Ford virtual reality shapes your reality

Story and photos by Joe Sage

Ford gets technology—witness their presence the past couple of years not only at the big auto shows, but also at the Consumer Electronics Show in Las Vegas, where they've shown off SYNC® and other tech systems. On-board gadgets, though, are really just the icing on the cake. Ford's Virtual Reality Lab program at the Product Development Center in Dearborn starts well before and goes well beyond consumer electronics. The incredible processing power that now lies beneath the entire design, engineering, planning and development process merges what you'd expect to find at Boeing's human factors engineering department with both craft development and pre-flight training at NASA.

In fact, the work is so advanced that Elizabeth Baron, who runs Ford's Immersive Virtual Environment (iVE) lab, received a call from NASA's visualization lab asking for a tour of the Ford facility. After NASA's visit to Baron's iVE lab at Ford, she was invited to Kennedy Space Center to see their virtual technology. "We found out what we shared in common and what we could learn from each other," said Baron. While Baron was at Cape Canaveral, she had an opportunity to see the space shuttle Discovery preparing for launch. "I even had a chance to take a peek inside the shuttle," said Baron. "It was just phenomenal."

The programs generate enthusiasm and support within the company, from the assembly line to top management. Although these implementations predate his arrival, it surely doesn't hurt that president and CEO Alan Mulally came to Ford from Boeing.

We're told very few people outside the design and engineering group at Ford ever get to experience all this. Though we don't have as much to offer in reciprocation as NASA did, we nonetheless were recently invited to tour the same facilities.

Photo: Ford Motor Company

Elizabeth Baron, Technical Specialist for Virtual Reality and Advanced Visualization, runs Ford's Immersive Virtual Environment (iVE) lab, a facility she helped create. The iVE uses state-of-the-art virtual reality technology—such as the PVM (Programmable Vehicle Module), above—so designers can fully experience a vehicle before it is ever built. The lab's work is so renowned that NASA requested a tour.

The virtual reality program addresses design and engineering of new vehicles from the standpoint of not only the people who will drive and ride in them, but also the people who will work the line to build them. If you can't get your hands around the concept—literally—there is more work to be done, and these are the tools that identify and define what's needed. From the days of drawing board, clay model and tape measure, things have come a long way through computerization. The Ford virtual reality program takes the process to a level of such detail and realism that designers and engineers can immerse themselves in a new vehicle before the first prototype is ever built, so it can be optimized and put into production—consumer-tested, yet—on a shorter timeline and at lower cost.

The virtual reality program comprises multiple resources: the Immersive Virtual Environment (iVE), CAVE, PVM, Powerwall, VIRTTEX and Virtual Manufacturing. We saw—and tried—all of it, guided by the key engineers who make it happen. Strap on your goggles, and let's step inside.

Immersive Virtual Evaluation (iVE)

Designers and engineers use the iVE to evaluate early vehicle designs against a backdrop of virtual conditions and literally experience a vehicle from someone else's vantage point before it is built. Anthropometric data gathered here—from the obvious such as visibility, reach, roominess, ingress, and egress, to examining door-handle location—is studied to ensure vehicle designs can accommodate the broadest range of customers.

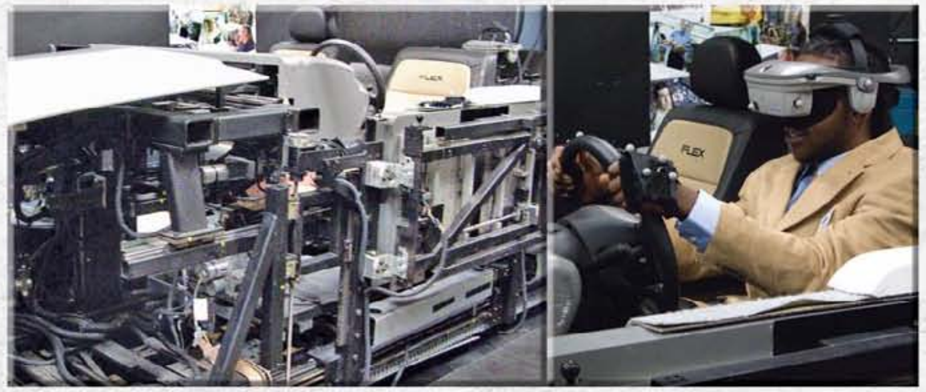
The iVE lab comprises 3 virtual reality stations: the Cave Automated Virtual Environment (CAVE), a Programmable Vehicle Model (PVM) and an Open-Volume Immersive Station. As program chief Elizabeth Baron points out, these three stations each have a strength and a weakness, for example field of view versus body relationship. "Together," she says, "they are not missing much."

