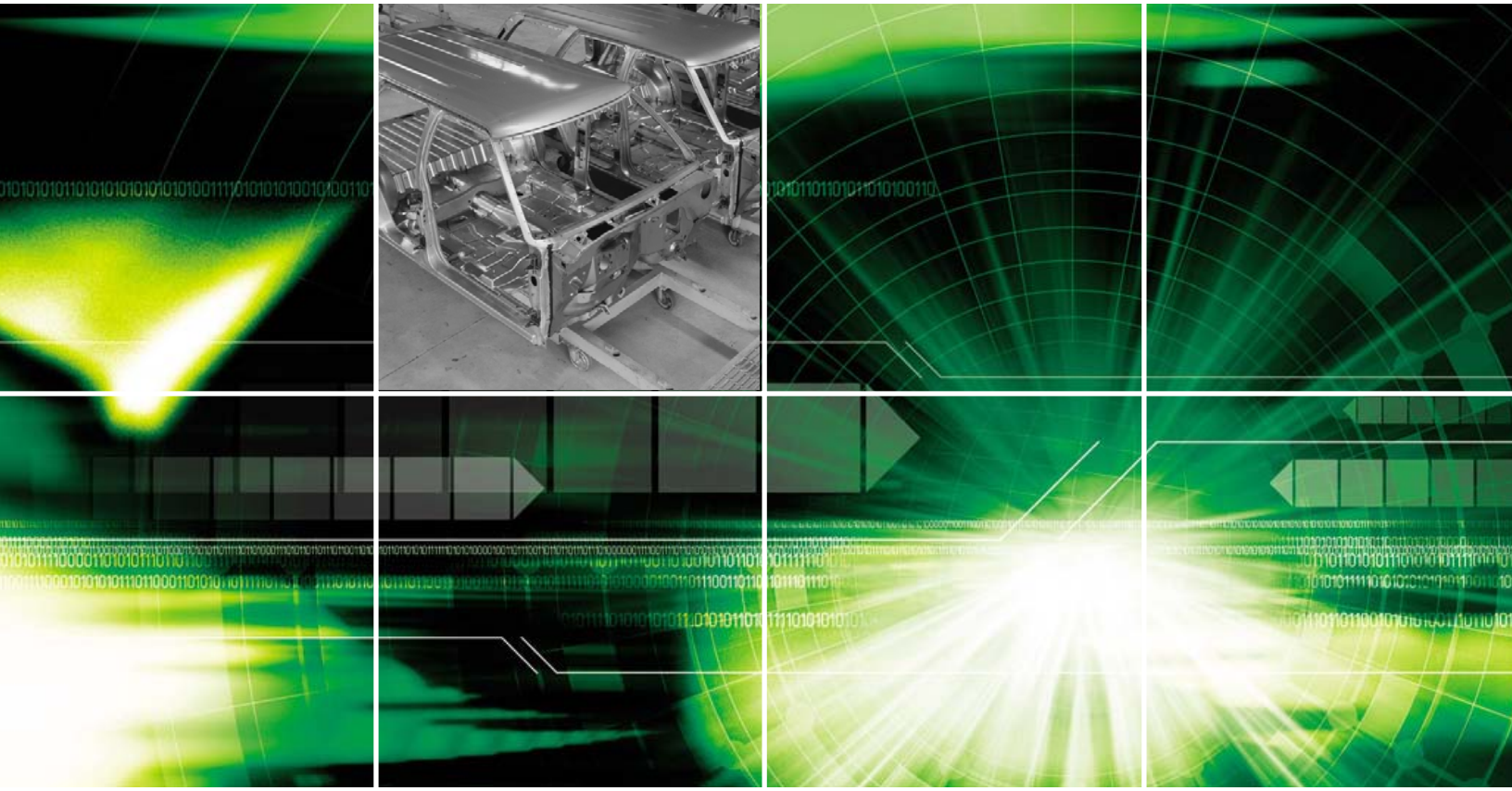
Embedded systems overhaul

It's time to tune up for the future of the automotive industry



An IBM Institute for Business Value executive brief

IBM Business Consulting Services, through the IBM Institute for Business Value, develops fact-based strategic insights for senior business executives around critical industry-specific and cross-industry issues. This executive brief is based on an in-depth study by the Institute's research team. It is part of an ongoing commitment by IBM Business Consulting Services to provide analysis and viewpoints that help companies realize business value. You may contact the authors or send an e-mail to iibv@us.ibm.com for more information.

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Introduction

For the automotive industry, the future is now. Increasingly complex embedded systems have brought disappointment as cars continue to roll into the marketplace with software and electronic defects. Warranty costs are on the rise as brand perception suffers. Solving the software problem sooner rather than later could mean significant returns for automakers. But before they can cash in on these opportunities, automotive companies must change the way they work – from development to delivery – overhauling their approach to manage the complexity of embedded systems from both a business and technology perspective.

