

SIEMENS

Ingenuity for life

Accelerating automotive innovation

Application lifecycle management (ALM) business best practices

Innovation has become an exercise of advancing embedded systems to stay ahead in the highly competitive automotive industry. While opening up great new opportunities, integration of software into mechatronics also presents unprecedented challenges to development teams. As different software and hardware components must be seamlessly fused to ensure functional safety and compliance, previously siloed teams must suddenly coordinate their development efforts in a dynamic ecosystem spanning the globe. But most collaborators don't have the unified tooling environment necessary to get them on the same page at the same time. Resulting disconnects show increasingly devastating impact, shaking the industry with new records in product failures, recalls, legal sanctions, loss in market position and associated cost explosions.

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Introduction

Topping the list of challenges in the new world of software-driven vehicles are the ever-accelerating pace in product development, the need for tight orchestration of all efforts, and the shifting role of suppliers as innovation partners. Automakers and manufacturers that are able to shift gears to meet the growing complexity and emerging trends will be well positioned to secure new market opportunities.

Advanced functionality in vehicles has become a market expectation. Just think about the parking assistance feature helping you get into even the tightest spots. In modern cars, not only can you see what's behind you on a screen, but an increasing number of models offer a feature that detects the size of a parallel parking space, guides you into the starting position, and then backs the vehicle into place without any action on your part.

To make this advancement possible, our cars have become rolling computers. It takes dozens of microprocessors running hundreds of millions of lines of code to get a premium car out of the driveway, and the software is only going to get more complex. Engines, transmissions, brakes, airbags and even power windows are equipped with intelligent electronics. Estimations indicate that more than 80 percent of car innovation already comes from computer systems. Software has become the major contributor of value, but also of new issues and associated costs.

Record numbers of recalls and the decrease in overall quality performance underline the need for new processes and tools to support collaborative software development and integration into associated systems. It is clear that the old way of managing software development in the automotive industry no longer suffices to address the wide range of challenges modern development teams face every day:

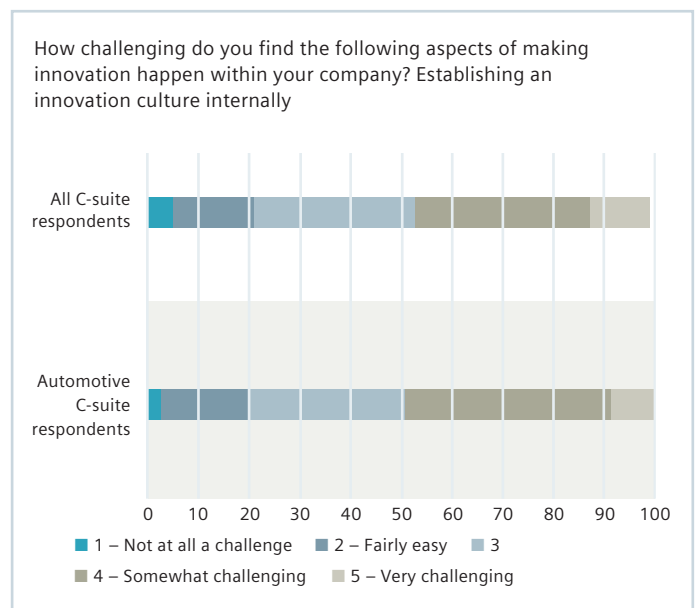
- Mounting speed in development and rising expectations for innovation
- Leverage existing assets and tools and re-use requirements to increase overall efficiency
- Increasing complexity of technology, supply chain and product portfolio
- Seamless integration of complex software for embedded systems
- Growing proportion of development and production processes delegated to suppliers
- Cost reduction mandates and competitive pressures diametrically opposed to safety requirements

The entire automotive industry is trying to come to terms with how to best deal with these challenges. According to Price Waterhouse Cooper's *17th Annual Global CEO Survey 2014*, based on 87 interviews across the automotive value chain conducted in 34 countries around the world, CEOs recognize that innovation is not going to slow down, and that global trends will continue to transform business. The following automotive CEO sentiments paint a picture of the road ahead:

- 79 percent anticipate that technological advances will be most transformative
- 75 percent aim to alter their R&D functions, but only 22 percent have already started or completed their changes
- 89 percent are exploring better ways of using and managing big data, but only 26 percent have made any headway
- 82 percent are changing their technology investments, but only 33 percent have completed the changes

Along with innovation come opportunities, but also increased challenges.

