BMW Leads in Chassis Control

FlexRay Network Is Key Enabler

FlexRay is not just for steer- or brake-by-wire anymore. BMW is about to bring to market some groundbreaking new chassis control features implemented on a FlexRay network—a world’s first. This unexpected deployment of FlexRay comes well before by-wire brakes or steering will be ready for production vehicles.

By-wire systems operate without mechanical or hydraulic linkages so they need safety-critical components such as FlexRay to ensure reliability. FlexRay is a time-triggered, deterministic data communication network that is many times faster than CAN (Controller Area Network), the communications bus that carmakers have been using for chassis control applications. But BMW’s pioneering application of FlexRay will lead other carmakers to use, or at least consider using, FlexRay in place of CAN in future real-time control applications, first in chassis control and later in powertrain control.

A FlexRay bus will first be used in BMW’s redesigned X5 SUV (sports activity vehicle), due in 2006, in an electronic damper control system to link an electronic control unit to four variable damper actuators. Damping forces are varied by a current-driven linear magnetic valve. The damper control system calculates proper damping forces using data from steering angle, acceleration and ride height sensors.

“This is a pilot project for us to learn what it means to bring FlexRay into a series car,” noted Karl-H. Gaubatz, general manager of electronics driving dynamics and lateral dynamics for BMW. BMW will build 15,000 cars per year with this FlexRay application so the carmaker and its suppliers can gain experience with the network hardware and software before it goes into high volume production.

“In the future, all new cars from BMW that come into production after 2006 will have FlexRay as a complete bus system in the car,” said Mr. Gaubatz. Indeed, the new BMW 7 series due in late 2008 will introduce a FlexRay-linked integrated chassis management (ICM) system that will coordinate damping, braking and steering from one central ECU. On result will be active yaw-torque control. “If you go around a corner and the car begins to drift where the rear part of the car is coming faster than the front, then you can control that with the braking system and the steering angle adjustment,” explained Mr. Gaubatz.

Chassis Innovation

“While I can’t talk specifically about them, we have a number of chassis innovations in the queue,” said Mr. Gaubatz.

Comparing CAN with FlexRay

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>CAN</th>
<th>FlexRay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data rate (gross)</td>
<td>500 kbit/s</td>
<td>10 Mbit/s</td>
</tr>
<tr>
<td>Data rate (net)</td>
<td>&lt;200 kbit/s</td>
<td>5 Mbit/s</td>
</tr>
<tr>
<td>Cycle time (message)</td>
<td>&gt;=10 ms</td>
<td>1 - 2 ms</td>
</tr>
<tr>
<td>Message jitter (depending on BUS load and ID)</td>
<td>0 - &gt;30 ms (no gateway necessary)</td>
<td>&lt;2 μs</td>
</tr>
<tr>
<td>Message delay</td>
<td>10 - 20 ms</td>
<td>1 - 2 ms</td>
</tr>
<tr>
<td>Message delay with gateway</td>
<td>11 - &gt;50 ms</td>
<td>1 - 2 ms</td>
</tr>
<tr>
<td>Synchronization STG</td>
<td>not possible</td>
<td>&lt;2 μs</td>
</tr>
<tr>
<td>Redundancy</td>
<td>none</td>
<td>2 channels</td>
</tr>
<tr>
<td>Maximum allowed load</td>
<td>35%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: BMW
**FlexRay...**

“The main innovations at BMW are coming in the chassis area and driving assistance, in steering, damping and braking. On the engine side, the last big innovation was direct injection. We had electrical valve train in development for years, but nobody is working on that now for a series car,” he noted.

Upcoming BMW models will soon employ a FlexRay bus to connect all five vehicle domains: infotainment, body controller, powertrain control, safety (airbag) and chassis control (brakes, damping and steering). Of the many possible new features involving chassis controls, one is using the steering wheel to alert the driver that he has wandered out of his lane by vibrating the steering wheel, as if the vehicle is driving over a rumble strip.

BMW and Mercedes were jointly ready to develop and promote FlexRay. But now BMW has taken the role as FlexRay's leading advocate, because FlexRay is an essential ingredient to the carmaker's advanced chassis control systems that will be brought to market over the next three or four years. In contrast, Mercedes' new S class, coming this fall, won't employ a FlexRay network. That suggests that FlexRay won't be needed at Mercedes anytime soon. In the past, new Mercedes technology has appeared in other M ercedes models only after it has been presented in the S class. The next S class redesign won't come for another seven to eight years.