The **CAVE** uses advanced motion-tracking hardware and software to create virtual vehicle interiors and exteriors at actual scale, reducing the need to build physical prototypes.

Here, CAD designs are translated into digital renderings of cars to evaluate ergonomics of the interior, exterior craftsmanship and the extent of views. Virtually anything you can see on a vehicle can be duplicated, from the A-pillar to the underbody. The CAVE offers a wide field of view with peripheral vision, so an evaluator can, for example, look over his or her shoulder to judge whether a second-row headrest may obscure a driver's view or to determine if the base of the rear window is too high.

We sit in a bare-bones vehicle interior—with the front seats, steering wheel, driver-side door and blank dash physically in place—put on sensors and special glasses with screens inside and you see what it would look like to be inside that car. We don 3-D glasses and suddenly experience the controls inside the car, surroundings outside, and have the ability to reach out and use our hand to try the features in the digital overlay. Data is gathered on whether controls are within reach and whether we can see things outside the vehicle well enough, such as the small child in the crosswalk in front of us.

The CAVE process has reduced the number of clays and prototypes made and cut six months out of the production cycle. The program has run full-bore for about 2-3 years, so the results are just now beginning to appear in production Ford cars and trucks.



The CAVE (Cave Automated Virtual Environment) lets a driver experience a vehicle's simulated instrument panel and views, providing a chance to identify preferred layouts and ideal interfaces early in the process. The Open Volume Station puts a headset-wearing driver into a full-size virtual vehicle to measure feedback.

Ford is the first in the industry to mesh a **Programmable Vehicle Model (PVM)** with complex motion-capture technology to create a realistic virtual vehicle and driving experience with passing cars and pedestrians.

Before the digital revolution, a design team would build a stationary three-dimensional physical buck to evaluate an interior under development. This accommodated one design iteration—so each round of design revisions required modifications to the existing buck or the construction of a new one, adding time and cost to a product's development.

Ford's PVM is an adjustable computer-controlled physical device that can instantly take on dimensions of any full-size interior, so engineers can evaluate multiple design options against a number of criteria, such as reach, blind spots, reflections, headroom and steering wheel angle. An evaluator can for example enter a Ford Flex-dimensioned PVM, wearing headset and gloves, and became immersed in driving a digital Flex. They interact with the Flex's steering wheel, center-stack controls and instrument cluster while moving through a virtual town. With their physical touch-points recorded in the PVM, Ford engineers can effectively simulate the comfort of the beltline, the ease of reach for the shifter and other key areas.

Original PVM simulations on the Flex led to several important design changes: the seats were moved closer to the door openings for smoother entry and exit, and the rocker panels were concealed, a unique Flex feature intended to provide an unexpected "surprise-and-delight benefit." Hiding the sill removed the need to lift your legs over a possibly muddy surface, reducing the odds of rubbing dirt onto your pants or dress..

In the **Open-Volume Station**, a driver is immediately immersed in a computer-generated virtual vehicle interior or exterior environment—complete with accurate depth perception—and asked to perform specific tasks such as closing a liftgate or decklid. This was set up as a Flex for us, and our actions were captured by sophisticated cameras that track the movement of sensors on our headset and gloves, which were loaded into a computer program for further studies. Information from the headset lets engineers can play the session back to see what we noticed most. The open-volume

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DEARBORN TRAVEL NOTES

We had been to Ford World Headquarters in Dearborn a few times, but though we'd heard about Greenfield Village and The Henry Ford Museum for years, and they're just a few blocks (and a century or two) apart, last year was our first visit to those. We were so impressed, we'd not only go again, we'd like to move in. Greenfield Village includes living, working examples of America's earlier history, conceived by Henry Ford out of personal motivation, and as significant a national treasure as the Smithsonian.