50 percent of automotive CEOs find it somewhat or very challenging to establish an innovative culture internally.



Source: PwC 17th Annual Global CEO Survey 2014

In the midst of all this pressure, the environment of the market has become highly focused on consumers and safety compliance, which forces the industry to respond quicker with more innovative capabilities to capricious market demands. Company size is no longer a guarantee for success, nor is past accomplishment and existing brand equity. The winners going forward will be those that can establish new ways to create value – mostly driven by software – plus find an effective way to bring tailor-made vehicles to market quickly, while at the same time meeting ever stricter regulatory demands for functional safety.

The purpose of this paper is to share industry best practices of Siemens PLM Software's Polarion® ALM automotive customers who have already successfully adjusted to the new realities and established a highly collaborative, fully linked development environment that allows them to mitigate risk while keeping their foot on the accelerator for the road ahead.

Following is a summary of what we found in our ongoing conversations with these customers, organized around the software-related challenges most worrisome to the managers in the trenches, who are responsible for successful software development for embedded automotive systems:

1. Effective collaboration across disparate teams in real time
2. Proactive protection of quality and functional safety
3. Rapid response to defects after market introduction
4. Smooth compliance with automotive standards
5. Integration of ALM and PLM – the road ahead

These challenges are all interrelated and in aggregate can have a tremendous impact on the success of an automotive organization. Strategies for mastering them are reviewed in the following sections.

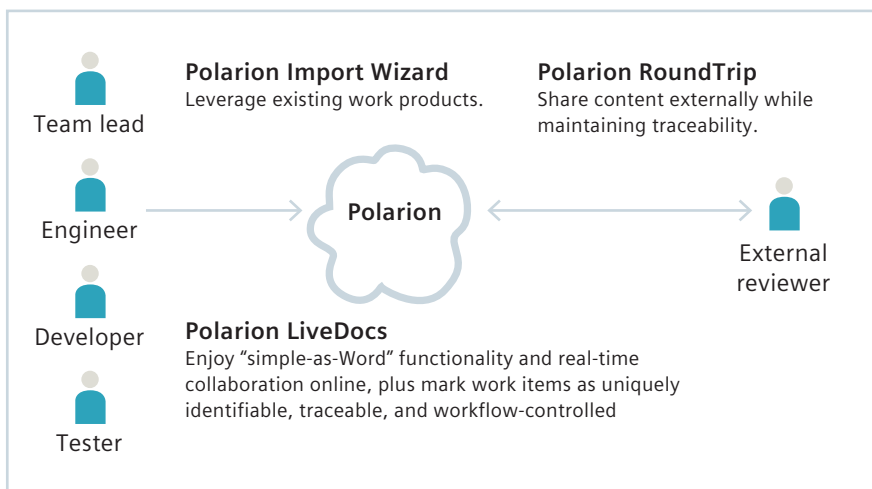
Effective real-time collaboration across disparate teams

Innovative automotive customers report that the ability to harness contributions from across the entire ecosystem has become a key factor for ongoing advancement, and the synchronization between the different engineering teams within their organizations and their suppliers around the globe has evolved into one of their main concerns. They point out the great value their disparate stakeholders derive from cross-functional collaboration in real time whenever questions arise, taking advantage of the 100 percent browser-based Polarion products from Siemens PLM Software for application lifecycle management. No longer do they have to wait for email responses – or worse, meetings to get answers to pressing questions. Instead, they can take advantage of the always-up-to-date online environment with live dashboards and wikis as well as access-controlled threaded commenting. Subscriptions for automated event monitoring and change notifications further enhance the rapid knowledge transfer.

