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FINDINGS

Nascar’s Screech and Slam? It’s All Aerodynamics

Chris Livingston for The New York Times

NONINTUITIVE PHYSICIST Diandra Leslie-Pelecky and a racer in Daytona.

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DAYTONA BEACH, Fla. — When Junior Johnson entered the Daytona 500 in 1960, he’d already achieved fame in two careers — first as a moonshiner who kept outrunning federal agents, then by applying those skills to win stock-car races.

Now he was ready for a new career as an “intuitive physicist,” a term borrowed from Diandra Leslie-Pelecky, who teaches nonintuitive physics at the University of Nebraska.

Johnson was stuck driving an old Chevrolet that was slower than the Pontiacs at Daytona that year. But in practice he discovered that he could keep up with a Pontiac if he stayed close to its rear bumper. He suspected, as he put it, that “the air was creating a situation, a slipstream type of thing.”

His hypothesis was confirmed near the end of the race, when that situation produced such a low-pressure area behind the leading car that the glass in its rear window popped out, allowing Johnson to win the race.

It was a revolutionary discovery, this trailing technique known as drafting, but in retrospect it seems quaintly simple. For the 50th running of the Daytona 500 this Sunday — billed with characteristic stock car understatement as “the Most Anticipated Event in Racing History” — nobody would dream of sending a driver out there with just his intuition.

To prepare the drivers for the “Car of Tomorrow” being introduced at Daytona, the racing teams’ engineers have spent the winter testing their versions of the new car in wind tunnels and running huge computer simulations called C.F.D.’s (for computational fluid dynamics). To understand what is happening on the track and in the garage here at Daytona, you need either a crash course in aerodynamics or the guidance of Dr. Leslie-Pelecky and her new book, “The Physics of Nascar.”

Dr. Leslie-Pelecky did not have any interest in Nascar until one evening a couple of years ago. While taking a break from her research on magnetic nanomaterials, she was channel surfing and saw a chain reaction of stock cars gone wild.

“It started when six cars were going around the turn, and one of them suddenly started wiggling and went into the wall for no apparent reason,” she recalled. “It was like spontaneous combustion. As a scientist, you look at that and say, ‘There has to be a reason.’ It drove me nuts because I couldn’t explain it. I felt as if I was in a different universe.”

She started investigating Nascar’s universe partly out of curiosity and partly because it jibed with another project of hers, to enliven the science curriculum in elementary and secondary schools. It occurred to her that students would be more interested in, say, the difference between the coefficients of static friction and kinetic friction if the kinetic example involved tires skidding on a turn at Daytona. (Her stock-car science quiz is at http://www.nytimes.com/tierneylab)

“So many kids lose interest in science because we’ve been teaching them that it’s all about memorizing facts,” she said. “What you do in school that’s called a lab experiment is not really an experiment, because you already know the answer. When you listen to a driver and his crew chief trying to figure out how to give the car more grip in Turn 2, that’s the scientific method in action. They’re asking questions about load transfer and downforce, and they don’t know the answers until they’ve done the experiment.”

In her book, Dr. Leslie-Pelecky explains everything from the mechanics of racing engines to the molecular properties of the drivers’ fire-retardant suits, paying special attention to the endless battle against that great evil force, drag.

Junior Johnson and his successors discovered that drafting could help not just the trailing car, but also the leading car by reducing the amount of turbulence at its rear. Two cars drafting together can go 3 to 5 miles an hour faster than a solo car, and extra trailing cars add a little more speed, which is why the drivers spend so much time in single-file bumper-to-bumper traffic.

The drivers and their engineers also learned that they could add speed — and make fans happy — if the trailing car nudged the leading car. That enabled the trailing car, which could go faster than the leading car because it faced less air resistance, to transfer its extra momentum to the leader through a technique called “bump drafting.” That evolved into “slam drafting” as the drivers became bolder and their crews added steel plates to the bumpers.

Meanwhile, the math grew more elaborate as engineers combined a classical technique for describing the movement of fluids, the Navier-Stokes differential equations, with computers that could calculate the air flow as the car moved under different conditions. Racing teams could figure out precisely how to reshape their car to suit each track. A car built to minimize drag on Daytona’s long straightaways and sharply banked curves had to be reconfigured for a smaller track so that there was enough downforce to keep it from spinning out of control on a tight corner.

Reshaping cars for each race became so expensive and grueling that Nascar ordered everyone this season, starting at Daytona, to use the same chassis and body (that Car of Tomorrow) at every track. The engineers can tinker with just two major aerodynamic features, a new wing atop the rear of the car and an adjustable shelf protruding from the front end called a splitter because it diverts air under or over the car.

These new limitations, of course, haven't stopped the aerodynamics arms race. It is has become more refined, as Dr. Leslie-Pelecky kept hearing this past week in the garage at Daytona from fellow Ph.D.'s like Eric Warren, an aeronautical engineer who is the technical director of Michael Waltrip Racing. To prepare his drivers for the new car, Dr. Warren relied on C.F.D. simulations calculating the airflow at 100 million points on the vehicle.

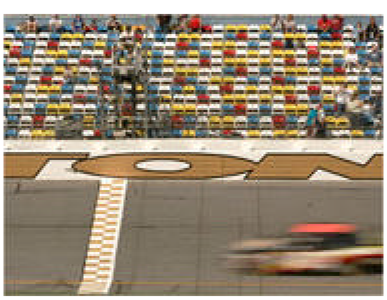
"The smaller the gains are to find, the more scientific the approach has to be," he said. "To pass a car, you need to know precisely where the minimum drag is for you and the maximum drag is for him. With the picture of airflow we get from the C.F.D., we can tell the driver that the ideal passing maneuver is a certain sequence of positions."

Dr. Warren wasn't about to reveal that sequence before Sunday's race, but he did elaborate slightly about the knack for finding good air when you are behind or alongside another car. "Less than a one-foot difference between cars is where a lot of the interactions are," he said.

Less than a foot? Well, that's the kind of experiment that Nascar fans will be watching for and, maybe, as Dr. Leslie-Pelecky hopes, it will also inspire some future scientists. I don't recall growing too excited about the old textbook problems involving locomotives lumbering at different velocities out of cities A and B. But I would have paid attention to two cars traveling 200 miles an hour separated by inches.

Chris Livingston for The New York Times

Tension ratings on suspension springs in Dave Blaney's garage.



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INTUITIVE PHYSICIST Juan Pablo Montoya's Dodge in a practice run at Daytona."Cars of Tomorrow" go through wind tunnels and computer simulations.