**CAN Limitations**

FlexRay provides significant advantages over CAN communications networks. (Please see the chart on page 1.) Not only can FlexRay transmit messages at a much faster rate, the protocol is time-deterministic, meaning that specific time slots are allocated for all messages, making them certain to get through. Claas Bracklo, BMW manager in charge of E/E architecture and systems design, described the disadvantage of CAN: “With CAN, messages have to compete with each other to get through; access to the CAN network is actually a matter of chance. We manage this situation by over-sampling. For example, if we need some piece of information every hundred milliseconds, we might transfer the data every 10 milliseconds. The need to over-sample leads to the bandwidth problem with CAN.” FlexRay's deterministic behavior means that you don't have to over-sample.

Since each new node brings more traffic, only a limited number of nodes can be attached to each CAN bus. Over the years, as more features were added, BMW has had to add additional CAN buses. Each CAN bus can handle no more than 500 kilobits per second, gross. Further, to be sure that messages get through, each bus should only be used up to 35% of its full capacity. Given all of the new vehicle features coming soon to the new S series in 2008, BMW would have needed a total of six CAN buses. With every additional CAN bus a gateway is needed to connect one bus to another. “We don't want that because those gateways make the vehicle continued on page 3

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**Coordination Through a Hierarchical Structure**

“BMW’s aim is to provide stability in every dimension,” said Claas Bracklo, “up, down, right, left, back and forth. This is what will differentiate BMWs from other vehicles.” To accomplish that, BMW has adopted a system in which control functions are organized into a hierarchy. With hierarchical control, all of the chassis control functions are coordinated by the integrated chassis management ECU. Hierarchical architecture contrasts with today's distributed control architecture where each microcontroller system operates almost independently. Mr. Gaubatz added: “If every ECU makes independent decisions, one ECU might decide to make the vehicle yaw to the right while another ECU might call for a yaw to the left—then the car does nothing.”

As part of its quality “categorical imperatives,” DaimlerChrysler announced in May 2004 that it would implement hierarchical bus systems based on CAN, LIN, MOST and FlexRay standards and on the Autosar software architecture.

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**The Hansen Report on Automotive Electronics**

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FlexRay...

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too complex,” said M. r. Gaubatz. “With one FlexRay bus we don’t need those gateways.”

Interest in FlexRay is not at all limited to BMW. With today’s Golf and Passat models already requiring five CAN buses, Volkswagen’s top electrical engineer, Jürgen Leohold, is looking seriously at FlexRay as a requirement for introducing safety-critical systems like advanced driver assistance and by-wire steering and braking. But Volkswagen does not yet have firm plans to implement FlexRay. “Before we can create a migration scenario to FlexRay, we must get FlexRay down to CAN prices on a system basis. … We need to get semiconductor producers to make FlexRay interfaces available on the same basis that CAN interfaces are available now,” he said.

According to BMW’s M. r. Bracklo, CAN prices will be nearly impossible to beat. “We think 20 cents extra for FlexRay is affordable, but the footprint for the FlexRay interface chip is four times the size of CAN.” It’s hard to say how much each CAN interface costs. “You almost can’t buy a micro today that doesn’t have a CAN interface; you have to pay extra if you don’t want it,” he said. For now BMW will use FlexRay chips that aren’t integrated with the microcontroller. A mong possible suppliers of microcontroller with FlexRay interfaces are Freescale, Renesas, N EC and Philips.

Software...

Continued from page 1

practices. It expands oversight into the entire product life cycle, as well as engineering activities, to be sure that products meet customer expectations. A s a step up from C M M , C M M I helps companies implement more robust high-maturity practices, and it more fully complies with ISO standards. C M M I covers the integration of software modules with electronics hardware and the overall system. SEI developed C M M I in order to integrate the various C M M s as well as systems engineering into a single model.

There are five C M M I levels, from 1, the “performed” level where the process is unpredictable, poorly controlled and reactive, to level 5, the “optimizing” level. A number of automotive players say they’re striving to meet either level 2 or level 3. Referred to as the “managed” level, level 2 is project focused and often reactive. Th e “defined” level, 3 is organization focused and proactive. Level 4 organizations are “quantitatively managed,” where the process is measured and controlled. At the highest level, the “optimizing” level, the focus is on constant process improvement.

