In the virtual world of computer simulations such as Computational Fluid Dynamics (CFD), ever more capability is offered for less and less cost. “The progression of computing power is pretty much following Moore’s Law,” observed Ray Leto of TotalSim US, Dublin, Ohio, “and that allows more and more computation to be done in a shorter and shorter time—and for less money.”

But even hardware-based simulation facilities (think wind tunnels, shaker rigs, and K&C rigs) are looking for ways to control costs—while others are offering capabilities new to the motorsports industry.

Blowing Hot and Cold
Among the latter is the ACE Speed Lab, owned by the University of Ontario and located in Oshawa, Ontario, Canada. Previously available only to OEMs, the $100 million,
175,000-square-foot facility opened last year to motorsports customers. Probably the most unique of its five test chambers is a climatic wind tunnel incorporating a chassis dynamometer within its test cell. “We specialize in thermodynamic testing,” explained Colin Howard, “optimizing airflow into your engine compartment, or through your radiator, or for brake cooling. We can put your vehicle on the dyno and measure the air temperature going into the vehicle, and how the air flows through the vehicle. And if you can improve your thermal management, that is, ensure that more energy is used in making power and less is lost as heat, then theoretically you can increase your horsepower.”

In addition to temperatures ranging from -40 to +140 degrees F, the ACE tunnel can replicate weather conditions from bright sun in a desert to a blizzard or freezing rain. “No one else has a wind tunnel like ours,” Howard continued, “where you can conduct both aerodynamic and thermodynamic testing, both in the same day.” Yet another feature of the ACE wind tunnel is a 360-degree turntable for testing vehicle behavior in crosswinds. A nozzle that adjusts from 75 to 140 square feet accommodates the additional width of the test body as the yaw angle increases. “If you wanted to,” Howard added, “you could do a 360-degree spin.”

Additional ACE facilities include two climate chambers with the same thermal range as the wind tunnel; one features a Mustang dynamometer for engine tuning at various temperatures. There’s also a climatic four-post shaker used mostly by OEMs for durability testing, “but there’s definitely potential for the motorsport community to use it as well,” said Howard. A separate, hemi-anechoic chamber houses a multi-axis shaker table, useful primarily for NVH testing at the OE level. “And because we’re owned by a university,” said Howard, “we have a different business structure from some of our...”
Competitors. We can offer the same high-level equipment, and the same high-level service, for a greatly reduced price.”

Into the Darko

Darko Technologies Wind Tunnel in Ogden, Utah, accommodates full-scale vehicles within a notably compact cross section. That smaller size, along with a fixed floor and an open-loop configuration, greatly reduced the initial investment and helps control ongoing costs. Specifically shaped walls and ceiling, combined with proprietary software, compensates for relatively tight choke points around the vehicle and a maximum wind speed of 76 mph. “Having the correct cross section, and the correct computer system to back it up, that’s the key,” said Pawel Bulka, founder of Bilt Racing Services in Momence, Illinois—and a satisfied Darko customer.

Another selling point for the Darko tunnel is its geographic location, “which can provide significant transportation and logistics benefits for western teams,” said Tom Burkland, Darko’s aerodynamic consultant and himself a record-breaking land speed racer, builder and engineer. Further, “our scheduling flexibility allows test times to be arranged around existing event dates, minimizing added travel expenses. And our test rates are reasonable for the data package delivered on each vehicle.”

That data “can be used to optimize the aerodynamic configuration of the vehicle,” Burkland continued, “whether concerning drag reduction for a land speed racer or total downforce and balance for a cornering application. The actual weight on the axles can be measured, just as the team would normally do with corner scales, but adding aerodynamic forces to the suspension setup. The smoke wand allows a more qualitative assessment of cooling ducts, driver and engine airflow, and overall flow disturbances. Potential corrections can be quickly fabricated from cardboard and tape.”

And just as quickly tested: Layne Christensen, who built the Darko tunnel, noted that computer modeling, however sophisticated, cannot provide such quick and accurate evaluation of ad hoc engineering. “And the fine-tuning of these modifications is very rewarding for the customer to witness,” Christensen added. “They finally know what each component is really doing.” That’s at least partly because “we don’t just test your vehicle and give you a list of numbers; we help aero-tune performance to a higher level. We actually guarantee that we’ll find improvements, or it costs the customer nothing.”

Burkland, meanwhile, pointed to some advantages a wind tunnel offers compared with on-track testing. “Many teams use sensitive ride height measurements, recorded by on-board data acquisition, to gather aerodynamic data, but then struggle...”
gle to filter out the track dynamics and isolate the data that’s purely aero. Back-to-back comparisons of multiple configurations can be problematic, as exact conditions are difficult to duplicate with any accuracy. But the wind tunnel can create consistent conditions, and filtering track dynamics is unnecessary because the vehicle remains stationary.”

