures to minimize risks associated with software changes.
- Updater includes robust documentation and validation processes for software updates.
- It supports clear communication to users about updates, including their purpose and impact, is mandated.

Uptane Framework

Updater adheres to Uptane's mandates for using cryptographic signatures and multiple layers of verification for OTA updates, ensuring that only authorized and authentic software is installed.

Updater supports the various entities and roles as defined by Uptane, each with specific responsibilities for secure update delivery and validation.

- It uses metadata to verify updates, ensuring that the correct software version is installed, preventing rollback attacks, and verifying the authenticity and integrity of update packages.
- It includes mechanisms to detect and recover from compromised components in order to maintain the integrity of vehicle software and updates
- Updater allows rigorous testing of all updates before deployment by simulating real-world conditions and verifying the update's integrity and functionality in a controlled environment.

Operational efficiency to enable more frequent updates

The higher frequency of updates envisioned for SDVs will require a greater degree of operational efficiency and lower costs. The functionalities in this section address both by lowering cellular transmission costs by optimizing update sizes and streamlining the software deployment process.

Reduce update package sizes by up to 95% using Intelligent Delta

Reduction in update sizes through Intelligent Delta feature

To handle the more frequent updates more efficiently, OEMs need OTA solutions that optimize the size of updates, reducing both cost and time associated with software deployments. Updater's Intelligent Delta feature automatically compresses update packages to the most optimal size to lower transmission costs and reduce installation time.

Optimal delta package generation

The Updater's OTA server plays a crucial role by collecting the current running image version from all vehicles in the fleet. For each distinct combination of source and target versions, the OTA server uses Intelligent Delta to generate a delta package. This package contains only the differences between the current and target versions, compressed using the optimal algorithm for the specific software artifact involved.

Because the properties of different updates can vary greatly, Sonatus Updater's Intelligent Delta feature automatically selects the most suitable compression and delta calculation algorithm based on the type of software artifact being updated. This tailored approach ensures that each update package is as compact as possible, achieving up to 95% reduction in size, which significantly reduces data transmission costs and update times.

Efficient delivery and reconstruction

Once the delta package is created, the OTA server transmits it to the vehicle, along with detailed delta metadata, the chosen delta algorithm and associated parameters. Inside the vehicle, the Updater's OTA controller uses the locally stored current image and the received delta package to reconstruct the target image. This method not only streamlines the update process but also ensures that each update is accurately applied, preserving the integrity of the vehicle's software.