A lso playing an important role in software development, especially in Europe, is ISO/IEC 15504 or SPICE, an emerging standard for software process assessment. Th e first parts of the 15504 Technical Report have been approved for publication; the remaining parts are due in mid-2006. O nce the report is published, 15504 will be considered for release as an international standard, which will help software customers assess the capabilities of software suppliers.

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Background

Founded in 1988 to provide CAN software tools and components, Vector Informatik’s roots go back to Bosch, which along with Mercedes invented the Controller Area Network (CAN) technology. CAN, a mid-speed multiplexing protocol, is now used by carmakers worldwide for serial data communications between electronic control units. Two of Vector’s three founders, Martin Litschel and Helmut Schelling, joined Bosch in 1982, a year before CAN development began. A long with deputy chairman of the Bosch management board, Siegfried Dais, and a few others, Vector’s Martin Litschel is named in the CAN patent.

CAN was first used for a powertrain application in a Mercedes S class in 1990. Vector’s first automotive CAN protocol stack was used by Mercedes-Benz in 1994, for CAN-based body controls on the E class, and in 1997 on the CLK class. Vector built its first CAN tool in 1992, the CANalyzer network analysis tool.

In 1996 Vector negotiated with Daimler-Benz for the rights to apply the carmaker’s CAN technology worldwide, which helped to make CAN more widely applied and therefore more affordable to carmakers. Today Vector serves a broad customer base. Mercedes is Vector’s largest customer, but accounts for less than 10% of sales. In the five years since 1999, Vector has grown annually at the rate of 25% and expects to grow at least 10% per year for the next five years, through 2009.

While Vector was founded to deliver embedded CAN software and CAN engineering tools, it now considers itself a “network company,” since it added MOST, FlexRay and LIN network products to its repertoire. “That’s our greatest challenge,” suggested Thomas Beck, managing director and co-owner of Vector, “maintaining our position as the market leader in engineering tools for networking and in networking software.”

In line with that thinking, Vector, as a premium member of the AUTOSAR consortium, actively supports development of the AUTOSAR open architecture standard, which will incorporate MOST, FlexRay and LIN network protocols.

Despite the fact that it is a network company, Vector’s U.S. operation is still called Vector CAN tech. Founded in 1997, the subsidiary produced $14 million in sales in 2004.

Vector Informatik’s four managing directors and co-owners include Thomas Beck and the three founders: Helmut Schelling, Martin Litschel and Eberhard Hinderer, who came to Vector from Vetronix. “We have similar capabilities, sales numbers and global footprint, although ETA S started with powertrain applications, and we started with body applications,” he pointed out.
Self-Funded

Vector’s owners have no interest in investment partners. With the company privately held and self-funded they are free to build and manage it without a lot of people looking over their shoulders. “We fear that investment partners would demand higher profitability,” explained Dr. Beck. “That would change our focus away from our two primary goals, which are our customers’ needs and good products that meet those needs.”

While the company does not publicly report profits, Dr. Schelling disclosed that “Profits are big enough for long-term investments. We are focused not only on products that bring in money in six months or a year, but also on those that will produce profits in five years.” For example, last year Vector committed about seven man-years to standards development work. Vector is active in MOST, FlexRay, ASA M (An association for Standardization of Automation and Measurement Systems), ODX (Open Data eXchange), LIN, Autosar and, through Vector Japan, in Jaspar, which is working on both FlexRay and Autosar specs.

Key Competitive Strengths

Why do customers buy from Vector rather than from its competitors? According to Dr. Beck two things stand out: Vector’s global presence and the friendly, easy-to-learn human interface to its tools. “We have operations where most automotive electronics and vehicles are produced: in Japan, the United States, France, Sweden, and Germany,” he said. Dr. Schelling noted that Vector’s first products were developed with a lot of close feedback from DaimlerChrysler and Bosch. “Our tools come from engineers for engineers,” he said. Vector mainly sells its products to electrical engineers in middle management including chief engineers and team leaders at carmakers and top-tier automotive electronics companies.

High Grades from Customers and Employees

Vector contracted with a German market research firm in early 2004 to survey German customers about Vector’s sales performance, customer interactions, product support, and the quality and functionality of Vector’s products. After more than 100 customer interviews, Vector was very pleased with the results. On a scale where 1 is perfect and 5 is poor, Vector received a score of 1.9. “That gave us a clear indication that compared with our competitors in Germany, our customers see us as on the top,” said Dr. Beck.

