Vehicle Development: View from the Trenches

■ A look at the tricks and tools automakers use to squeeze time and cost out of new-product development.

by Gary Witzenburg

'Vehicle Development' means different things to different people, even among auto engineers. To some, it's the way-up-front process: defining a vehicle's role and requirements, benchmarking its intended competition, choosing its content and componentry. To others, it's vehicle-level refinement from earliest test "mule" through prototype to production-ready pilot.

Realistically, as program timing has compressed with intense competition in recent years, it seems to have evolved into a hybrid of both — "from napkin to showroom," as one engineer succinctly put it — and the lines between once clearly defined steps have blurred.

As applied to vehicles, Webster's most appropriate definition of "development" is "a gradual growth or advancement through progressive changes." In today's go-fast auto engineering environment, the mission is to maximize "advancement" while minimizing "changes." And there is no time for "gradual."

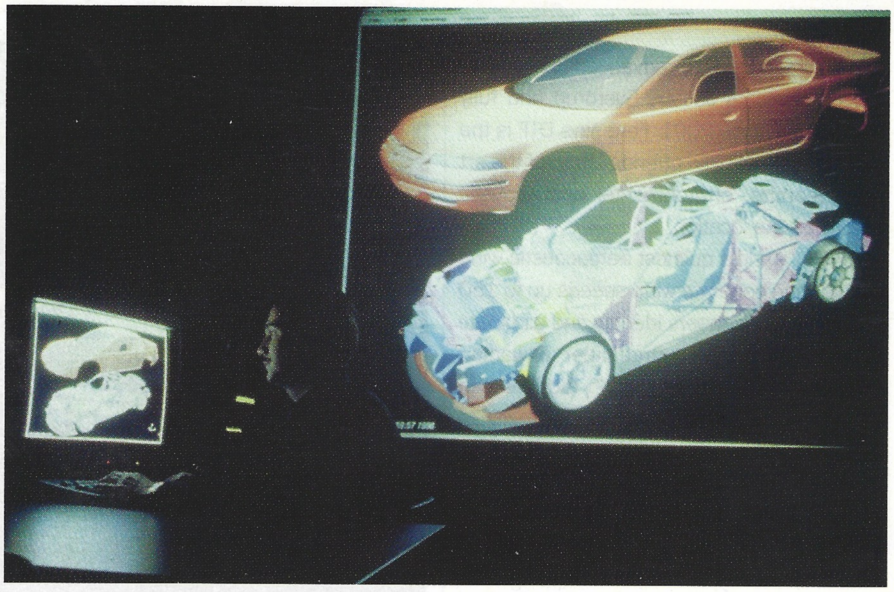
Every motor vehicle is an integrated set of subsystems — body, chassis, powertrain, structure, electrical, HVAC — each made up of many individual components. Design, development and validation (verification, through testing, that requirements have been met) happens at each of three levels: component, subsystem and vehicle.

Traditionally, the process has been mostly sequential: Vehicle requirements defined subsystem requirements, which defined component requirements. Components designed, developed and validated to meet those requirements were combined into subsystems, which in turn were developed and validated before coming together as a vehicle. The final step, full-vehicle development, ensured that all subsystems were happily married and interfaced and functioned as a team to meet the vehicle requirements and ultimately delight the customer.

Engineers put several Hummer H2s through the paces at the Milford, Mich. proving grounds. The twist ditches, rock climbs, sand pits and other obstacles aid in the development of products with serious off-road intent.

Today, the luxury of sequential development is no longer an option; it simply takes too long and costs too much. Tier 1 suppliers (subsystem sources) are being brought into vehicle teams very early, and development, including vehicle-level work, is being pushed further and further upstream through computer simulation and in laboratory environments. Only where important and absolutely necessary are portions still done on roads and tracks.

Looking primarily at dynamic vehicle development — mostly chassis dynamics (ride, handling, steering, braking) and NVH (noise, vibration and harshness) — which still must be accomplished by trained and skilled experts in running vehicles — we talked to engineers from GM, Ford, DaimlerChrysler and Nissan to learn how each company approaches the process, what has changed in recent years and where they are headed in the future. Also how they, like everyone else, are coping with relentless pressure to improve results while taking more and more time, money and headcount out of the process.



A majority of a vehicle's early developement is done with math data. Computers can now simulate just about anything up to and through virtual builds.

Computer Development

Correctly criticized as cumbersome and slow in the past, General Motors has consolidated and streamlined every aspect of what is now its Global Vehicle Development Process (GVDP). Enabled by computing capability increased more than six-fold in the past couple of years, GM claims to have reduced development time — as measured from Verified Data Release (VDR), the moment when a vehicle concept is approved and its styling surfaces digitized, to start of production (SOP) — from 48 months four years ago to 18-24 months today, and says it is "headed toward" 12 months .

