GREEN TECH / ADVANCED CARS

Autonomous Vehicles Complete DARPA Urban Challenge

Six of 11 autonomous vehicles finish 90-kilometer course with no major accidents

By JOHN VOELCKER / NOVEMBER 2007

PHOTO: JOHN VOELCKER

Click here to see a slideshow about the DARPA Urban Challenge

Adelanto, Calif.—Imagine a typical California suburb of one-story stucco homes, curving roads, and cul-de-sacs, but abandoned—the lawns and plants dried up, the windows broken, the rooms empty.

Add dozens of identical Ford Tauruses driven by stunt drivers in endless loops through 16 kilometers of vacant streets, stopping at stop signs, passing each other over and over. Then throw in 11 robot cars and SUVs. No drivers, just software controlling their stops and starts, merging, passing, and parking. Eerily well behaved, the autonomous vehicles join the intricate dance—blending in with the Tauruses, obeying all California traffic laws—and move through the silent landscape.

Was it fantasy? Or the setting for a zombie movie? Neither. It was the DARPA Urban Challenge—a competition put on by the Defense Advanced Research Projects Agency of the U.S. Department of Defense to learn whether autonomous vehicles could maneuver through urban and suburban settings amidst unpredictable traffic. Those dozens of Tauruses were driven by professionals—protected by racing helmets and NASCAR-quality roll cages—who knew how to get out of potential accidents. But the robot cars also had to play well with one another.

Eighty-nine teams had applied to take part in the competition; DARPA accepted 35 of them. But before heading out, contenders were subjected to a week of individual testing. Each robot had to show that it could merge into traffic, negotiate a road and a stop sign, and so forth. Of the 35, only 11 made the cut.

The DARPA Urban Challenge took place at the former George Air Force Base, in California's high desert. Closed in the early 1990s, it's now the Southern California Logistics Airport—and much of the suburban course was actually the area containing the abandoned officers' quarters, soon to be demolished for industrial buildings.

Autonomous vehicles from the 11 finalist teams were each given three "missions" to complete. Each of those was broken into "submissions," consisting of a set of GPS waypoints (or locations) the robot had to pass—finding its own way there and back—before returning to base. The waypoints were ordered differently for each vehicle, creating random and unpredictable traffic patterns that each autonomous vehicle had to interpret and navigate in real time.

Officials admitted they had no idea how the challenge would turn out, but the results surprised and pleased the agency, as well as the 1500 people who attended. And the military services, under a mandate to make 30 percent of their vehicles autonomous by 2015, can now set their expectations for the technology. "Once you show it *can* be done," said

DARPA director Tony Tether, "others come out to do it better."

Six of the 11 contenders made it through the entire trial, covering roughly 55 miles in less than 6 hours. The winner averaged roughly 23 km/h, and maximum speed on the fastest part of the course was 48 km/h. The winner—the robot that completed all of its missions the quickest, minus any deductions for traffic infractions or unsafe behavior—was a Chevrolet Tahoe SUV named Boss, fielded by the Tartan Racing team of Carnegie Mellon University and General Motors Corp.

Close behind was Junior, Stanford University's Volkswagen Passat wagon. Favored to win, the Stanford car had been the first of five finishers in the previous DARPA challenge two years ago, which took place on a 132-mile desert course, without traffic.

Rounding out the top-three finishers—the only ones who beat the 6-hour time limit—was Odin, a Ford Escape fielded by the VictorTango team, made up of Virginia Tech and an autonomous-systems spin-off company called TORC.

Every robot had names, and the vehicles quickly seemed to become people—almost entirely male—as if they had free will and personalities. "He's doing well," said a contestant. "He seems hesitant off-road," said another. Even the men and women driving the chase cars personalized the robots they were following: "He likes to cut awfully close to the barrier before he turns…."

The finalist vehicles ran the gamut, from used cars to a huge industrial truck, though SUVs were common. The most striking was a gigantic off-road pickup truck from Team Oshkosh Truck—its tires chest-high, its grille taller than the tallest team member, its cab floor at nose level. And the most unassuming was an 11-year-old Subaru Outback wagon with 100,000 miles, nicknamed Knight Rider.

That Subaru, fielded by the University of Central Florida, had belonged to the wife of the lead engineer, Don Harper, before it was robotized. And the UCF team clearly earned some kind of award for maximum effectiveness on minimum dollars. Unlike the several dozen team members from Stanford and Carnegie Mellon, with matching polo shirts and corporate sponsorship, UCF had just six smart, determined people.

UCF's on-the-cheap approach cost them in the end. To save time and money, UCF employed a commercial GPS system—and accepted the maker's assertion that all the output data was checked for errors. It turned out, however, that once in every few million data points, the system generated an invalid number, which the team hadn't thought to check for. Halfway through the six hours, the Subaru got some bad data and gently steered itself into a cul-de-sac driveway, nosing right up to an abandoned house and stopping. Said the chagrined but still proud team leader, Benjamin Patz, "We were just one IF [statement] away from success."

Indeed, in the words of Stanford team leader Sebastian Thrun, it was "a software race." The sensor arrays themselves varied far less. For example, five of the six finalists used the spinning LIDAR from Velodyne—a firm that had entered the 2005 Grand Challenge but chose not to compete against its customers this year.

As the weekend wound down, more than one participant compared the event to the first flight at Kitty Hawk. That airplane went only 300 feet, but the Wright Brothers achieved something that no one had ever done before—and the world was never quite the same.

The morning after the final competition, Tether said, "Yesterday was a historic day. For the first time ever, we saw robot-to-robot interaction at real speeds." And it all happened without catastrophic failures or accidents. Twice, two robots touched, at very low speeds; other than that, the only damage was during early qualifying, when one robot crashed into a Ford Taurus. That car suffered damage to a door and rear fender but was far from disabled (and, in fact, continued to act as random traffic during the rest of the event).

So among abandoned military housing, on ghostly streets, the six finalist robots showed the first glimpses of a very different future. That day, the nature of all vehicles—whether unmanned military convoy trucks or prosaic family

minivans—was changed forever. While the technology that met DARPA's challenges is only part of the picture for civilian passenger vehicles, now the world knows that autonomous vehicles do exist. Let the innovation begin.

About the Author

JOHN VOELCKER has written about automotive technology and other topics for 20 years. He covered software and microprocessor design for IEEE Spectrum from 1985 to 1990.