Christensen said rates are $500 per hour, with assistance getting the vehicle into the tunnel, properly secured, and all through the testing and tuning procedure.

The Force Be On You

Another type of fundamentally mechanical testing is Kinematics & Compliance (K&C), which applies known displacement or force inputs to a vehicle suspension and measures the resulting position changes at the wheel center. “K&C provides a highly detailed look at the suspension that can’t be found elsewhere,” said Simons. “In addition to highly accurate measurement of suspension kinematics, we can also apply lateral and longitudinal loading at the tire contact points, and measure how the suspension flexes and bends under these loads. With this capability, there is no longer any reason to guess about suspension forces. You can know.”

Morse Measurements, said Simons, “sees customers from race teams in various series. The NASCAR teams, and particularly the Cup teams,” are the leaders in making use of this technology. “We also see OE automakers as well as suppliers to the auto industry, UTV manufacturers, and aftermarket suspension companies. Not many amateur race teams have the budget to do K&C work. But we’re working to change that, with budget programs to make K&C testing more affordable.”

For many budget teams who are new to K&C testing, Simons continued, “simply understanding what they already have is valuable.” It’s a big step forward just to locate their roll centers, analyze their anti-dive and anti-squat geometry, and to determine their camber curves and bump steer. For example, “even though many
teams will measure and set bump steer in their shop, we have found that bump steer under load—with springs in the car—can be very different from what is measured in an unloaded condition.”

“K&C allows our engineers to determine the performance of suspension and steering systems under all dynamic conditions,” added Richard Adams of Horiba-MIRA in the United Kingdom’s Midlands. In the past year MIRA (Motor Industry Research Association) “has added a second K&C rig, at the cost of $4.5 million. Our new machine provides higher-precision measurement than our original K&C rig, as well as adding moment-of-inertia measurement, and the option to activate suspensions at frequencies up to 5 Hz, in order to study the effects of damping and hysteresis.” The facility is currently using this new high-frequency capability to further improve their Computer Aided Engineering (CAE) simulations. Additionally, the new K&C equipment allows Horiba-MIRA to “perform whole-vehicle dynamic characterization, plus moment of inertia measurements, on the same rig, in rapid succession. So running a complete suite of tests is now faster and more accurate.

“For these professional race teams, accurate simulation allows them to arrive at the track with a setup that is much closer to ideal than was previously possible.”

“Looking wider, we can see our increased computing power driving higher-resolution CAE solutions in the same timescale; or, alternatively, solutions of the same complexity delivered faster,” continued Adams. “We always work hard to make sure the potential reduction in computing 'crunch time' is reflected in our overall project outcomes, and that computational overhead is deployed for best effect.”

Established in Nuneaton, Warwickshire, in 1946, MIRA now comprises more than 35 major test facilities, covering “every critical area of race car design,” said Adams, “including crash safety, aerodynamics, vehicle dynamics, body engineering, thermal management, and electronics,” which are all “integrated with simulation and consultancy support. This close pairing of simulation and testing means our customers can confidently engage with one company to access all of the design and development services needed to win—all in one location, saving time and money.”

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Certainly, computer simulations offer their own unique capabilities. “As computer power continues to increase,” noted David Dupont of Wirth Research, Bicester, Oxfordshire, United Kingdom, “simulation in general, but CFD modeling in particular, has been able to deliver even finer detail while solving more complex levels of physics. A complete simulated design, development and testing process reduces the need for the wasteful manufacture of developmental models and prototypes. Our entirely digital development process also reduces overall project timing and costs—and has created a string of record-breaking designs.”

TotalSim’s Leto emphasized better modeling of transient, even ephemeral phenomena. “In the past, the majority of CFD was done through a steady-state method called Reynolds Averaged Navier-Stokes (RANS). But in reality, even most so-called steady-state flows are somewhat transient in nature, with wakes and vortices that are moving. And in order to model that, you need a simulation where the flow is varying with time. Those are a lot more computationally extensive, and they still take a long time to do, usually a matter of days.” But only a few years ago the same simulation would require a week or more.