In the February 2005 “Great Place to Work” survey, a European-wide initiative, Vector Informatik finished fourth among companies in Germany with up to 500 employees and sixth among all companies in Germany. In the survey, Vector employees were asked 59 questions regarding the company’s credibility, respect, fairness, pride and team orientation, the five dimensions that correspond with the Great Place to Work model. Vector’s success with its employees is not a matter of high salaries—Vector pays its employees the going rates. Rather, it’s about the respect Vector pays to its people. “We share a lot of information with our employees,” said Dr. Schelling. “We have an open door policy. A new employee can come in and talk to me.”

Products

Embedded Software Components

Vector offers OSEK operating systems and network management components for CAN, LIN and FlexRay.

CAN embedded software can cost anywhere from €50,000 to €100,000 for each car/microcontroller platform, depending on what’s in the protocol stack or what diagnostics software is included. The software Vector supplies covers the life of the platform.

continued on following page
Business relationships vary from OEM to OEM. For example, Vector sells the CAN-based Ford Network Operating System (FNOS) and General Motors Local Area Network (GM-LAN) directly to those carmakers’ suppliers. But BMW purchases its network software directly from Vector and then distributes it to BMW suppliers.

**Tools for Networking**

CANoe and CANalyzer tools not only support the development of CAN networks, but also of LIN, MOST and FlexRay networks.

CANoe is helpful both on the downstream and upstream sides of the product development V-cycle, especially for designing the network, simulating the network including gateways, and testing. With CANoe, engineers can answer some basic questions about the network, for example, “How many messages can the bus handle?” or “Is the distribution of the body control functions possible from the point of view of the communications bus?” A network and system modeling tool, CANoe simulates and also runs actual embedded software code to check it against the requirements model.

CANoe ranges widely in price—from €2,500 to €18,000, depending on which options are included. If you want to connect to all networks, CAN, LIN, MOST and FlexRay, the platform costs about €18,000 per seat, not including the PC. Since 1994 when the product was first brought to market, Vector has sold a total of 10,000 CANoe seats.

The CANalyzer network measurement and analysis tool, Vector's first major product, is part of the CANoe platform but is also sold separately for roughly €3,000 per seat. Vector has sold about 20,000 CANalyzer seats since 1992.

Software-based, all Vector's tools are run on PCs. Vector also sells interface units (PCMCIA, PCI, USB) to connect to the different networks.

**Tools for Automotive Electronics**
The Tools for Automotive Electronics product segment includes tools for measurement, calibrations and diagnostics. Central to this product line is Vector's versatile CANape Graph tool used for development, calibration and diagnostics of ECUs including controls for engine, A/C, electronic stability control, active suspension, air conditioning, adaptive cruise control, vehicle electrical systems and navigation. With CANape Graph engineers can arrange multiple windows on the computer's display for visualizing and evaluating measurement data. The tool also provides controls for executing diagnostics functions in ECUs.

Diagnostics tools are an important part of this segment. While today tools for diagnostics account for just 2% to 3% of Vector's sales, the demand for diagnostics capability is growing fast. At the core of Vector's diagnostics product line is the CANdela (CAN Diagnostic Environment for Lean Applications) product family. Used for acquiring, editing and processing diagnostic data, CANdela is a software environment in which a consistent XML database can be used across the development cycle—in requirements engineering, to implement diagnostics functionality within the ECU and in the parameterization of diagnostics testers. XML (Extensible Markup Language) is the universal format for structured data bases on the Web.

**New Products**

A site evolved from a CAN-focused company to a network company by expanding and adapting its portfolio, Vector intends to evolve over the long term to an engineering company. “We will adapt the product portfolio according to the needs of the auto industry,” declared Dr. Beck.

Perhaps the company’s most promising new product category is tools for engineering process management. Inside the company, Vector refers to the new product line as “SA P for development,” not to imply that it is in league with the giant G-
The CMMI methodology within their organization. Vector will soon have three employees certified as CMMI lead appraisers. Vector also has a SPICE assessor on staff.

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The Company Profile Continued

man software company, but to suggest that the products will be like SA P's, with a focus on engineering processes. SA P is a global market and technology leader in client-server enterprise application software.

