RETHINKING HOW CARS ARE BUILT—WITH MODERN CONSUMERS IN MIND

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BLAME IT ON SMARTPHONES. Consumers are so accustomed to getting new features through frequent software updates that they want upgrades for other things to be just as fast and easy, including cars. That demand, coupled with the fact that newer software-based features can be refreshed more often than hardware, is rendering automakers' existing engineering operations passé.

Two decades ago, car makers realized that, in order to operate efficiently, they had to engineer cars as modular units with components that could be used across their entire portfolio of vehicles. Under this model, components such as air suspension, brake systems, and dashboard displays debuted at the same time, most often on the latest high-end models. In addition to being efficient, it let a company maximize its capital investment in factories and tools. This model worked when cars had predominantly electro-mechanical parts, most components worked primarily independently, and consumers did not expect vehicles to change much from year to year.

In the ensuing 20 years, though, cars have become highly software-driven, requiring multiple components and software systems to work together. Today's cars have connected-car services such as internet-based navigation and infotainment systems, and, like smartphones, features that can be upgraded quickly based on consumer demand. With over-the-air firmware updates, in-vehicle infotainment (IVI) systems can get updates almost as often as smartphones.

To keep pace with consumer demand and to develop integrated modular components effectively, automakers must now take a different approach. They must adopt systems engineering, an interdisciplinary method for designing and managing complex systems over their life cycles. Using systems engineering to better organize and run vehicle production includes creating a product architecture with interchangeable modules that can be used to update software more often than hardware. It entails reorienting research to what consumers want and bringing an engineering workforce's skills in line with what's needed to make those and other changes.

Car makers have begun to adopt some of these elements. However, companies that adopt all of them can gain a major competitive advantage in the form of lower costs and lower risk of problems that result in recalls. Already today, integrated electronic components and software features account for the lion's share of automakers' recalls. Without a wholesale change, it's easy to imagine the problems getting worse as companies add even more electronics to keep up with both consumer demand and the push to get highly automated self-driving vehicles on the road by the end of the next decade.

Auto Engineering Operations Face Mounting Pressures

Car companies are navigating multiple, often competing, trends that affect new car features and how they are built.

To be competitive, automakers must sell more of the features that consumers want, which today means connected-car services and cars with electric motors, ADAS, and autonomous-vehicle technology. (See *Revolution in the Driver's Seat: The Road to Autonomous Vehicles*, BCG report, April 2015.) BCG research shows that on average, 62% of buyers globally would pay up to $5,000 more for a fully self-driving car. (See Exhibit 1.)

Consumer interest in ADAS and connected features is reflected in the greater amount of news media coverage of the technologies compared with coverage of traditional differentiators, such as engine size and trim line. For example, natural-language processing systems that use voice commands to control vehicle operations, such as Apple's Siri and Amazon's Alexa, have received intense news coverage.

Automakers also must add new features that meet consumer interest in connectivity and IVI systems. They must incorporate autonomous-vehicle technology as well, because almost one-quarter of all new cars will either be fully autonomous or include at least some self-driving features by 2035.

At the same time, however, car companies are grappling with tighter engineering budgets. One of the biggest battles is balancing spending on components for the new features that customers want with spending on updates for traditional modules.

Meanwhile, problems with electronics and software-based features are increasing. Through our work with clients, we have seen that up to 90% of problems that occur while a company is preparing to start manufacturing a new model are related to electronics and software. In addition, close to a third of auto recalls could be addressed through over-the-air software fixes, representing a potential $6 billion savings, according to ABI Research.

EXHIBIT 1 | Consumers Worldwide Would Pay More for New Automotive Technologies

Source: BCG analysis.

Automakers already devote significant resources to electronic components research and development, and fixing problems with new systems could create more of a drain. Today, electronic components account for about 35% of a car's materials costs, a share that is expected to increase to more than 50% by 2030. By our estimates, for example, a large automaker with annual revenues of $70 billion to $100 billion and a $4 billion annual engineering budget would spend up to $2 billion a year on R&D for electric and electronic components and software.

Today's Engineering Function Is Neither Consumer-Focused Nor Collaborative

In order to address the trends and challenges outlined above, engineering operations must become more consumer-focused and collaborative.

Many engineering organizations still add features simply because they're technically possible—not because consumers want them. For example, some automakers sell all-wheel-drive cars with torque vectoring, a performance booster typically found on sports cars, even though BCG research has shown that most drivers don't even know what it is.

Historically, automakers clustered features on the same development and release cycle because consumers expected new car models to have the latest updates and were willing to pay a premium for them, which benefited a company's bottom line. That timeline worked when automakers introduced new car models every seven years or so. But as innovation cycles speed up, customers expect to see new features more often, and on more cars than just the top-end models. Some car makers are already responding. One manufacturer, for example, introduced natural-language voice controls in its least expensive car. Car makers that can't deliver new features more often run the risk of losing market share to competitors that can.