Leto cited a car in a wind tunnel—intuitively a steady-state situation. But even there, “where the flow separates at the back of the vehicle, vortices form, and the shape of that wake oscillates. Portions of the flow over the roof will stay attached, then separate, then re-attach. And that’s the transient behavior that we’re trying to capture, because it can influence that last couple of percent in performance that the customer is looking for.” Consider also how the aerodynamic wake of a front tire affects the rear tire behind it. “In a steady-state simulation, you’ll likely overestimate that effect, whereas in a transient simulation you’d see how that flow around the front tire is flickering. Steady-state simulation is still quicker, and works well for most situations. But if we’re looking for more detail, or if we’re looking at areas of the car where we know the flow separates, then we have to do the transient simulation.”

The engine beneath TotalSim’s proprietary software is Open Foam, which Leto described as “a suite of software in command-line Linux. “We’ve taken that and put an engineering process around it, so engineers can use it to solve problems. We’ve essentially automated the process, from building your initial 3D CAD model to setting up simulations and then the post-processing to get the information you need. And once you have a base-line model, changing out parts is even easier.” For the most part, TotalSim collects customer data and performs the simulations, “but we also have a large number of what
we call supported customers. We install the software for them, and then support their use of the software."

Most of TotalSim’s motorsports customers are “manufacturer-supported race teams” (including Aston Martin, for its Vantage GTE race car, though Leto would say nothing about that). But Leto estimates that perhaps 20 percent are privateers, and “just in the last three years, as we continue to lower the barriers, we’ve penetrated deep into the grassroots. We’ve had conversations about Late Models and modifieds.” A free web app for Formula SAE students was slated to roll out in January 2016. “So we see this ramping up, and the barriers to entry continuing to drop.”

Danny Nowlan of ChassisSim in Carrum Downs, Victoria, Australia, likens older-style simulations to a series of snapshots—where transient simulation is more like watching digital TV. “The thing that makes ChassisSim unique is its transient lap time simulation algorithm. ChassisSim allows customers to reverse-engineer vehicle parameters from race data. Then, using our transient simulation engine, they can evaluate what will or won’t work. Combining that with the ability to overlay our data across a wide variety of existing data-acquisition platforms (including Cosworth, MoTeC, Magneti Marelli, Bosch and McLaren Atlas) provides an unbeatable one-two-three punch. More importantly, it gives racers an innate feel of the numbers that they can use to make changes on pit road.”

Nowlan pointed to Australian ChassisSim dealer Pat Cahill, who “used our shaker-rig toolbox to develop a setup methodology for GT3 cars, which played a critical role for the winning team in the 2014 Bathurst 12 Hour.”

He continued, “And we are always adding features. For some time now we’ve offered an online version. To that we just added the option of unlimited use for $350 a month.” Other recent additions have included track replay simulation, aero replay analysis, and the ability to predict hot-running tires.

New from Wirth Research, said engineering manager Rob Roswell, is a “revised performance simulation vehicle model” using Dymola, a commercial modeling and simulation environment developed by Dassault Systèmes AB of Sweden. “This revised model will provide a common physics core for all of our full-vehicle simulation. It can quickly generate new suspension mechanisms as true multi-body models that can run at high computation frequencies in real time.”

At the same time, “we are continuing to evolve our thermo-mechanical tire model, called MuRITyre, adding higher-fidelity physics for the same computation time,” said Robin Gearing, Wirth’s technol-
Guy Babbitt from Czero in Fort Collins, airflow through the engine, according to sis (FEA) and composite manufacturing. modeling, finite element analy and simulation, tire modeling, circuit scan
gopy manager. Wirth’s “complete suite of vehicle design services” include CFD and aerodynamic analysis, vehicle modeling and simulation, tire modeling, circuit scanning and modeling, finite element analysis (FEA) and composite manufacturing.
CONVERGE and other CFD tools are extremely effective for visualizing airflow through the engine, according to Guy Babbitt from Czero in Fort Collins, Colorado. “Engine designers typically have a pretty good idea of what will happen inside the engine as a result of specific design changes. CFD analysis gives you an actual image of how those specific changes will in fact affect the forces, reactions and interactions at work inside that black box. It’s a powerful tool that enables you to confirm the expected results very quickly without the hassle and cost of making hardware and testing it.”
Babbitt continued, “Multiphysics platforms, such as GT-SUITE and ANSYS, enable engineers to simulate multiple physical phenomena simultaneously. For example, instead of analyzing structural mechanics, thermodynamics, chemistry and fluid flow separately, it’s all done at the same time. As a result, multiphysics simulations can produce a very comprehensive representation of what’s happening to and in a physical system.
“This enables engineers to see and thoroughly understand the big picture of a new design more quickly than if running analyses separately,” he added. “Using these new multiphysics platforms for R&D can give performance racing teams significant advantages on multiple levels—simulation quality, design insights and iteration speed—which can all pay off on the track.”
As a specialized engineering firm, Czero offers race teams high-level design analysis, including Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), multiphysics simulations, embedded controls and testing.
“We use the same sophisticated software used by R&D teams at OEMs and
Tier 1 suppliers, plus we’ve developed our own tools and integrations that enable us to iterate faster,” noted Babbitt. “This means whether we’re improving an individual solenoid or a complete powertrain, Czero can help designers and builders for racing teams move a concept from napkin sketch to dyno to track significantly faster.”