Vector's new tool suite will be designed to run all the processes in the engineering area, including change request management, project management and configuration management. The client-PC server based suite will be run from an Oracle database, the software Oracle sells to manage large amounts of data. The suite will also include a workflow engine.

At this point, Vector management is not certain just how big the business will grow in light of the fact that they will be competing with huge players like SA P and IBM. "Our business will either be very small—several billion euros in revenue—or very big—several hundred million euros," said Dr. Beck. "We don't yet know.

Within the process management segment, Vector already provides consulting services to companies implementing CMMI and SPICE software process methodologies. For more on CMMI and SPICE, see the article "Software Process Standards Gaining Influence," which begins on page one.

New Products for Autosar

Vector will provide software components and tools in the Autosar environment, a software architecture standard promoted by the German auto industry, which later this decade could be used in production vehicles made by carmakers worldwide. More encompassing than networks, the Autosar consortium intends to develop standard interfaces for plug and play software modules used throughout the car. That will lead to many product opportunities for Vector, for standard Autosar middleware and software tools used to describe, develop and integrate software applications based on Autosar.

Software...

The purpose of 15504 was to harmonize a number of different software development models including CMM, CMMI, ISO 9001 and ISO 12207, along with some others. While 15504 is frequently referred to as SPICE, the two names are not synonymous. SPICE (Software Process Improvement Capability Determination) was actually the name given to the ISO and IEC joint technical committee's project to provide the common framework that resulted in 15504. The goals of the SPICE project are to assist in the standardization effort, undertake user trials and create market awareness and acceptance of the 15504 standard.

While SEI has been working with the international standards community to align CMMI closely with 15504, it is unlikely that one standard process will be adopted worldwide by all carmakers and suppliers. A path to competitive superiority, quality performance is too important to be left entirely to standards bodies. More likely, automotive companies will eventually use parts of these protocols but supplement them with their own proprietary processes.

General Motors exemplifies this mixed-and-match approach. While GM is an SEI partner, the carmaker isn't in lockstep with the entire CMMI package. Instead it has created what it terms a Target Profile that is more in keeping with GM's business objectives and GM's intention "to develop a common, global approach to software requirements definition, development and validation," wrote Ronn Jamieson in an email to The Hansen Report. Mr. Jamieson is responsible for GM's electronic controls and software strategy worldwide. A common practice will be used not only in chassis and body systems, but also within the GM Powertrain (GMP) group, which pioneered software process development at GM.

In an email from Dennis Bogden, GM powertrain electronics director, explained: "We have internal goals that are defined by specific metrics, which relate to rework due to errors, on-time delivery, changes to requirements after the requirements have been finalized, supplier errors and tool chain issues."

Reaching specific CMMI ratings isn't GM's goal. "We [at GMP] decided not to spend the money to do a CMMI audit [since] we already have a quarterly ISO audit covering our processes," wrote Mr. Bogden.

CMMI ratings don't necessarily lead to success. "We have worked with some organizations that have been rated very high on CMMI but needed improvement in the delivery. So rather than requiring our suppliers to be rated, we require them to deliver on time a robust product according to our requirements, with no errors, and no faults when installed on the system," Mr. Bogden elaborated. GMP is ISO 9001:2000 certified. ISO 9001:2000 is a family of specifications and standards of quality assurance management.

Vector Informatik, the German company profiled in this issue, conducts seminars on building expertise in engineering development and provides consulting services to companies interested in applying the CMMI methodology within their organizations. Vector will soon have three employees certified as CMMI lead appraisers. Vector also has a SPICE assessor on staff.

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SPICE Capability Levels
0 Incomplete
1 Performed
2 Established
3 Managed
4 Predictable
5 Optimizing
Note: See www.isospice.com/standard/assessmentmodel.htm for level definitions.

CMMI Capability Levels
1 Performed
2 Managed
3 Defined
4 Quantitatively Managed
5 Optimizing
Note: See www.sei.cmu.edu/cmmi/presentation/euro-sepg-tutorial/ld052.htm for level definitions.
Like GM, Toyota has developed software development processes that, while based on CMMI, are tailored to meet Toyota’s requirements. Toyota asks its suppliers to use this custom Toyota system for continuous improvement in their own development processes.

IBM’s Peter Robison, director of Product Lifecycle Management, Automotive Operations, said his organization is in the process of developing products that can help the automotive industry integrate processes such as CMMI. IBM sees the demand to meet CMMI requirements growing globally, more so than for SPICE. Internally, IBM has reached “high levels” of CMMI ratings, according to Mr. Robison.