Document-centric team members appreciate the fact that they can easily import existing work product into the online tool using the patented Polarion Import Wizard.

Once unfettered by the limitations of desktop application-based documentation, granular work items can be established and workflows can be kicked off individually, so team members can start working on them without having to wait for the rapid knowledge transfer.

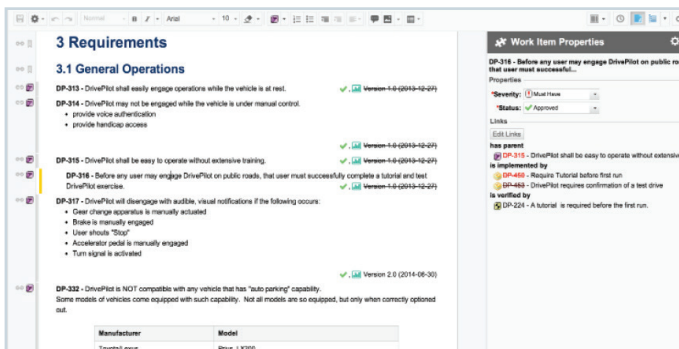
Better yet, team members fond of editing capabilities of the Microsoft® Office® suite don't have to worry about losing any of their productivity. Once online, they can enjoy Polarion's patented LiveDoc technology, which comes with much of the same user-friendly functionality, but without the distractions of bloated desktop tools. Automotive customers tell us that even die-hard users of traditional desktop applications have been surprisingly easy to convert. As soon as their counterparts start reporting that document management almost seems easier in the online environment, while providing the power of contextual access to information, adoption hurdles quickly dissolve. This has proven to be of great help in migrating stakeholders that author and manage software requirements into the online environment.



Besides contextual collaboration as one critical factor for shortened cycles and faster time-to-market, workflows also play a key role. Any time you have diverse groups within and outside the organization working together on a project, as is the case in the complex automotive ecosystem, the resulting complexity of the operation becomes a challenge. Governing the way the work gets done becomes imperative given all the tight regulations and importance of functional safety. A sophisticated workflow engine with the ability to enforce business rules across company boundaries is essential to ensure team coordination and cooperation success. Siemens PLM Software's Polarion customers confirm the ease with which streamlined workflows can be established at the work item level, enabling task-oriented information exchange between development, operations and quality assurance. Templates for most common methodologies come with the tool that can be used out of the box to get teams started, and rapidly configured to map to specific business scenarios. At the same time, incorporated process automation and domain-specific templates are available to safeguard that no steps are missed or bypassed.

With one centralized repository at the core of all activities serving as the single source of truth, the capabilities have helped software development teams transform how they collaborate regarding key processes like ideation, software requirements management, detailed development and after-market support. In fact, the centralized nature of information exchange enables development teams sitting in different locations (or even in completely separate organizations) to effectively convey automotive design ideas, intent and context much faster than the use of email, instant messaging and teleconference calls. And the functionality not only brings distributed teams closer digitally, but also fosters the healthy discussion of product concepts across business and domain areas that is so important for ongoing innovation.

Beyond that, comprehensive traceability allows developers to refer back to the software requirements that underlie their assigned tasks, and to reach out to the respective authors when they have questions. The same applies to the testers that verify whether the requirements have been met. All