The custom automotive hardware Czero develops includes valvetrains (variable timing and lift, deactivation, camless), ultra-fast solenoids, actuators, cylinder heads, fuel injection systems, high-bandwidth hydraulics, and hybrid and energy recovery systems, according to Babbitt.

“At Czero, in automotive R&D we focus primarily on powertrains. The biggest advancements we’re seeing in that domain are in the sophistication, power, integration and ease of use of simulation packages, especially those for CFD and multiphysics simulations,” Babbitt explained. “Combining this next-generation software with the increased processing power now readily available via cloud computing is really taking simulation and testing to the next level.”

Where to Begin?

So where, we wondered, does the initial data used in computer simulations come from? “Spring forces and anti-roll bar rates can be sourced from standard setup sheets,” Nowlan suggested. “The same applies for engine power and gearing. Damping rates can be sourced from a damper dyno, and ChassisSim can reverse-engineer aero and tire properties from race data.

“Honestly,” he said, “getting going is easier than you think.”

More and more, however, computer simulation relies on 3D CAD models, which just about anyone designing a new car today will have made already. And according to Leto, models of popular production cars are surprisingly available. “You can buy a model of a 1955 Chevy for a couple of hundred bucks. And it will be pretty close. We often start with things like that. But that’s still the barrier to entry for a lot of people—not having a CAD model of their car. Obviously, then the only way to do it is to 3D scan it or reverse-engineer it some other way. Fortunately, 3D scanning has come a long way in the past five years, and in the past two years it’s become less and less expensive to do.”

Time for the Track

Finally, how well and how often does advanced testing and simulation translate into faster lap times? And for whom? “Most of the time we can’t say anything,” said ACE’s Howard about clients. “I can tell you that we don’t get many open wheel cars, because they do better in a rolling-road tunnel—at four or five times what our tunnel costs. We have worked with some Trans Am teams, including CBRT.” Canada’s Best Racing Team “came in for
a day, and they told us quite confidently that they found some time on the track. We’ve also worked with some real grassroots racing teams. One brought in a Nissan 350Z, and in just a few hours they had a whole bunch of lift on the front end—it kind of blew their mind how much. But after some adjusting, they made some serious improvement, and again they told us that the car drove better for the rest of the season.”

Additionally, stock cars have used the tunnel’s climate capabilities to improve qualifying laps. “They want the car to perform at the highest level for that one lap,” he added. “So they tape up certain vents to improve aerodynamics, while sacrificing engine cooling.” But if the engine heats up too much or too early, they lose horsepower. “So they come in, and they do a bunch of taping at different temperatures and different wind speeds, and measure engine heat. They try to find that balance point, for the fastest lap possible.”

Burkland recalled how a land speed racing team running a highly modified two-stroke Saab was running into the limits of front-wheel-drive traction at over 300 mph. “Their wind tunnel testing had three primary objectives: One, to demonstrate the aerodynamic stability of the car in yaw and pitch, which affected both driver comfort and safety; two, to verify the effectiveness of the canard dive planes added to the front of the body”—that is, did they provide enough downforce to make the necessary traction available; and three, “to find any drag reductions that could be easily incorporated. All three objectives were met, and the car owner commented that it was the best financial investment in terms of performance gained ever made in the project.”

Bilt Racing builds, preps, services and manufactures high-performance parts for road racing Porsches. Bulka made some significant discoveries while testing one of Bilt Racing’s own Porsche Caymans in the Darko Technologies tunnel. His team presumed that the Cayman’s stock side mirrors were causing significant drag; testing proved the mirrors produced almost no drag while contributing a slight but significant downforce. “So if we’d replaced them with smaller door mirrors,” he said, “like we were planning to do, we’d have actually lost downforce on the car.” And that wasn’t all. “We’d already installed NACA ducts, to improve engine induction and brake cooling. And we learned that where we’d placed them was completely incorrect. They were in a dead spot, where the air wasn’t going in them but glancing over them, which actually created suction, the opposite of what we were trying to achieve. So we were able to test those things immediately, and the next weekend we implemented those changes, and they helped us on the track.”

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