Across the street, Ford's Dearborn Development Center test track, technical labs, wind tunnel and other engineering facilities share a high-security campus.

Photo: Ford Motor Company

We were booked at a Marriott near the test track for one night, and we visualized the ordinary. Not so. We should have seen it coming. The Dearborn Inn, operated by Marriott, is another Henry Ford historic treasure, reminiscent of Independence Hall or Monticello. The hotel ties in to the history of the test track, as well. Henry Ford developed aircraft, too, significantly the famous Ford Tri-Motor. With booming business interests in Dearborn, he built the Ford Airport to accommodate his visitors. The Dearborn Inn was the world's first airport hotel. No, this is not your typical roadside Marriott, but Marriott is to be commended for the fine job they've done preserving the property in its original glory, while operating a high-caliber hotel there today.

Photo: Marriott

For more information, visit marriott.com.

An evaluator dons an array of "cloud markers" (far left) to test reach, sequence and accessibility issues in the Virtual Manufacturing and Assembly stage. VIRTTEX, a huge carbon-fiber-and-nomex dome (near left), puts a driver behind the wheel of a simulated vehicle moving within a 12-by-12-by-6-foot range, an indispensable tool for testing control options against human reflexes. Mike Blommer and media spectators were privy to the challenges being run, via a bank of monitors, while one journalist at a time ran the drill and generated data. Track time included a wide range of vehicles on slow and fast courses, plus a demo of Active Park Assist in the Escape.

data also allows engineers to adapt results to people of different statures. Results can be quickly scaled to another person's stature, performing the same tasks. A 4'9" woman can become a 6'3" man or vice versa.

Virtual Manufacturing/Assembly

Next stop: Ford's Advanced Engineering & Technology department, where Allison Stephens, Ford technical specialist in assembly ergonomics, demonstrates how advanced motion capture technology and human modeling software—similar to that used in major Hollywood animation or in top-flight digital games—can ensure manufacturing feasibility, while predicting and eliminating on-the-job fatigue and injuries, part by part.

Glenn Harrington, technical expert in assembly ergonomics, is suited up and running an assembly process on the 2012 Ford Fiesta, virtually, with ergonomic simulation specialist Jim Chiang at the controls. "You see this vehicle in front of you in 3D," says Stephens. "How would you reach in? What postures would you use? While you're doing those postures, I can capture the motion and get a data model, and can then analyze it."

The suit uses "cloud markers" to record a worker's motions and transfer them to digital avatars. "Basically, the markers are the same highly reflective material you have on athletic equipment," says Stephens, "and they're put on joint centers so we can identify for example elbow and knee joints, and cameras are capturing the markers." When our live cloud markers move, the digital models move onscreen. This is essentially the same technology the motion picture industry used to bring us Avatar, with live actors generating movements that were transferred to synthesized extraterrestrials. Ford takes this process farther than Hollywood, transferring to fully digital human models with bone, muscles, complete data about compressive forces, joint torques and so on.

There are cameras all around. The high cameras are probably best at capturing, although in the midzone if something is blocked by movement, as long as three cameras capture a motion, they achieve the tracking. So whatever is tried in the suit is transferred to avatars Jack and Jill, the department's "digital employees." In the past, they would have to get a tall and a small operator and set up a mock vehicle several times, but this system has the capability to scale everything, once motion is captured.

The mechanical set can become any vehicle, by loading product data and hard points; when immersed, key points of the car will anchor your position for the rest. They also load key points from every station in the assembly plant, as posture is also influenced by those. We suit up and walk toward a virtual Ford Fiesta. As instructed, we reach toward the car and feel the fender.