Outmaneuver obstacles, unleash opportunity

Consumer expectations, technological innovations, competition, product differentiation and legislation are leading to the increased use of embedded systems in automobiles. As electronic and software content in the vehicle increases, so does complexity. And as embedded systems become more complex, so have the problems encountered by automakers.

Today's embedded systems often miss their mark. Faulty electronics and quality problems contribute to rising warranty costs. The lifecycle mismatch between cars and embedded systems can render electronics functionality outdated by the time vehicles roll off the line. Original equipment manufacturers (OEMs) and suppliers find that their ranks are short on the skill sets needed to support the growth of increasingly specialized software. Lastly, the automotive industry's reuse of parts, subsystems, designs and architectures related to embedded systems is limited.

As a result of these unfortunate realities, the automotive industry faces further pressure on already tight margins, shrinking revenues and increasing customer dissatisfaction. But there is light at the end of the tunnel.

Technological advances based on software and electronics offer companies the opportunity to improve customer satisfaction and differentiate from the competition by creating innovative functions and features. However, in order to target these opportunities and make embedded systems a point of differentiation rather than disappointment, automotive companies will have to effect significant changes in the way they currently operate. The evolution of embedded systems will, by necessity, change the automotive industry.

The IBM Institute for Business Value has performed an extensive analysis of the automotive industry, identifying industry challenges and drivers of change as well as a roadmap to the future to help companies address the issues created by the quick evolution and growth of embedded systems. The approach is two-pronged, offering both a business view in which automotive companies must work to assess and change the way they work internally and with external players, and a technical view in which companies must adapt technology to support evolving business activities.

Change, challenges and consequences

Commute to the future: A car that helps you take charge

It has been a long day at work and you are anxious to get home. Unfortunately, like most commuters, you'll have to navigate through rush hour traffic to get there. But the trip has been much easier since you got your new car.

As you merge onto the highway, the vehicle's adaptive cruise control system automatically adjusts speed to maintain a proper distance from the car in front of you. When you maneuver into the fast lane, the state-of-the-art radar installed behind the car's grill detects the speed and distance of the vehicle ahead of you and accelerates accordingly. Your lane-departure warning system monitors the lane markers on the road, and causes the steering wheel to vibrate if you stray over the line unintentionally, while at the same time helping you avoid a collision with vehicles cruising in your blind spot.

If traffic becomes unbearable, the vehicle's navigation system formulates a detour that is projected onto a semitransparent display projected in your peripheral line of vision on the windshield, designed to help you keep your eyes on the road. Ultrasound technology targets sound directly at you so that while you hear traffic information, your passengers can enjoy music on the entertainment system.

As the sun goes down on the residential roads closer to home, infrared laser headlights on the front of the vehicle "light" the road up to 150 meters ahead, and an infrared camera enhances the landscape. The intelligent system detects the body heat of pedestrians and animals and alerts you on your semitransparent window display when a live object crosses your path. If a child or cyclist darts into the road ahead, you see it even if it is beyond the range of your regular headlights.

When you arrive home at last, you don't even have to worry about fitting into your cramped parking space. With the touch of a button, electrically operated power steering, cameras and sensors park the car for you, hands free. And there's no worrying that your teenager – or someone else's – will take your car out for a drive tonight: the fingerprint recognition security system allows only you to activate the ignition.

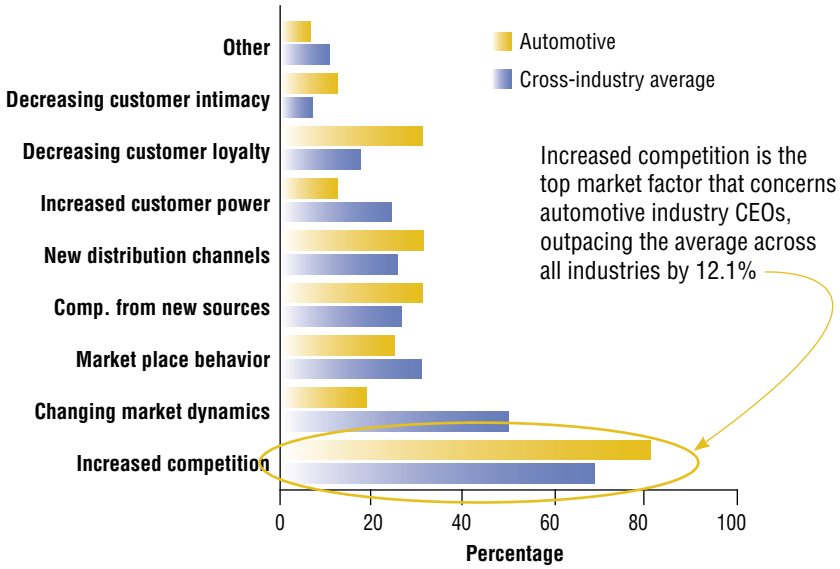
Embedded systems have the potential to raise the bar for vehicle safety, as well as luxury and convenience, but only if they work. What if they don't? Conveniences like the ones above can become outdated during a vehicle's lifetime. If the system is not upgradeable, you won't benefit from software updates that offer new functions for your existing hardware. What if the occupant sensors that help the vehicle's airbags deploy properly cross signals with the intelligent park assistance system and cause a malfunction? Or the vehicle stalls in the middle of a busy road due to a software error in safety-critical systems like adaptive cruise control or lane departure warning? What if your new car is so laden with software and electronics glitches that your mechanic can't solve its problems, and module changes only make the situation worse? Warranty or no warranty, you may decide that a car without all those expensive features would have been a better choice.