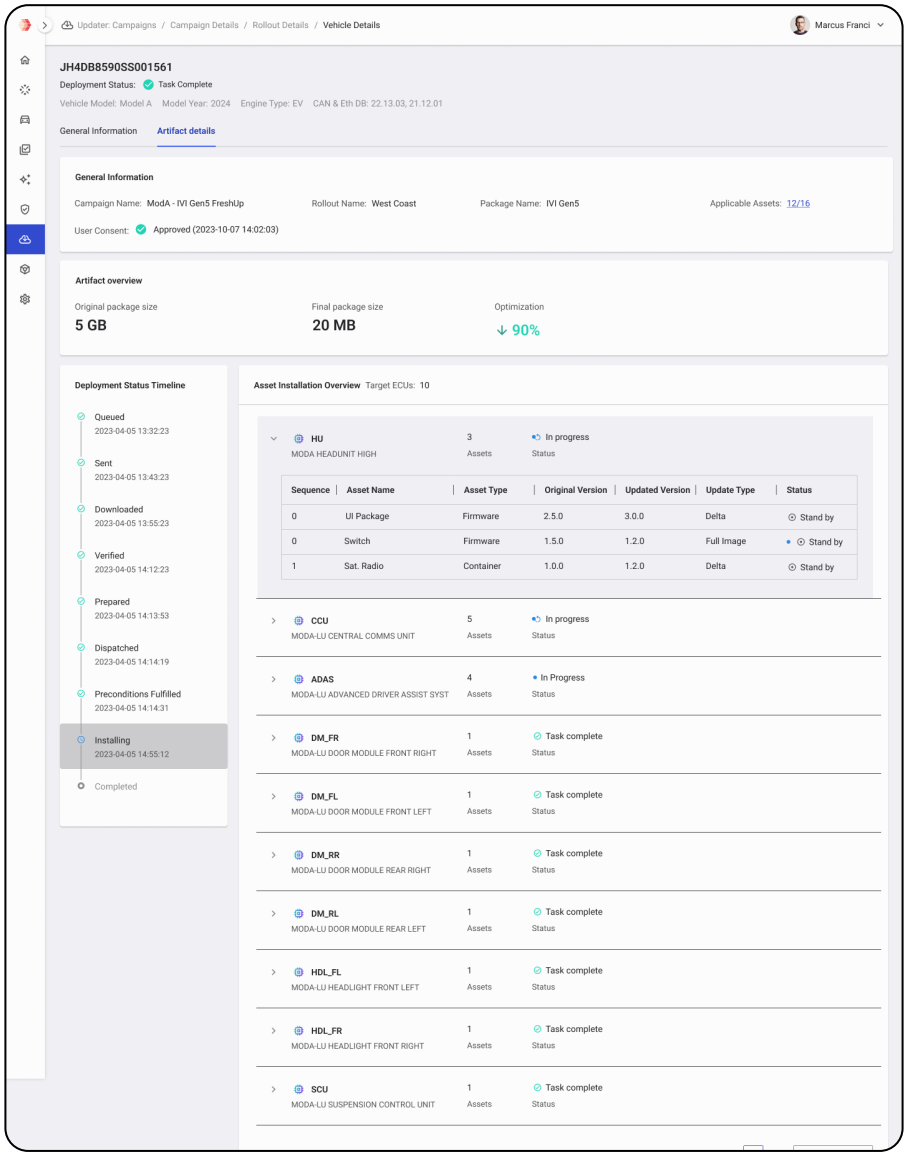


Figure: Intelligent Delta feature minimizes update package sizes

Seamless integration with CI/CD pipelines

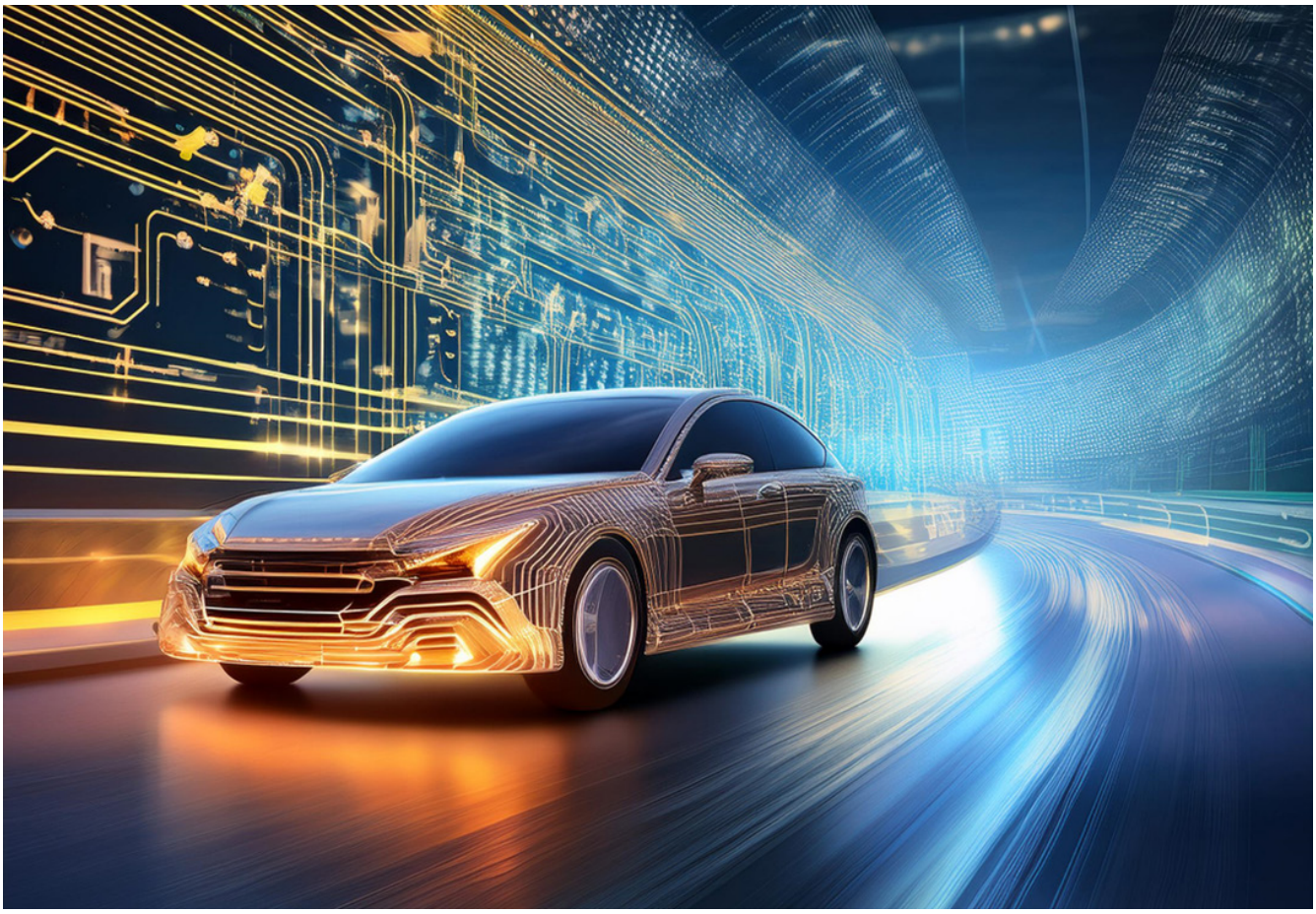
SDVs require cloud-native development and deployment to enable rapid innovation and continuous improvement. As OEMs and their suppliers implement CI/CD pipelines, it's crucial for Over-the-Air (OTA) solutions to seamlessly integrate with these automated tool chains to extend the process all the way to vehicle OTA updates.