From our simple exercise to touch a virtual hose, they can learn whether the part is reachable during assembly, whether that puts a particular strain on a worker, whether in fact other parts (e.g. the space-consuming front fascia) should be assembled in a different sequence that allows access to deeper parts, earlier in the process, and so on.

Ford set up their first lab in 2001, a magnetic system, but issues inherent in mixing magnets and steel yielded only a few studies. In 2005, they switched over to the digital camera system, at the time working on vehicles for 2008. From studies done in 2005 and forward, they now have three good years of products—2008, 2009, 2010—on which they've done complete studies of the process.

Results are impressive. There has been an 80% improvement in assembly line injuries over the past 10 years, which is huge, though they know they can't claim all of it. But for example, studying data specific to hoses, they saw a 35% reduction in injuries based on recommendations from this system.

Most impressive of all: in 2005-2008, they would see about 300 issues on a build (parts that are hard to install, not enough hand clearance, and so on). With the virtual program in operation, this is down to just 30 issues, a massive 90% reduction.

Nobody likes to find a problem, says Harrington, but if you're going to find a problem, you want to find it early. In prior methods, finding a problem 14 months before production would create a panic; now the details should be squared away in a process that starts three years before build, with parts manufacturing starting 18 months out. Locating problems during digital preassembly can save time from concept to production, yet provide more time for problem-solving.

"For example," Harrington tells us, "we're looking at the new Ford Fiesta. It's a 2011 model year that's sold in calendar year 2010, but we studied it back in '07. Next week, we're studying the '13, so the process has moved very far upstream."

Success has been so good so far, in fact, that the team notes they've caught most of the low-hanging fruit by now. Their success has been so high that now, if anything, expectations for perfection may be the biggest issue at this point. "You had all this, yet you missed something....?"

As Harrington says, "When we get to the physical build with physical parts and we have an 80-90% reduction in issues, we're not finding nearly the late stuff we used to. And this is not just in ergonomics. Manufacturing, design, crash, emissions—all the parties have benefited from up-front analysis.

Virtual Powerwall

The Powerwall (Ford's Electronic Design Presentation Room, or EDPR) is a 60-foot-wide HD rear-screen projection using three 20-foot screens simultaneously, with interior and exterior views of a vehicle. Our session has been bumped by a visit from Ford Group VP of Global Design and Chief Creative Officer J Mays. That we can easily understand. We instead are in a room with one screen—no cameras!—and it's quite impressive in its own right.

The Powerwall replaces the design stage of full-size prints on walls, adding 3D rotations, engineering points, and even the ability to drive the vehicle by keyboard. A polygon wireframe image comes to life, rendering an occlusion (shading) pass, adding high-resolution surfaces, then adding real-world backgrounds shot with their hemispherical environments camera, and changing paints as well as times of day, to see how things come together. With Powerwall studios in seven other locations in Europe, Asia and South America—fully linked for three years now—the design process is easily spread worldwide within the company. Collaboration is complete, immediate and weighs nothing, and research can be completed on multiple continents in one day. And changes that used to take 3-4 weeks now take 3-4 days.

Visuals can be shown on smaller screens, so a focus group can be held in six cities without shipping, say, 18 pickup trucks (including competitors), but just six USB memory sticks. Field experience shows that with distractions minimized, a customer can focus, evaluate and offer opinions better than ever. The 2010 Taurus was the first Ford vehicle program to conduct digital consumer marketing research, helping deliver it 12 months sooner while cutting research costs by nearly 50 percent.

What for decades was a hand-carved clay-model process, then evolving through a "hybrid" stage of math-modeled clay, is now completely digital. The screens display full-scale computer-rendered vehicle designs—again, prior to actual fabrication—for up-front high-fidelity review of options and details. Models are still made, ultimately, but are now considered verification, not iteration.

VIRTTEX

Mike Blommer holds a PhD in Electrical Engineering and is Ford's technical expert in sound quality, psychophysics and sound and motion control for driving simulators. He is our guide to VIRTTEX—the VIRtual Test Track EXperiment—a full-size driving simulator very much like a flight simulator and incorporating many of the same technologies.