Most automakers continue to maintain separate engineering teams for different components and software, which leads to problems syncing up the systems and to miscommunication between work teams. The disconnects can also cause issues for ADAS features such as parking assist, which are built on multiple components, including the car's central computer processor, sensors embedded in side fenders, the backup camera, and sonar warning system.

Finally, engineering personnel lack the digital skills that are needed to reorient operations to put customers first. Typically, these workers are able to assess vehicle attributes such as vehicle dynamics, perform tests, and develop modular components. But only around 7% of engineers at major automakers rate themselves as proficient in such areas as data analytics and programming, according to BCG analysis. This figure highlights a gap that automakers will need to fix, given that they spend almost 50% their engineering budgets on electronics and software development.

Key Steps for Implementing Systems Engineering

Adopting a systems engineering approach to auto production requires transitioning to a different product architecture, uncoupling hardware and software production timelines, redoing the structure of the engineering organization, and updating workforce skills—all set against the backdrop of better research into the features that consumers want and will pay for.

Create a product architecture that allows for interchangeable modules. This type of architecture works on the same principle as toy building blocks, such as Legos: although some components might be simple and others complex, they all plug into the same grid and work together regardless of when they were made. Consider the sensors that regulate lane-change or blind-spot monitoring systems, which are embedded in a vehicle's front, side, and rear bumpers and trim. If the sensors are built on a universal product architecture, in a near-future scenario old components could be replaced with new ones when the car's owner brings it into the shop for routine maintenance.

We expect car makers to initially use universal product architectures to build new vehicle models. In the future, they also could use the architectures to add updated hardware or other features to existing cars, potentially extending the vehicles' lifespans.

Develop separate timelines for updating hardware and software. Once the product architecture is in place, hardware and software updates can be uncoupled so that electronics can be upgraded at will, similar to the way that smartphone makers update operating-system software independently from introducing new devices. Some automakers are already using over-the-air updates to refresh navigation-system software regardless of when new car models are introduced.

As part of this change, automakers are beginning to physically relocate the software that regulates hardware programming and updates. They are detaching the various types of software from the devices that they run and clustering them together in central computer units. We expect that automakers will need four to five years to fully adopt this new electrical and electronic architecture, given the high levels of funding and preparation involved.

Once the dissociation from hardware updates is complete, software updates should occur at designated points in a vehicle's life cycle. For example, if a car maker expects to produce a vehicle model for five years with one midcycle update, software updates could take place twice a year and coincide with the midcycle hardware update. In addition, updates for such issues as bug fixes and non-safety-related consumer-facing features could be implemented as needed.

Tier-one automotive suppliers also have begun separating hardware and software development. An ADAS supplier, for example, might have one team building hardware and a second team building the software recognition algorithms that sync with the hardware but are updated more often.

Automakers that separate hardware and software updates to add new features to existing cars will also need to add quality assurance systems and testing procedures to ensure that the new features function as they are intended.

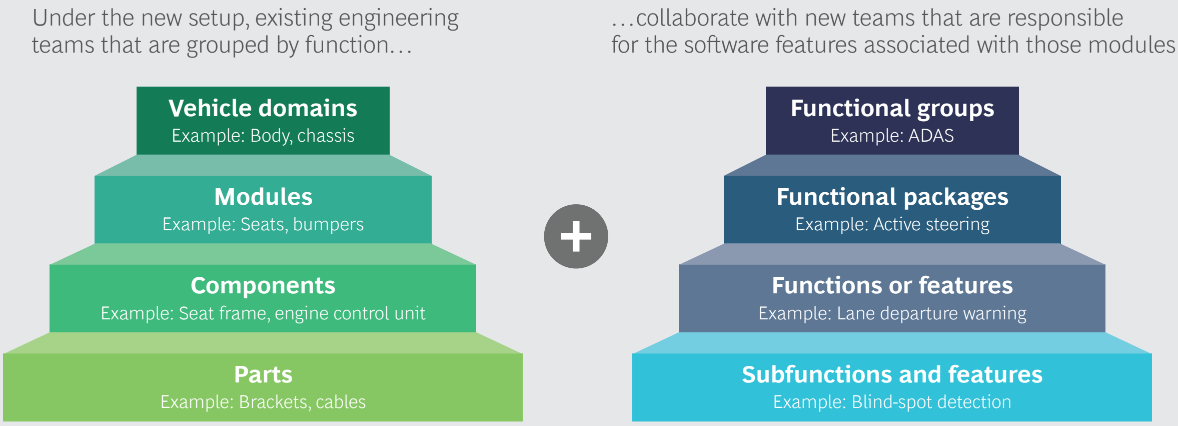
Redirect product development with research. As part of adopting a systems engineering orientation, companies must refocus engineering on the customer in order to deliver features that consumers want and use. To balance what people want with the cost of offering those features, automakers can conduct quantitative consumer research to determine the value of such a feature—that is, the price that a driver would pay for it. Determining value was easier when features were hardware-based because the material cost was simpler to calculate. But software-based features might have value over and above the material cost of producing them, such as parking assist.