Tested and validated software artifacts (binaries, container images, etc.) once approved, are deposited in either the OEM's or the supplier's image repositories. Sonatus Updater supports API integration with many of the commonly used repositories (e.g. Artifactory, JFrog, GitHub, GitLab) to automatically fetch the validated images to make them available as software artifacts for OTA campaigns.

This seamless integration allows for the automation of not just the CI/CD pipeline but also the entire OTA update process, ensuring that updates are quickly and reliably deployed to vehicles. By bridging the gap between software creation and deployment, Sonatus Updater enables a more efficient, end-to-end solution that streamlines the flow from image creation to vehicle updates, optimizing the entire lifecycle of software deployment in the automotive ecosystem.

Post-deployment, Sonatus Collector facilitates precise monitoring of vehicle telematics and user experience to ensure that the updates perform as expected. This feedback loop provides valuable insights to both the OEM and supplier, helping to identify issues or potential enhancements, which can then be fed back into the CI/CD pipeline for future updates through Updater.

Through this integrated approach, the OTA solution not only automates the CI/CD process but also extends it to the execution of comprehensive update campaigns, ensuring a seamless, secure, and efficient software delivery lifecycle for SDVs.



Summary: Deliver continuous innovations with an SDV-ready OTA solution

The shift to SDVs mark a new chapter in the evolution of the automotive industry - one where vehicles keep improving and deliver fresh driving experiences through software long after they are built and sold. OTA solutions play a pivotal role in this transition, and OEMs must adopt a solution that is uniquely suited for this new chapter. Sonatus Updater is purpose-built to handle the rigors of continuous and diverse software updates, delivering:

- **Ease of operations** through a unified interface to manage updates across the vehicle E/E architecture and diverse software types
- **High degree of success** through end-to-end visibility, cloud-simulation, fleet-wise dependency management, with adherence to strict security standards
- **Cost-efficient and seamless updates** through intelligent reduction of update sizes and integration with CI/CD pipelines

Sonatus Updater empowers automakers to stay agile and innovative in the software-defined era, ensuring vehicles remain at the cutting-edge throughout their lifecycle.

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