Increasing software content in vehicles has given rise to new complexities that raise challenging issues for today's automotive companies. Unfortunately, many companies have found that their current approach to embedded systems is not adequate to address these issues.

Industry challenges

Several industry challenges drive the need for the increased use of software in vehicles. Intensifying competition is a top-of-mind issue for automotive industry CEOs (see Figure 1). Strong global competition has resulted in overcapacity and price wars: overcapacity is as much as 30 percent in some regions,[1] while North American customer incentives totaled US$45 billion in 2003.[2] Competition is even heating up in China, where continued sales growth was projected to be near 60 percent, but only reached 10-20 percent in 2004.[3]

Figure 1. Increased competition is the top market factor of concern for automotive CEOs.



Source: "Your turn: The global CEO study 2004." IBM Business Consulting Services.

Providing features that are important to customers is critical for competitiveness – design has always been important, but functional differentiation is on the rise. Differentiation means innovation. It is estimated that 90 percent of innovation by 2010 will be electronics-related, and 80 percent of that is in the area of software. Even conservative projections place the software innovation fraction between 60-70 percent.[4, 5] The value of electronics and software is expected to grow from 25 percent today to 35-40 percent of the vehicle value by 2010.[6, 7]

Safety is a big factor with both consumers and legislators. Consumers consider their cars to be an extension of their personal and family space, and hence demand active and accurate safety and security systems in the vehicle. By 2006, all vehicles in the U.S. must have electronic sensors to detect the size, weight and position of a front-seat passenger to control or stop the deployment of airbags.[8] In Europe, legislation will target increased pedestrian protection with a proposed implementation in 2010.[9] Emissions legislation and the TREAD Act are also pushing the increased use of software and electronics.

Hybrid vehicles and fuel cell technology increasingly require advanced electronics and software. As the shift from hybrid engines to fuel cell engines occurs, the value of electronic vehicle content is expected to reach 50 percent in these vehicles.[10] Lastly, consumer expectations like entertainment, personalization, uniqueness and individuality drive embedded systems growth (see Figure 2). For instance, tomorrow's in-car video systems will allow each passenger to view a different program, while sound is transmitted through infrared headphones. In the future, TV screens will allow the front-seat passenger to watch programs while the driver sees only a blank screen. When the car is in reverse, rear passenger screens will retract into the roof to clear the driver's line of sight.

Together, these challenges lead to the increased use of consumer needs-driven software and electronics in the vehicle. As a result, embedded systems will become more complex. Simply removing software and electronic functionality in an attempt to eradicate flaws is not a feasible long-term solution. To move into the future, automakers need to find a way to become more adept overall at managing complexity.

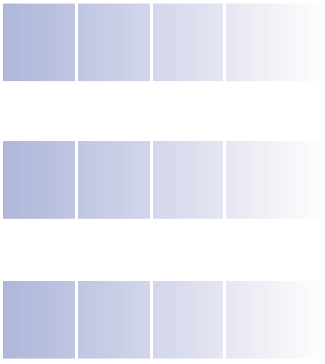
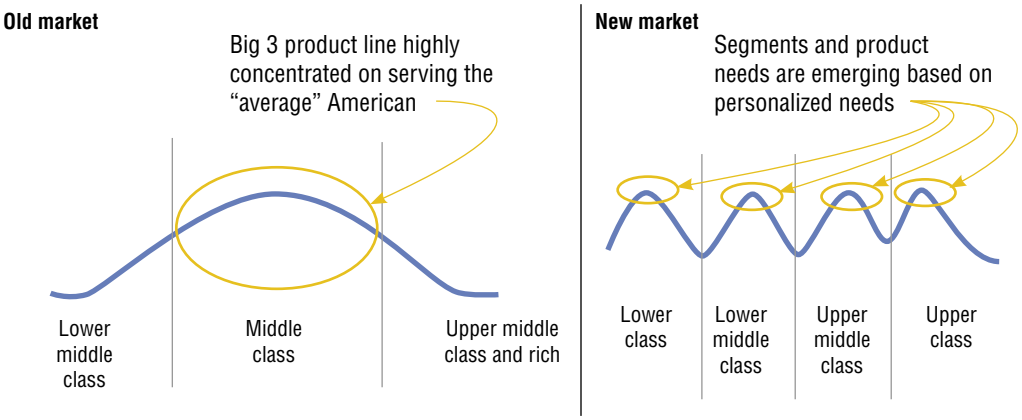


Figure 2. The customer desire for uniqueness and individuality is increasing.