Automakers can use connected-car services to collect data on existing car owners' driving habits and analyze the data to quantify the features that existing drivers use the most. That information could help the company prioritize which new features to add on the basis of what future car owners might be willing to pay for.

Reorganize engineering organizations and update employee skills. To carry out these changes, automakers need to restructure engineering operations. They should add new teams to existing module-based teams and make the new members responsible for the specific software features that are associated with those modules. (See Exhibit 2.) As part of this, automakers need to set up protocols and communications channels to ensure that the teams and the products they create come together properly. In addition, they need to create new quality-assurance tests for making sure that over-the-air feature updates work.

Teams responsible for specific features need autonomy to control their work. One way to provide for that and to ensure that the finished product delivers on expectations and goals is to adopt agile ways of working. Agile is a process for getting work done that uses

EXHIBIT 2 | Systems Engineering Adds Feature “Owners” to Traditional Work Teams



Source: BCG analysis.
Note: ADAS = advanced driver assistance systems.

cross-functional teams, minimum viable products, rapid updates, and frequent feedback. (See “Five Secrets to Scaling Up Agile,” BCG article, February 2016.)

Along with helping employees adopt agile ways of working, automakers need to provide more of their engineering organizations with digital skills in areas such as model development and software testing. They also need to have staff who know how to track what car owners want and can pick up on changing consumer sentiments in order to adjust what the company offers in a timely manner.

These changes are fundamental to how engineering operates, and could yield significant economic benefits, so companies must learn to manage the transformation themselves without relying on outside suppliers. Until they have developed sufficient in-house resources, however, companies may want to team up with an outside partner to fill the gap. Ultimately, car companies must bring this expertise in-house or seek partnerships with other automakers, though, since it will give them an edge over competitors that are slower to complete their own transformation process.

Getting Started with Systems Engineering

Before they can apply systems engineering across their entire engineering organization, automakers must make sure they have the basics in place.

Lay the groundwork. Create a product architecture and a catalog of modular components, and then decide how to decouple the refresh cadence of hardware and software components.

Start with critical features. Before introducing it throughout the entire organization, first roll out systems engineering in one critical consumer feature, such as ADAS or IVI. Starting small ensures that resources are deployed for high-value opportunities. It also ensures that the organization can manage the changes that accompany adapting to a new way of working.

Build a catalog of features and functions. Similar to creating a catalog of modular components, map out a catalog of features and functions, and indicate how they will be managed. The catalog should describe who owns key features and functions and what measures will be taken to make sure they are consistent across the company’s vehicle portfolio. It also should describe how updates will be scheduled and managed so they are current and pass quality inspections throughout their lifespans.

Define the new organizational model. To sync the development of features and functions with that of related hardware modules, include precise directions for how the work and responsibilities will be assigned. Uncertainties about who does what are some of the biggest stumbling blocks to successfully adopting systems engineering, so it's critical to get this right.

Create procedures to ensure over-the-air features meet regulatory standards.

Hardware modules for established driving functions, such as braking, are governed by processes and procedures that ensure those modules meet regulatory approvals. Similar processes and procedures for software-based features that can be updated over the air, however, have yet to be created. Until they are, automakers need to adopt their own guidelines to make sure that those features meet technical and safety requirements.

Because of smartphones, consumers have become comfortable receiving operating-system software updates more often than they buy new devices, a mindset that has recast their relationships with other things they use every day, including cars. Automakers must restructure their engineering operations to be more responsive to changing consumer demands and to keep up with the complexities that arise from building vehicles with more electric and electronic components.

Some automakers and tier-one suppliers have already adopted parts of a systems engineering approach to the production of new vehicles. To succeed, they must switch entirely to a platform-based architecture and unbundle component updates. They must also optimize engineering for cross-team collaborations and hire or retrain personnel so they have the right skills. For such a monumental shift to be successful, these activities cannot be entrusted to a skunkworks project with a few dozen people, a peripheral business unit, or a joint venture with an outside partner—especially if the majority of engineers continues doing things in the traditional manner. Automakers that fail to go big will risk being outrun by the competition.

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