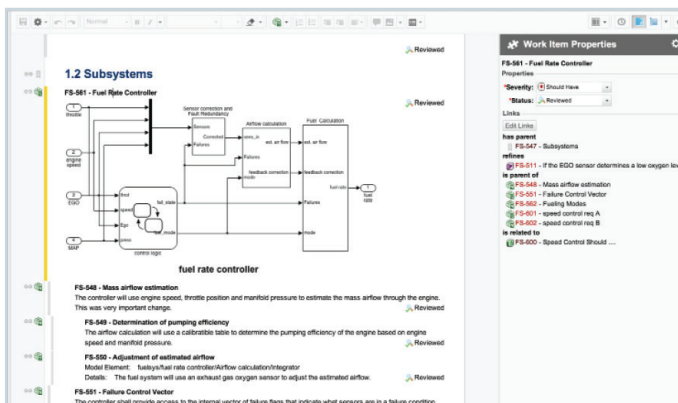
activities and decisions are automatically tracked, with collaboration history available to reveal how decisions were made every step along the way. Formal approval processes with compliant e-signatures complete the information exchange. All this functionality contributes to a much more cohesive way of cooperation in today's complex automotive ecosystem. Customers confirm that using Polarion has allowed their development and quality assurance teams to spend much more time and focus on the left side of the V-Model, and catch issues before they become problems.

Domain experts who want to stay in their familiar environments can do so and still be tied into the centralized repository. The Polarion software's native integration with MATLAB®, for example, enables customers to include Simulink® Model-Based Design workflows as an integral part of their application lifecycle. Bidirectional traceability facilitates navigation from Simulink model elements to associated Polarion work items and vice versa. Versioning aids collaborative design, opening up the assets for easy re-use and variant management across an entire automotive portfolio. This goes back to the critical factor of establishing an effective way to bring tailor-made vehicles to market quickly, mentioned at the outset of this paper.

Another native integration that is popular among automotive customers is the round-trip for Requirements Interchange Format (RIF/ReqIF) through which traceability across multiple documents or tools is maintained. The Object Management Group's (OMG's) standard for requirements exchange, a widely used Extensible Markup Language (XML) file format and workflow to support lossless exchange between partners, brings OEMs and their suppliers together around the globe. As automotive suppliers are becoming increasingly involved in strategic development initiatives and provide mission-critical innovative functionality that must seamlessly fit into the overall development efforts, this is critical for successful collaboration.

“With Polarion we found the solution to both of our biggest pain points: achieving SPICE compliance and enabling us to seamlessly fit into the OEM supply chain.”

Christian Posluschni
KÜSTER Automotive



Proactive protection of quality and functional safety

Of course, real-time collaboration and seamless integration of tools by themselves do not protect development teams from errors and defects. As current recall crises show, it is clear that the entire auto industry's approach to quality management must change and become more proactive. The old ways of dealing with safety flaws, which essentially boiled down to issuing recalls and compensating victims privately through nondisclosure agreements, no longer suffice. Regulators won't tolerate them, and the public won't accept them either. To make matters worse, emerging details of stalling, incompetence and lax behavior at manufacturer's leaves everyone else without a plausible defense going forward. The industry is pivoting as a result. The economics of auto safety are fundamentally reversing, making the cost of repairs far more expensive than prevention.

Troubleshooting issues along the automotive development continuum can be a very time-consuming task, especially when traceability is not readily available in the software development process for each individual component. To this day, it can still be a cause for car manufacturers and their suppliers to either delay a release, or ship a car with a plan in place to issue very costly recalls once the defects surface. Determining release readiness across the isolated groups and systems in today's global automotive development ecosystem is time-consuming and error-prone. Also, the risks of making key decisions increase in direct proportion with the complexity, incompleteness and inaccuracy of data on which they are based.

This has led to the rise of ISO 26262, an adaptation of the Functional Safety standard IEC 61508 for Automotive Electric/Electronic Systems, which defines functional safety for automotive equipment applicable throughout the lifecycle of all automotive electronic and electrical safety-related systems. VDC Research reports that adherence to ISO 26262 is expected to increase significantly in the next two years, making it imperative to understand the various safety processes as well as legal responsibilities required to achieve compliance.

Siemens PLM Software is the first ALM vendor to receive ISO 26262/IEC 61508 qualification by TÜV NORD for the Polarion suite of products. The qualification at the highest Automotive Safety Integrity Level (ASIL-D) as defined in ISO 26262 is based on evidence that Polarion's software development processes can be reliably implemented and replicated. Due to the nature of the qualification, any software and hardware systems developed using Polarion's processes is also deemed to meet the functional safety requirements of ISO 26262, in turn radically reducing compliance efforts.