Source: IBM Institute for Business Value analysis.

Consequences of change

A leading automobile company claims that faulty electronics are responsible for 7 out of 10 of its brand's defects.[11] In its 2004 report, the German Automobile Club attributes responsibility for 36 percent of 2003 breakdowns to electronics.[12] And in 2004, breakdowns due to electronics are projected to increase to almost 40 percent.[13] Customer satisfaction depends very much on the reliability of a vehicle. According to a German survey of over 2000 drivers, only 60 percent saw an advantage in car electronics.[14]

Today, the cost associated with software defects per OEM is approaching what it takes to design a new platform, roughly US$0.5-US$4 billion.[15] In addition, U.S. auto warranty claims rose to US$14 billion in 2003 – an average of US$700 in claims per vehicle.[16] This has brought to the forefront the need to effectively manage embedded systems complexity. Warranty costs shave off 1 to 3 percent of automotive revenues. By cutting warranty costs in half, an automaker could increase its profits by as much as 300 percent.[17]

The lifecycle of a vehicle is one to two decades in some cases, while the lifecycle of consumer electronics products is often only one to five years. Due to this lifecycle mismatch, even the most cutting-edge embedded electronics systems are likely to be outdated by the time a car rolls off the assembly line.

Reuse of parts, subsystems, designs and architectures around embedded software is a common goal for OEMs. Parts reuse can decrease engineering time by 60 percent, resulting in reduced cost, improved quality and faster time to market.[18] However, engineers often find themselves reinventing the wheel because it takes too long to find what they need – the result of a hardware-driven approach to design and the absence of a modular strategy to promote commonality of components.

Lastly, automotive software and system engineering skill sets are not mature enough to support the growing requirements for complex software. While the information technology workforce is growing, according to Meta Group, skill shortages are most acute in highly specialized areas.[19] Software architects and managers with software expertise are often difficult to find. In addition, OEMs and suppliers find that they are competing for the same valuable skills and resources.

Fuel for success: A roadmap to the future

In light of these consequences, what can automotive companies do to steer toward success? Moving into the future will involve significant changes to the business. IBM analysis suggests that to address the issues surrounding the rapid growth and complexity of embedded systems, automotive companies must first begin to change the way they work internally and with external players. The roadmap includes a business view with three key plays that automotive companies can enact to hone their approach to embedded systems: implementing an enterprisewide, team-oriented development approach, moving to an architecture-led development model and increasing cooperation across existing development domains. The technical view offers maneuvers that support changes to the business with the appropriate standards, modular architecture, methods and processes.

Business view

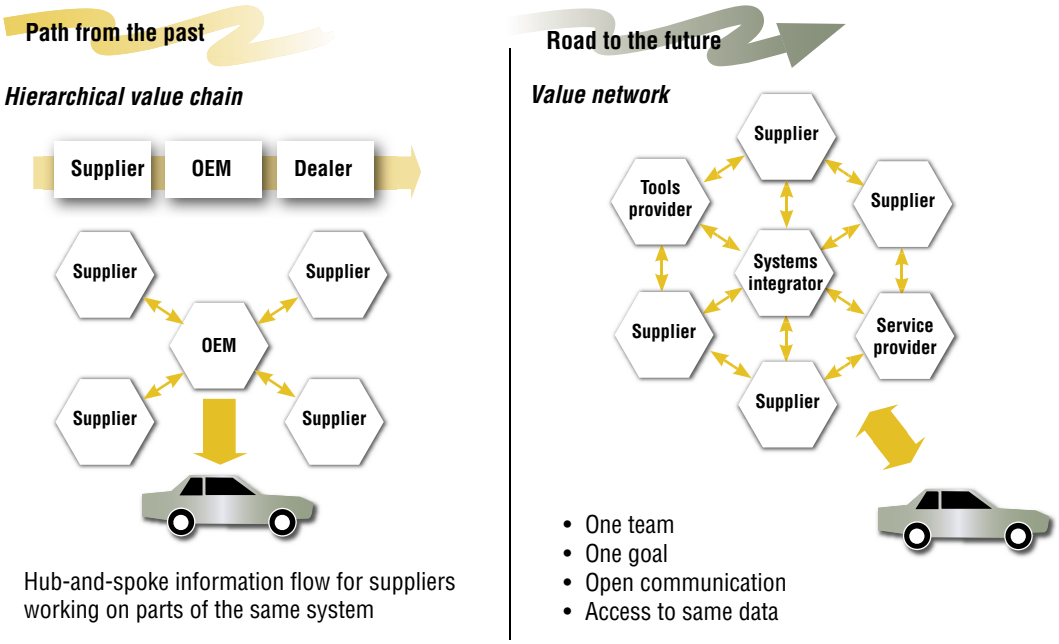
Play 1: Implement a team-oriented development approach

To date, the development relationship between an OEM and its suppliers has resembled a disjointed wheel: the OEM is at the center, and connected to each supplier through a one-way communication spoke. Contracts often preclude suppliers conferring with, and working with, one another. As a result, components are based and built purely on (at times uncertain) specifications. Suppliers have no view of the entire system, and the OEM can not or will not provide the detailed knowledge to bridge communication gaps between suppliers with detailed questions.