On the dynamic development front, Executive Director for Vehicle Performance Harvey Bell says there are three key differences today vs. a few years ago. First is consolidation of resources into a new Vehicle Development building at GM's Milford Proving Ground. Second is the power of math-based development, "which allows us to work in a single language and communicate with each other quickly and effectively." Third is the VLE (Vehicle Line Executive) system, "which provides good single-point contacts for decision-making."

GM Vehicle Dynamics Director Larry Fletcher explains: "The process has evolved into a combination of work that we're able to do in math and work that we do in hardware. I think we're doing at least half the work upfront in math — laying out the architecture, fundamental systems, the geometry of the suspensions. We're still doing a lot of fine-tuning after the fact, which takes a lot of time, hence the other 50 percent.

"When we combined the organizations, we not only brought the divisions together but also brought the math and hardware people into the same organization. We're cross-training some of our math people in hardware development and some of our hardware people in math development to bring everyone's skills up to a higher level and get them working together more effectively. And we're using more common advanced analytical methods."

Adds Bell, "It's a critical move forward when you can have the engineer ride the vehicle then go back and work with the math model. It improves the correlation between math and hardware and helps the decision-making."

This is but one example of what has been happening industry wide. Different companies have different approaches and may be at different points in the process of change, but each is doing everything it can as fast as it can to improve and streamline its process.

DaimlerChrysler engineers made excellent use of the company's Berlin-based driving simulator during early development of its new Chrysler Pacifica crossover vehicle. "We had vehicle architecture, suspension architecture and tire issues," says Vehicle Dynamics Engineer Jac Brown. "We hadn't yet built a car but needed to decide the direction."

Working with the simulator, the team determined that a proposed five-link rear suspension design provided better tuning capability than other alternatives. Also, that a tire upgrade was necessary to take advantage of that capability. "So we ended up with an H-rated touring tire and pushed the track width out to the maximum to maximize the available handling out of that suspension," Brown relates.

"A big focus of our vehicle development in the last few years has been to push as much of it into the computer as possible," adds DCX's Cole Quinnell, manager of Engineering and Technical Affairs communications. "We do some incredible modeling on computers now that just wasn't possible five or 10 years ago."

Ford engineers agree that reductions in development cost and time result primarily from increased capabilities of analytical tools, which provide both speed and confidence, and from extensive work in full-vehicle laboratory facilities. "Before our vehicles ever start physical testing," says Ford Lifestyle Vehicles chief engineer Dan Arbitter, "hundreds of simulations have been completed, not only for the nominal design but also for the effects of variability."

Laboratory Development

Significantly reducing development time while increasing the quality of current and future products is the role of Ford's new Driveability Test Facility (DTF) in Allen Park, Mich. Managed by advanced technology testing company Jacobs Sverdrup and fully operational since 2001, Ford says DTF is the world's only facility offering state-of-the-art aerodynamics, environmental and acoustic testing in one location.

DTF's "world's quietest aeroacoustic wind tunnel" can generate wind speeds up to 150 mph to help engineers identify and eliminate wind noise, squeaks and other unwanted sounds. Advanced simulation facilities can provide temperatures ranging from -40 to 131 degrees F. and altitudes from 28 ft. below to 12,000 ft. above sea level. For powertrain, climate system and other weather-related development, this saves substantial time and money once spent shipping vehicles and staff to remote locations chasing naturally occurring weather cycles.

"In the past, they were having to go through two or three complete seasons to do all the development and pre-sign-off work," says Bob Doyle, who oversees DTF and other Ford test facilities. "Now that can be done in about a year in our laboratories, and the environments are more reproducible." Only once, for final "engineering sign-off," do the vehicles have to go into actual environments, and by then the engineers have attained a high degree of confidence. "We've spent a lot of time over the past couple of years correlating between the results we get in the field and results we get in the lab," Doyle adds.

Ford, of course, is not the only automaker with climactic facilities. DCX has climactic test cells at its Auburn Hills Technical Center (CTC) "where we can drive a car on rollers, both two-wheel and all-wheel drive, make it snow in July or take it to minus 40 F for cold warm-ups," Quinnell asserts. "That's where we do a lot of extreme temperature development work at a preliminary level. They can soak a car, do a cool-down test or generate a Death Valley condition and get to where they are quite confident, then it becomes a validation issue to take to the real world. It really is state of the art."

The range of capabilities of these cells includes temperatures from -40 to 130 F, 20 to 95 percent humidity and wind speeds to 100 mph with electric dynamometer, plus infrared solar, rain, snow and heated road simulations.

Germany's famous Nurburgring was the test track for developement of the Cadillac CTS. GM continues to use it to road test this premium product.