Siemens PLM Software customers have been able to take advantage of this qualification and its underlying functionality to quickly comply with the new standard. They are using out-of-the-box features including a custom work item type called "Risk," as well as Failure Mode and Effect Analysis (FMEA) templates and preconfigured workflows that involve before and after Risk Priority Number (RPN) scoring based on user-defined values of severity, occurrence and detection. Additionally, Polarion solutions have elevated risk analysis to first-class citizen status within the solution workflow.

This means that customers can easily achieve traceability starting from the granular risks identified in an FMEA, to mitigating requirements and subsystem designs, and from there outward to test cases that verify such requirements. From there, they can further trace those same risks through the results of the executed test cases, right to the source code used for implementing the corrective software components. Thanks to extensions such as the Polarion Connector for MATLAB Simulink, it is even possible to achieve traceability all the way into model elements. This capability has enabled Siemens PLM Software customers to become much more proactive in their risk assessment and functional safety practices, and much faster in being able to prove compliance.

Besides supporting the effective management of defects and risks, multidirectional traceability and change history tracking are essential for fast proof of compliance. Every artifact change in Polarion is tracked using the underlying configuration management system. The tool itself comes with the Subversion open-source versioning software, but can also be easily tied in with any of the other configuration applications such as Git and Perforce. The automated tracking functionality makes it impossible to change anything without leaving a trace, and helps further reduce the risk of defects and functional safety complaints. This proactive approach to ALM is a much more cost-effective business practice. Siemens PLM Software customers confirm that their development teams can bring high-quality automotive products to market much faster when they can find and fix issues before they become a problem. In fact, correcting errors long before final verification leads to tremendous overall savings in development time and project costs, along with reducing the probability of expensive recalls and legal action due to bodily harm.

“I’ve been working for over 20 years in automotive electronic development. With Polarion, it is the first time that the entire spectrum of development activities is covered by one tool. This allows closer collaboration between software, hardware, mechanical, project management, test and software requirements management which improves the product quality, protects functional safety, and saves time and money.”

*Rainer Kirchner
ASK Industries*

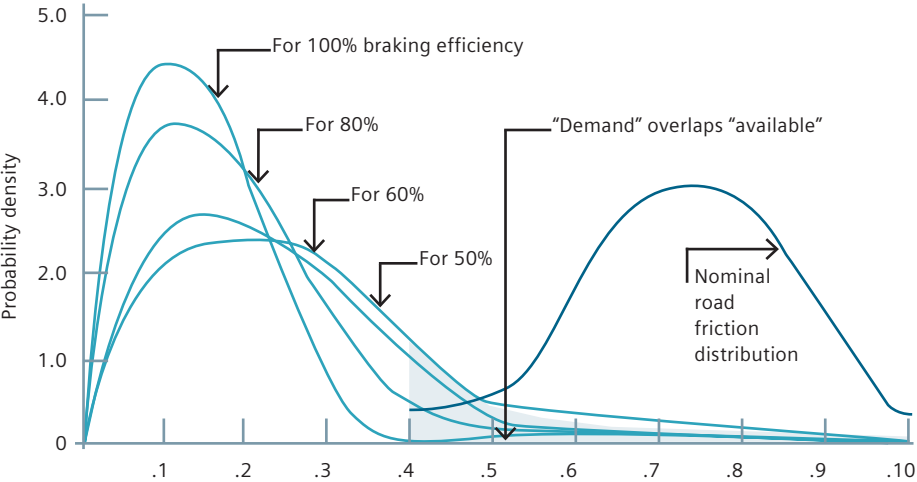
Rapid response to defects after market introduction

As valuable as preventative measures are, the first law of software development is that there is no such thing as bug-free software. In the automotive industry it is a variation of the “last mile” challenge, described as the “last .001 percent” problem. In other words, debugging the first 99.99 percent of software defects is part of standard business for any manufacturer. But beyond that, it is really difficult to catch problems because software has grown so complex.