Industry analysis shows that poor supplier relationships can negatively impact OEMs' ability to remain competitive. This is reflected in the fact that Asian OEMs success in gaining marketshare correlates with their attractiveness to suppliers. Meanwhile, suppliers are finding it increasingly difficult to work with automotive OEMs in the U.S., citing poor treatment.[20] Consequently, U.S. OEMs may continue to lose marketshare.[21]

A team-oriented approach to development, where collaboration among OEMs and all suppliers and service providers is commonplace, breaks down the barriers erected by procurement pressure and exclusive contracts that preclude suppliers from sharing information. Team-oriented development embeds architects and developers from suppliers in development teams instead of holding them at arm's length, and promotes an inclusive environment with open communication, shared access to data and a common end goal for OEMs and suppliers (see Figure 3). In an ideal situation, everyone works together as a cohesive project team on one model for test cases, simulation and requirements. If a participant checks in a module for testing, the entire team (including the OEM, several suppliers and service providers) will promptly see the results and the impact on the system.

Figure 3. The future of OEM and supplier relationships.



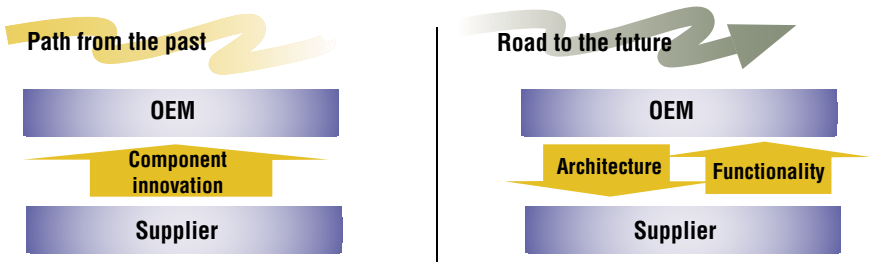
Source: IBM Institute for Business Value.

Before developing the exterior design for its new 1 and 3 series platform, BMW designed the electronic architecture. The inputs and outputs for functions like body control and telematics were defined by the architecture, which also established the communication rules the components must use. Then BMW defined how the components and their controllers would communicate with each other within the architecture. By defining and modelling an electronic network and communication system that can be used in all the group's vehicles and can accept changes and upgrades within its defined limits, BMW's design provides the capability for efficient reuse and the capability to upgrade cars after they drive off the lot. Customers potentially can get the latest technology, even if they don't have the latest model vehicle.[22]

Play 2: Move to an architecture-led development model

Currently, suppliers drive the software and electronics innovations that OEMs buy, test and integrate into vehicles. Since some leading suppliers spend more on R&D than OEMs, they tend to have higher software competence and innovation capability. To date, suppliers have driven embedded system growth by pushing single component innovations to the OEM. We anticipate that they will move from pushing components or modules to supplying innovative functionality (see Figure 4). The role of OEMs must evolve from system integration to managing system architecture and requirements as a means to manage cost and quality.

Figure 4. Suppliers will continue to drive innovation, but OEMs will lead the embedded system architecture.



Push innovation model
- OEM
  - Limited software expertise
  - System integration
- Supplier
  - Deep software knowledge
  - Extended innovation capabilities
  - Provides component or module

Architecture-led model
- OEM
  - Establishes vehicle system architecture
  - System integration
- Supplier
  - Deep software knowledge
  - Extended innovation capabilities
  - Provides functionality

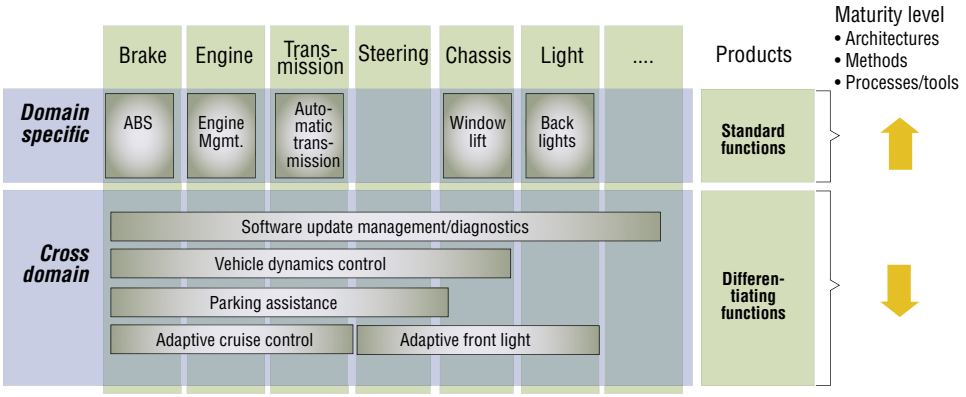
Source: IBM analysis.