GM Powertrain's climactic wind tunnel offers wind speeds up to 150 mph, temperatures from -40 to 140 F, 5 to 95 percent humidity, sun loads up to 1,155 W/m2 and hot road simulations up to 175 degrees F. Such previously surface- and weather-dependent tasks as smooth-road shake and pass-by noise development are also moving into dynamometer cells, and new state-of-the-art low-coefficient tiles are being installed at the Milford Proving Ground to enable year-round ABS brake, traction control and stability control development.

On-Road Development

Despite such tremendous recent advances in computer and laboratory simulation capabilities, a lot of critically important vehicle work must still be done on proving ground test surfaces, public roads and even race tracks. "I don't think there's ever going to be a day when we'll have an effective computer-simulated total vehicle," says Lance Miller, Nissan North America's director of Vehicle Evaluation and Test.

"For products sold here, we do some of it at our Arizona Test Center, but we like to get with our Japanese counterparts on public roads so they can see what the customer usage will be," Miller explains. "We may go to New York State, or Florida or Los Angeles. That info then goes back to Japan, where they build a mule vehicle. That vehicle is then developed — primarily for suspension tuning and NVH — both here and in Japan and is used as a basis for 'initial production' vehicles, which we used to call 'prototypes,' built off production tools. For a program that will be produced here, that is when Nissan NA receives full responsibility."

When development engineers need cold weather in the summer, or vice versa, they head for the Southern Hemisphere. "If you run out of snow and cold in Northern Michigan, you start heading up into Canada, then Alaska, and eventually you end up in June or July in New Zealand," says Chrysler's Brown. With robust affiliates there, GM and Ford typically go to Australia. GM also has a facility, primarily for truck work, in Brazil. Such world travel adds costs, but wedging two hot or cold seasons into a single calendar year compresses program time, saving huge structural costs and getting vehicles to market sooner.

GM now favors twisty road-racing tracks for handling development and public roads for ride and steering work. "But we still do a fair amount of work on property," Fletcher says. "We'll identify a problem or issue on a road or track, then come back here and find some section of proving ground road that we can use to resolve it." The U.S. has a wide variety of available race tracks, some in nearby Michigan and Ohio, but no other track in the world offers the diversity of "events" (unique combinations of surfaces, bumps, curves and elevation changes) of Germany's famous 13.6-mile Nurburgring course, where most European makers test. To better compete with upscale Mercedes-Benz and BMW sport sedans, GM used "The Ring" for extensive development of its Cadillac CTS and continues to use it for premium and image products where the results justify the cost.

GM also has its own simulated race track, sections of which can be wetted for tire development, at its Mesa, Ariz., Desert Proving Ground and is building a bigger and better one at Milford. "It will include elevation changes and duplications of curves and events from many of the tracks where we do development around the world, including the Nurburgring," Fletcher says, "which will reduce the time we spend at other tracks." Also new at Milford is a rugged off-road course with a variety of challenging hills, rock climbs and sand pits for development of vehicles such as the Hummer H2 and other products with serious off-road intent.

Instead of waiting for complete prototype vehicles, all makers make more and better use of "mule" vehicles — typically current models fitted with a single development subsystem — much earlier in the process. For DCX's Pacifica program, early mules were essentially minivan structures cobbled up to fit various chassis or engine components. "Other phases utilized early floor structures that were design-representative of the direction we were heading," says Brown. "We're trying to continuously improve the reliability of the information we're getting from them without investing too much money in full-skin prototypes too early."

A Ford engineer (top) checks the sleekness of a Mustang convertible inside the "world's quietest aeroacoustic wind tunnel" at the Driveability Test Facility in Allen Park, Mich. A drive over the Beligian Blocks (bottom) at GM's Milford test facility accelerate suspension wear in real time.

Future Development

As we have seen, each company has a somewhat different set of processes and priorities to achieve the desired result of great new products. Toyota has matter-of-factly announced that it is preparing to do product programs from simulation and past experience alone, with no development vehicles at all. That probably means eliminating mules by moving from computer to "early production" vehicles, which will still have to be dynamically refined. Few development engineers can see the day any time soon when they won't be spending at least some time doing subjective tuning on real roads in real environments.

Among the U.S. Big 3, Ford might be closest to that day. "The greatest volume of vehicle development," Arbitter asserts, "is done on our computers from very early in the program all the way through to Job One. Physical vehicle testing is there for verification and alignment, but analytical capability offers far greater opportunities to analyze the 'what ifs,' production variability and model complexities.

"For the future," he adds, "the area that I see as most promising is the ability to improve integration among lab, track and analytical testing. Linking these three environments into an integrated environment where data can be input and measured at any of the three nodes will be extremely powerful."

Even as engineers develop innovative new ways to eliminate steps and move more vehicle work into labs and computers, DCX's Brown — like most of today's vehicle development experts — believes that the bottom line of satisfying and delighting customers will continue to depend very much on skilled people spending long hours in vehicles perfecting those final few degrees of feel and performance. "Once you get to where you have to have a car on a road," he says, "there isn't any substitute for spending the time to get it right." ★