Variations of real-world test conditions can be near-infinite, such as the differences in temperature, speed, acceleration and torque when combined with specific software-driven functionality. In turn it has become cost-prohibitive to test all software and systems combinations across all operating conditions.

To continuously manage against risks, hazards and cost has become a giant probability exercise, managed over thousands of dependent and independent variables.

Friction “demand” distributions



Source: U.S. Department of Transportation

One automotive manufacturer's recent filing with the National Highway Traffic Safety Administration (NHTSA) sheds more light on this new reality by revealing three important findings:

- The recall stemmed from transistors that at high operating temperatures could potentially shut down the car's hybrid system. In other words, the issues surfaced at the nexus of hardware, software and real-world operating conditions.
- The recall impacted a single model produced over a four-year period, from 2010 to 2014. This means it was small enough to persist undetected through multiple vehicle validation cycles.
- To date, the defect has caused no injuries or accidents, and the recall has been solely preemptive and voluntary.

This is a good example of the complexities the automotive industry is facing, causing record-breaking recalls that have become the new norm rather than the exception. Almost all automotive manufacturers have included recalls into their standard operating procedures, both voluntarily and in response to regulatory directives and legal demands. Lately, these recalls are more and more often due to a supplier's error that didn't become apparent until after the car was introduced into the market.

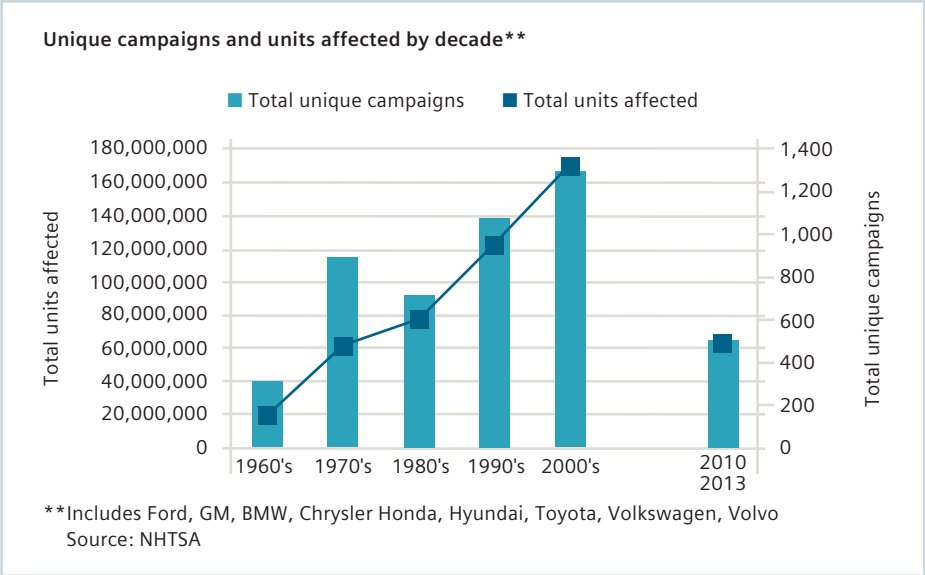
There is yet another kind of recall that can be just as costly. Car manufacturers often issue "silent" recalls that we only learn about when we bring our cars to a dealer for service. The cost of developing a resolution for the issue, training

dealer employees to repair the issue, and the effort to deliver the parts and to apply the software patches to thousands of dealers across the globe can easily eliminate most profits from the car model that is affected by a silent recall.

While total numbers of recalls vary from year to year, they have climbed steadily in each of the past decades, according to analysis of nearly a half century's worth of data from the National Highway Traffic Safety Administration.