Ford is the only vehicle manufacturer in North America with motion as part of its simulations. In place since 2001, the fundamental motion system hardware is unchanged, though they've followed a continual upgrade path for video and processing power.

Such technologies as lane departure, collision warning, braking assistance, distraction and drowsiness indicators—as well as advances in user controls—have made it more important than ever to determine how drivers react to visual, audio and tactile cues.

VIRTTEX puts you in the driver's seat of a simulated (partial) vehicle, in a dome made of carbon fiber plates with a nomex honeycomb core—light enough for considerable motion, but strong enough to support five hung projection screens. The dome is set atop hydraulics that move the whole apparatus within a 12-foot by 12-foot by 6-foot realm, introducing pitch, yaw and roll, simulating motion within six degrees of freedom.

By watching the driver interact with an environment, Ford is able to compare, for example, handheld versus hands-free controls. Or for such safety add-ons as lane-change or collisions warnings, they can gain valuable data on what's the most effective notification: sound? light? vibration? With VIRTTEX, they can measure reactions to each.

Do virtual drivers think of this as real life, or a game? Blommer says they of course know it's a simulation, but typically within 3-5 minutes they are immersed and react normally.

A typical VIRTTEX session lasts about 20-30 minutes. Several in our group were put in the simulated driver's seat, where we could watch (and we were cued, while they weren't) as they were given an instrument task as a mild distraction, while a semi came up at high speed to pass them, just as something in front of them would stop, perhaps forcing them into that left lane. And so on. The session ran out of time before we got to sit in that seat, but by then we had a pretty good idea what the tricks might be.

Blommer points out that real motion makes a major difference in analysis, for example revealing motion multipliers in oscillations, that could otherwise go unnoted. Real motion within a dome, however, cannot replicate everything. 12 feet of lateral motion in the dome is good at replicating lateral motions in the real world. But a 130-foot stop has to happen in no more than 12 feet, and whereas they can multiply and mimic to a point, this has some limits.

As impressive a machine as this is, Blommer points out that it is "one tool in the suite of tools." Field operations are still important, inherently, and they also help as impressions change over time.

Nonetheless, as with the rest of the virtual reality suite we've seen today, the VIRTTEX device lets engineers test a powertrain before a vehicle is ready, long before they can otherwise take it out in the field for actual testing and calibration. This makes VIRTTEX a valuable manufacturing research device even 5 to 10 years out.

Ford Proving Grounds

There are few things we encountered this day that did seem to have slightly more than one version of a name, and the Dearborn Development Center a.k.a. Ford Proving Grounds a.k.a. test track are one more.

After a morning in the virtual world (and a quick lunch), we headed into the sunshine to see how the rubber meets the road.

As one of the oldest in the industry, Ford's Dearborn test track, at 366 acres, is among the smallest. (Some are tallied in the thousands of acres.) Packed into this space are eight different track facilities, with access granted according to the level of driver.

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FORD START CONCEPT: AN INSIDE LOOK AT THE DESIGN PROCESS

On the lawn during dinner our first evening was the Ford Start concept, designed in Ford's southern California design studio and revealed three weeks prior, at the Beijing auto show. Ford designer Jeff Nield was on hand to share with us the finer points of this small concept car's design.

"There are a lot of design cues to give this the presence of a car twice its size," says Nield, "creating an emotional and beautiful very small city car, cues that we consider 'romantic,' that would be more likely to be found on a luxury vehicle.

"If you look at the beltline, it's in a very horizontal position. It has rake to it, so the car still looks lunging, but it's not overly aggressive; it still looks very relaxed. The second feature you'll notice is the shoulder line; it has reverse rake, higher in the front than in the rear, like you'd see on a Chris-Craft or luxury boat, giving kind of a chariot feel. You'll notice very few surfacing features on the body side, just the shoulder line, and then a line in the rocker. In the industry today, this is a long distance to go without any other 'entertainment,' and that's very intentional. We wanted to communicate with minimum lines, to give the viewer time to relax and breathe. We talked about making music and not noise. If you're making music, the notes are important, but the space is important, too. You don't want to overstimulate the person; a car can become irritating if it's overstyled.