Valeo, one of IBM’s customers, told us its new VIA S (Valeo Interbranch A automotive Software) division, a joint initiative with IBM, is “benefiting from IBM’s expertise in software development processes and tools.”

<table>
<thead>
<tr>
<th>Organization</th>
<th>Favored Process</th>
<th>Current Maturity Level</th>
<th>Goal(s)</th>
<th>What Do Carmakers Require of Suppliers?</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMW</td>
<td>E/E Process Chain</td>
<td>CMMI in addition to specific BMW targets</td>
<td>None</td>
<td>BMW relies on SPICE to assess suppliers, according to the HIS agreement ³</td>
</tr>
<tr>
<td>Chrysler</td>
<td>E/E Core Engineering²</td>
<td>CMMI/SPICE</td>
<td>None</td>
<td>Not Applicable</td>
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<td>General Motors</td>
<td>Powertrain, Vehicle Engineering</td>
<td>GM-specific, based on parts of CMMI ³</td>
<td>From 0-4 depending on process, according to in-house assessments</td>
<td>Considering goal to reach equivalent of level 3 in target processes by 2006</td>
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<td>Honda</td>
<td>E/E Systems R&amp;D</td>
<td>Considering CMMI and other methodologies</td>
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<td>Not applicable</td>
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<tr>
<td>Mercedes Car Group USA</td>
<td>Germany</td>
<td>CMMI SPICE</td>
<td>None</td>
<td>SPICE level 3 in 2007/2008</td>
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<td>Nissan</td>
<td>Proprietary, based somewhat on CMMI</td>
<td>None</td>
<td>Not applicable</td>
<td>&quot;Quality software,&quot; but Nissan does not specify CMMI or SPICE</td>
</tr>
<tr>
<td>Toyota</td>
<td>Proprietary, based somewhat on CMMI</td>
<td>None</td>
<td>Not applicable</td>
<td>Requests suppliers continually improve their processes, based on Toyota’s system</td>
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<tr>
<td>Volkswagen</td>
<td>E/E Engineering R&amp;D</td>
<td>SPICE</td>
<td>Various levels, depending on tasks</td>
<td>SPICE level 3</td>
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<tr>
<td>Bosch Automotive</td>
<td>All software business units, plus component development departments</td>
<td>CMMI/SPICE</td>
<td>CMMI level 2–4 in software; some level 2 in hardware; SPICE level 3 in gas &amp; diesel software development</td>
<td>Staged CMMI level 4; SPICE level 3</td>
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<td>Continental Automotive Systems</td>
<td>All business units that deliver software</td>
<td>SPICE</td>
<td>From 0–3, depending on the product or project</td>
<td>Level 3 by year end 2006</td>
</tr>
<tr>
<td>Delphi</td>
<td>Electronics &amp; Safety</td>
<td>CMMI</td>
<td>CMMI assessment planned for Q1 2006</td>
<td>CMMI level 3 short term; level 5 long term</td>
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<tr>
<td>Siemens VDO</td>
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<td>CMMI</td>
<td>None</td>
<td>Level 3 by year end 2005; level 5 long term</td>
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<tr>
<td>Valeo</td>
<td>All divisions that deliver software</td>
<td>CMMI/SPICE</td>
<td>CMMI level 2; global deployment in progress</td>
<td>CMMI level 3 by early 2006</td>
</tr>
<tr>
<td>Visteon</td>
<td>Visteon Engineering Process (VEP), which uses elements of CMMI and SPICE</td>
<td>CMM-SW level 3 since 2000</td>
<td>VEP</td>
<td>Some will require at least CMMI level 2 within the next few years; others want SPICE</td>
</tr>
</tbody>
</table>

¹ In December 2004, five German carmakers within the HIS (Herstellerinitiative Software) interest group agreed to apply the SPICE assessment method.
² E/E Core Engineering no longer writes software for the controllers it purchases. Instead it creates STATEMATE models to convey desired controller behavior. Chrysler E/E Powertrain may deal with software differently.
³ GM Powertrain Group is ISO 9001:2000 certified. Vehicle Engineering has adopted all ISO work practice methodologies but is not officially ISO certified.
²The above list includes only those carmakers and suppliers who responded to The Hansen Report’s survey.