For 2014, the Society of Automotive Analysts (SAA) *Annual Warranty and Recall Report* lists the following as the most influential forces driving the record-breaking recalls the automotive industry has been experiencing:

- Increase in new vehicles: 37 new vehicles introduced in 2014 stressed ecosystems
- Increase in sales volume: 16.3 million in 2014 causing production and capacity constraints
- Cost-cutting efforts to improve short-term profitability expected to lead to a deterioration of product quality
- Technological innovation complexity results in software glitches that drive "hard failures"



The good news is that Siemens PLM Software's Polarion solution has a powerful answer for this reactive scenario as well. The same linking and traceability capabilities that enable teams to collaborate seamlessly and ensure smooth compliance with automotive standards before vehicles get introduced to consumers also helps them track down the source of any issue that surfaces after the fact. The common practice is that engineers get called off their projects to frantically search for root causes. Sometimes defects have such a negative impact that management decides to shut down production lines until defects are found and fixed. To make matters worse, modern organizations tend to use an amalgam of testing tools, making it harder to get to the bottom of issues and prolonging costly disruptions. As a result, affected OEMs and their suppliers are facing billions of dollars in damage any time a serious defect surfaces after market introduction.

Polarion software addresses these challenges head-on thanks to its role as a central hub where all testing routines are orchestrated. This encompasses unified defect management, where every issue is tracked as a work item in Polarion regardless of the testing tool that identified it, including details about the test routine that was performed, the results that were found and the remedy that was assigned to each resource. As a result, a comprehensive and fully linked audit trail allows teams to trace market-facing defects quickly, all the way back to the source code regardless of the number of testing tools used in an organization. Furthermore, software requirements related to the case are directly accessible as well, completing the picture.

“Thanks to Polarion, we can rely on a single platform to collect our data, exchange documents, collaborate, keep traceability and control our workflow. With Polarion, we can not only measure our productivity but also improve productivity in our projects. And we can keep track of this!”

Andreas Deuter
PHOENIX CONTACT Electronics

Smooth compliance with automotive standards

Electronics technology not only helps differentiation, but has become indispensable for ensuring reliability. In fact, as the code size of software for microcomputer control continues to expand, ensuring its reliability has become a crucial matter. In addition, car manufacturers utilize hundreds of suppliers to develop the various components that go into a car.

Each of these components must pass stringent audits regarding compliance with processes such as Automotive SPICE and CMMI, as well as safety standards such as ISO 26262 and MISRA.

The underlying software developed by diverse specialized companies and then incorporated into the development chain in different stages by the manufacturer sheds light on the increasing importance of standards. Growing regulatory environments, higher business complexity and increased focus on accountability have led enterprises to pursue initiatives that are planned and managed in silos and sometimes in parallel, and they increase the overall business risk while the duplication of efforts can cause costs to spiral out of control.

To put things in context, governance, risk and compliance processes can help coordinate and integrate initiatives and manage them more successfully through control, definition, enforcement and monitoring:

- Governance is the oversight role and the process by which companies manage and mitigate business risks.
- Risk management enables the evaluation of relevant business and regulatory risks and controls, and monitors mitigation actions in a structured, fully documented manner.
- Compliance ensures that an organization has the processes and internal controls to meet the software requirements imposed by governmental bodies, regulators, industry mandates and internal policies.

The improved organizational effectiveness based on one single point of reference, provided by the Polarion solution, has been essential in supporting governance, risk management and compliance for our automotive customers. It has furthermore helped eliminate redundant work across initiatives, and makes “a single version of the truth” available to employees, customers, auditors and regulatory bodies, turning compliance burdens into straightforward, repeatable processes.

The Polarion ISO 26262/IEC 61508 qualification by TÜV NORD, mentioned earlier in the document, makes it easy for customers to demonstrate that they can reliably implement and replicate the processes and meet the functional safety requirements of ISO 26262. Additionally, The Polarion integrated workflows with automated control mechanisms help customers demonstrate that steps cannot be missed or bypassed even at crunch time. Indeed, customers report that they have been able to pass audits and regulatory inspections smoothly due to their use of workflow control as well as the comprehensive artifact history, which removes headaches usually associated with compliance documentation.