Play 3: Increase cooperation across development domains

Traditionally, the development of embedded systems has been specifically focused in individual engineering domains such as brakes, transmission and steering. However, as demands for increased functionality mount, collaboration across engineering domains is paramount. Since many OEMs and suppliers are organized by domain, organizational barriers and conflicting methods and processes make developing cross-domain functionality extremely difficult. IBM research suggests that, currently, cross-domain functionalities are typically less mature with respect to architectures, methods and processes – a problem that OEMs and suppliers must rectify in order to manage complexity and create embedded system functionalities that will differentiate them from competitors (see Figure 5).

"During the lifecycle of a product, there are literally tens of thousands of changes made. As a change is made, it may take as much as 90 days to communicate that change throughout the organization."
– Automotive Executive[23]

Figure 5. The level of maturity for architectures, methods and processes is typically low for functions that cross development domains.



Source: IBM Institute for Business Value.

Technical view

In addition to the business view, automotive companies will need to maneuver differently from a technology perspective. Companies must adapt standards, architectures, methods, processes and tools to support changes in the business.

The AUTOSAR partnership, which includes as core members BMW, DaimlerChrysler, Volkswagen, Bosch, Continental, Siemens VDO, Ford, Toyota, GM and PSA Peugeot Citroen, is currently working to establish a standard for an open scalable system architecture. AUTOSAR is striving to be a global standard in the automotive industry, with standardized interfaces and physically dimensioned components that are independent of hardware. AUTOSAR estimates that standardized software components will be developed by August 2005, with the tested integration process completed by August 2006. The first AUTOSAR enabled vehicle is expected to be released by 2010.[24]

Maneuver 1: Create system standards

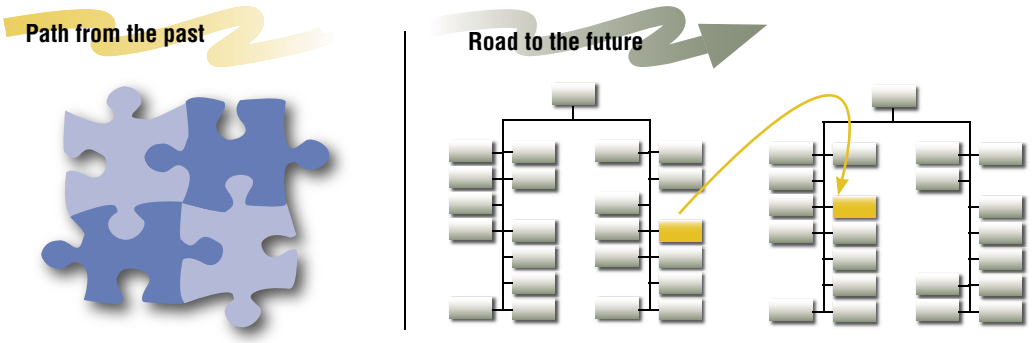
The automotive industry is exploring system standards that will support the independence of software from hardware components, which would allow the same software to be used on different systems. System standards such as Automotive Open Systems Architecture (AUTOSAR) support hardware independence and enable software component standardization. This can lead to increased reuse and interchangeable software modules among OEMs and suppliers. Hardware and software independence also means that a single electronic control unit (ECU) can be used for multiple functions, reducing the number and cost of ECUs in the vehicle and the overall complexity of embedded systems architecture. As standardization progresses, brand-specific standards will make way for the rise of enterprise-specific and open industrywide standards.

Maneuver 2: Adopt a modular architecture

As open standards become more commonplace, they will pave the way for modular architectures and modular embedded systems. In modular systems, standardized and interchangeable components are designed independently but function as an integrated whole.

Today, the term "architecture" is used to describe the placement of ECUs, and defines connecting technology and data traffic between ECUs. Complex systems are decomposed into manageable subsystems, but assembly principles are not transparent and decomposition and interfaces are proprietary. In the future, architecture will be used to describe all aspects – from design to operation – of the electronics and software in a vehicle. In this model, complex systems are still decomposed into manageable subsystems. But assembly principles are transparent, interfaces are standardized and functions are flexible and reusable (see Figure 6).

Figure 6. The new look of system architecture.



Source: IBM Institute for Business Value.

A modular architecture reduces complexity, software integration time and costs, extends the life span and resale value of the system, allows for greater reuse of software modules among different ECUs, increases quality and reduces maintenance and training costs. Finally, a modular architecture builds the groundwork for advanced software product and services revenue opportunities.

Siemens: Reaping the rewards of reuse [25]

According to Siemens VDO executives, nearly 60 percent of the code involved in engine management systems could be transferable across programs. A further 30 percent would need only minor adaptations if based on generic code. Only 10 percent of the software is specific to programs or customers. Siemens is building a software library of code modules or "aggregates." These aggregates, such as ignition and combustion control, are developed independently and then used within different vehicle development programs. An aggregate is reusable only when it has been released, validated and put into production on a project, so programmers and managers must record and list changes or adaptations to each aggregate.