"In the rear, this is an extremely narrow car. So the taillamps wrap much further around the corners than is really necessary. You could stop at the back corner and have it still functional, but by bringing it all the way around, your impression is of more width and more presence. It makes the car look more grown-up. We gave the roof more section, the curve that makes the roof come across as thicker than on a more traditional vehicle. This gives a feeling of more occupant protection. There's glass 360 degrees around the vehicle, with very thin A, B and C pillars; that gives the person on the inside a lot of visibility so they don't feel confined.

"The first thing we did on the interior is make the floor very clear and open. There isn't a parking brake or shift knob. The seats are attached with a monorail through the center, so you can see more floor, and you feel like you're in a bigger space. It's the same thing you do when you try to furnish a small apartment with furniture that has legs on it.

"With the gauges we wanted minimum distraction, a back-to-the-basics approach so you can focus on driving, focus on the road. Two main gauges are analog on the outside, digital on the inside. I think a lot of people enjoy the mechanical nature of looking at the car through an analog gauge," says Nield, "so we didn't want to remove that, but the center is a digital readout. We can send an infinite amount of information to the driver, but through the center of an analog gauge. It blends yesterday and tomorrow.

Make it look wider, stronger, more mature and romantic, and you have a better chance of a customer who wouldn't consider a vehicle this small maybe saying you know what? it has good interior space, I like the styling, it's exciting, and for some reason it doesn't feel that small to me; that's what we tried to do," says Nield.

Nice job.

Employees must go through one program to graduate to higher levels and perform other vehicle testing. Included are a Low Speed Track (giving a driving experience like suburban roads), a High Speed Track (simulating a highway), and what they call World Roads (20 different examples from around the world, including cobblestones and other challenging surfaces). Add a Vehicle Dynamics Area and a Wet Vehicle Dynamics Area (slaloms and such, wet and dry), a Steering and Handling Course (winding and hilly), a Straightway with tight banked turns at each end to build up speed, and Special Test Surfaces (a large hill and various trench and pothole surfaces to navigate, including curbs that test drivers will hit on purpose). You can see they've made the most of their acreage. (And if less acreage inspired the virtual facilities, then that's a compounded benefit.)

We have a couple of hours between lunch and airport departures, and we have a range of new vehicles at our disposal: the 2011 Ford Fiesta, Edge Sport, Mustang, Mustang GT and Transit Connect; and the 2010 Taurus, Fusion Hybrid, Lincoln MKT, Flex, Escape and F-Series Super Duty. Some vehicles are here to demonstrate a range of technologies and user features, from Active Park Assist to SYNC®, Ford Work Solutions and our first peek at Ford's new inflatable seat belts. Others are here to drive, both on the Low Speed and High Speed Track.

"Drive them all the same," we are told. "Compare their DNA." It's a good cross-section for such a short time at such a comprehensive facility. We've driven most before, but not on the track. It's interesting to find slight shifts in our analysis and preferences. For example, we had driven the new Transit Connect van on a coned course at Firebird Raceway in Phoenix, prior to its introduction, and at the time were surprised how well it handled. And it does, but it doesn't seem as striking immediately after, say, a Mustang GT. We also had just driven the all-new 2011 Ford Fiesta for a week in Arizona (see page 24) and were quite impressed. We had also noted that we specifically might want to check the raves we'd heard for its available automatic transmission, as we'd had the manual. Having now driven both, we'd still stick with the manual, but that's us. We benefited from the fact that some of the tech (as opposed to automotive) writers at this event had never driven a stick, and weren't about to start today. So every Mustang GT fell into our hands. The manual transmission and the lightly upgraded rear axle make this a favorite for the day.

Then it's off to the airport, a four-hour flight, a three-hour clock change and Phoenix the same evening. But we make a note to do this all again. ■