Customers and auditors alike appreciate the automated tracking of every change via the configuration management system, which records a complete audit trail of who did what, when and why, which in turn makes it easy to access the information as a report for compliance documentation. Beyond this critical role, a wide range of reports provide real-time insight into the state of projects and increase release predictability at any moment in time. Teams can choose from a range of ready-made versions or quickly establish their own, and browse and report on any historical baseline state via the Polarion TimeMachine.

All in all, Polarion ALM has proven to be a powerful tool for the highly regulated automotive industry, as it enables the automation of verification and validation (V&V) of products and systems over their full lifecycle via comprehensive traceability, forensic-level accountability, enforcement of electronic signatures and real-time reporting. This ensures that no software requirement goes unapproved and untested, no test goes unexecuted, and no risk goes unmitigated.

“Polarion's ISO 26262 qualification is saving us a great deal of effort and cost in our own qualification process. We leverage the Polarion ALM solution across our complete development lifecycle for software requirements tracking, release packaging, test results, and full traceability coverage for vehicle hazards ISO 26262.”

Maria Eugenia Zuniga
Quantum Technologies

Rapid response to defects after market introduction

As we have seen, in today's hyper-competitive environment, accelerating time-to-market for innovative products is critical for success. The source of the challenge associated with accelerated lifecycles is that most manufacturers still apply separate development processes, and independently use application lifecycle management tools for software development while employing product lifecycle management (PLM) tools for hardware engineering. This is laden with inefficiencies and synchronization delays, and their corresponding costs and risks.

The vital role that systems and software play in product innovation intensifies the need for synchronization of both development efforts so that the efficient use of people, processes and tools can be achieved. Siemens PLM Software believes that interoperability and data federation, at the core of the integration of software engineering processes into systems-driven product development (SDPD), help organizations make smarter decisions that lead to better products.

ALM-PLM Integration benefits include:

- Integrated processes streamline cross-discipline synchronization.
- Access to product and software requirements supports comprehensive understanding of the product definition.
- Bidirectional linking enables cross-discipline lifecycle management and audit readiness.

- Change propagation and automatic notification enable comprehensive change impact analysis.
- Synchronized testing and reporting support cross-functional defect management.
- Linked, versioned data architecture without data duplication delivers closed-loop decision making.
- Integration makes holistic compliance reporting for every aspect of the manufacturing process a reality.

Orchestrating both lifecycle management disciplines unlocks tremendous synergies, helping organizations accelerate collaboration, integrity and innovation at the highest level. And as systems and software play an increasingly vital role in innovation and product value, the need for greater collaboration across design, development, testing and production of both software and product only intensifies.

“Polarion ALM is the ideal Siemens Teamcenter companion to converge software and product development tools and talent to accelerate innovation.”

Raj Khoshoo, Sr. VP of Strategy Initiatives
Siemens PLM Software

Conclusion

Building cars for the next generation is no doubt exciting, but it also brings with it unprecedented challenges. The only way to meet them is for automotive manufacturers to rethink how they approach security, quality, performance, cost and supply chain complexities. Development organizations must create the right development platforms and establish new processes and means of real-time collaboration around the globe to meet the opportunities on the road ahead.

The revolution in software development is happening, and the time to act is now. The chance to transform processes is yours for the taking so that you can harness the opportunities ahead. A unified approach to application lifecycle management and the integration with PLM is not a futuristic technology trend. It is here today, and the good news is that with Siemens PLM Software as the right partner and Polarion technology you aren't forced to completely stop and reset, but can smoothly transition from getting the most out of your existing business processes to making your organization thrive in the future.

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About Siemens PLM Software

Siemens PLM Software, a business unit of the Siemens Digital Factory Division, is a leading global provider of product lifecycle management (PLM) and manufacturing operations management (MOM) software, systems and services with over 15 million licensed seats and more than 140,000 customers worldwide. Headquartered in Plano, Texas, Siemens PLM Software works collaboratively with its customers to provide industry software solutions that help companies everywhere achieve a sustainable competitive advantage by making real the innovations that matter. For more information on Siemens PLM Software products and services, visit www.siemens.com/plm.

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