Siemens estimates that reusable software will save considerable time and effort in validating software and allow creation of hardware-independent code and higher quality output. Currently, Siemens has 40 engine management aggregates ready for reuse.

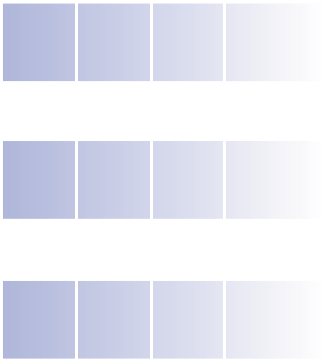
AUTOSAR and other industry initiatives increase the possibility for reuse of software. In many current programs, almost no code is carried over, and new software has to be developed every two to three years. But many tier one suppliers are working to build software libraries from which they can pluck a transmission control module, for example. Software reuse helps companies get to market faster, which has downstream benefits such as better brand perception (first to market with innovative new products and services) and increased profits (beating competitors to the sale).

Standardization and modularity are setting the stage for increased software use. As the importance of software in a vehicle increases, the way in which it is sourced is also changing. Significant changes are expected in the way software is developed and paid for in the automotive industry. Currently software is bundled into the price of modules or components. There are no separate negotiations regarding software content or pricing. But as the amount of software in the vehicle grows, and emerging system standards and modular architectures increasingly allow independence of software and hardware, the way software is marketed today will need to change.

In the future, functional software will likely be sold as a standalone product that is not tied to a particular ECU. If enough of the major automakers embrace modular architectures and system standards like AUTOSAR, suppliers will be able to sell non-differentiating software based functions to many different manufacturers. Suppliers would also be able to develop software independently of hardware. Besides allowing greater design flexibility and simplified integration, software development costs would be drastically reduced. To be successful with software as a product, OEMs and suppliers must develop new purchasing models for software including approaches to pricing, liability and lifecycle management.

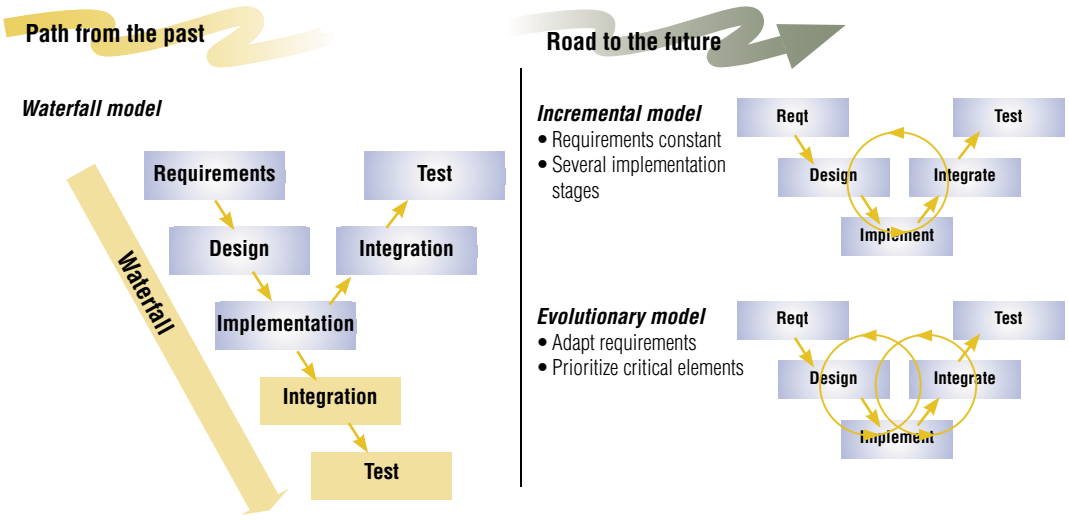
Maneuver 3: Update development methodology

A system engineering development methodology that helps deal with the complexity of embedded systems is paramount. In the context of complex embedded systems with a focus on software development, the current system engineering methodology is inadequate. Today's "waterfall" or "V" model suffers from poorly structured requirements and long test cycles that lack test coverage and end-to-end support. In addition, collaboration and tracking are insufficient. More successful development methodologies for embedded systems are based on software as the primary element in the development process.



Some of the current issues associated with the development methodology represented by the traditional waterfall system engineering process can be addressed with the move toward an incremental or evolutionary model (see Figure 7). This allows companies to adapt the software requirements during implementation stages and prioritize critical elements. The approach is based on an iterative software prototyping model that has been used in software design and system integration in other industries.

Figure 7. Incremental and evolutionary system engineering models are better suited for the development of complex embedded systems.



Source: IBM analysis.

Maneuver 4: Adapt processes and tools

To better manage the risk and complexity involved in software development, organizational structures and development processes need to evolve. Automotive companies must work to achieve standardized, repeatable processes as the key to making increasingly complex projects a reality. Furthermore, automotive companies and tools providers must improve the traceability of information within the system engineering process. In the current tools landscape, data exchange formats and functionalities are ad hoc, creating gaps in the flow of information. Automotive companies can use a middleware layer to connect independent tools and data repositories, enabling end-to-end traceability of data.

Staying ahead of the curve: Magna Vectrics adapts core business strategy [26]

Magna Vectrics, a newly founded division of auto parts supplier Magna International, is working on leading-edge technologies to support the implementation of "smart" air bags. They have adopted a standardized approach and methodology for the development of technology, allowing them to bring their product to market quicker than competitors.

Says one Magna Vectrics executive, "Embedded systems have specific processes and practices. To manage rapid innovation, we adopted these processes and practices as a core part of our business strategy. We anticipate that structured, embedded system-specific processes will become a requirement by OEMs for all suppliers. Therefore Magna Vectrics will be ahead of the curve."

Get good mileage: The benefits of change

The use of software and electronics in vehicles is increasing. Automotive companies that are able to manage the increasing complexity of embedded systems can add differentiating and innovative functionality with less effort (and cost) to their vehicles. By surmounting the obstacles raised by embedded systems complexity, companies can go to market more quickly with products that have fewer software and electronics-related defects. The benefits of these results are differentiation, decreased warranty costs, better consumer brand perception and increased profits.

Increased safety can equal improved brand perception [27]

U.S. government regulations require that by 2006, all new vehicles have the capability to sense not only where a person is in the interior of a car, but whether they are an adult or a child so that vehicle airbags and safety devices can deploy properly. Current safety systems can injure passengers that are out of their seats or positioned improperly (for example, children in infant seats). But in the near future, new interior sensors will help automakers increase the safety of passengers. Piezoelectric bolts will register weight and balance, and electronic seat contact pads, radio tags, ultrasound, infrared thermal imaging and computer chip-based video cameras placed throughout the vehicle will assess the size and position of vehicle passengers. Based on the vehicle's continuous computing of these variables, safety systems will be armed, disarmed or deployed with less impact.

This technology could also be adapted to detect drivers that fall asleep, are distracted at the wheel, or a child or animal that has been left in a closed car. The system could take emergency measures, opening windows and communicating with a service such as OnStar, as needed.

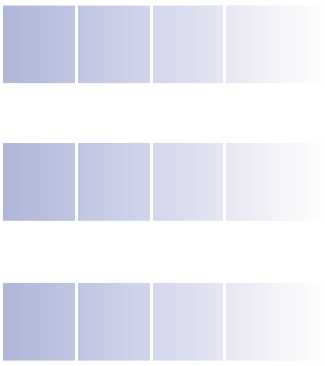
Though the technology for the scenarios above could be expensive, and certain liabilities and privacy issues would have to be addressed, automakers must consider this type of functionality not only to differentiate them from the competition, but to experience the benefits of improved brand perception and satisfy legislation. When software-based features and functions work well – and reflect top-of-mind customer wants and needs such as safety and comfort – brand perception is enhanced.

Automotive companies' success will depend on their ability to manage the complexity of embedded systems. A team-oriented development approach, architecture-led development and cross-domain cooperation together with technology support allows faster innovation, more robust solutions and, finally, customer satisfaction. This can lead to increased sales, a decline in software and electronics-related warranty claims due to embedded systems improvements, and a significant increase in profit margins.

On the road to results: Test your software savvy

Will the road to your future be paved with good intentions instead of solid results? To effectively plan your route to success with embedded systems, you need a firm grip on where your company stands today. The following questions are designed to help automotive executives assess their current approach to embedded systems and begin to understand where improvements may be necessary.

- How do your software and electronics-based features contribute to the positive perception of your brand?
- What percentage of your warranty costs are due to electronic system problems?
- Do you have a business model in place to buy/sell software as a product?
- Are you working in a team-oriented, collaborative approach with your software development suppliers, providing access for everyone to one model for test cases and requirements?
- How much of your software code is transferable across programs, brands and OEMs without changes?
- Are you buying to build an architecture instead of buying to satisfy requirements?
- Are your software development processes as mature as your mechanical design processes?
- How much time do your development engineers spend transferring parameters from one tool to another?



Conclusion

Software technology holds the key to the future for the automotive industry. We anticipate that in the not so distant future, software will be designed first – with electronics and the vehicle itself designed to best support quickly evolving software capabilities. Remaining competitive will mean moving swiftly to assess the market and upgrade software products and related services to meet customer wants and needs during the lifetime of the vehicle. In some automotive companies, this type of innovation is already taking place. For many others, the rapid growth and complexity of software in vehicles requires that they take control to actively manage a new approach to embedded systems development.

Regardless of the technology-related products and services they offer consumers, automotive companies will need to change the way they do business to make embedded systems work better. Differentiation is driven by innovation. And fast innovation begins with a team-oriented environment where collaboration within the organization and with suppliers allows the company to implement cutting-edge ideas quickly.

To discuss ways in which your company can increase its software savvy, please contact us at *iibv@us.ibm.com*. To browse other resources for business executives, visit our Web site:

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Produced in the United States of America
12-04

G510-3987-00