In the predawn hours of Saturday, November 3, 2007, the former George Air Force Base, in Victorville, Calif., was a beehive of activity as industry and academia teams made a flurry of last-minute adjustments to nearly a dozen of the most unusual vehicle platforms to ever run in a military competition.

Called Urban Challenge, the event marked the third major robotic competition organized and conducted by the Defense Advanced Research Projects Agency (DARPA).
“We are the central research organization for the Department of Defense, conducting leading-edge and far-out projects that push the boundaries of technology,” explained Dr. Norman Whitaker, DARPA’s program manager for Urban Challenge. “We’ve been looking at the problem of protecting people on the battlefield for quite a while now. Unmanned aerial vehicles have been very successful; they are used extensively in the military context. We’re now looking at ‘the ground problem’ in terms of unmanned ground vehicles.”

DARPA’s first significant competition focused on the ground problem was conducted in March 2004. Called Grand Challenge, the event included a 142-mile desert course between Barstow, Calif., and Primm, Nev. Fifteen autonomous ground vehicles attempted the course, but the best performance only stretched seven miles, and the $1 million cash prize went unclaimed.

A second Grand Challenge, held 19 months later, showed a quantum leap in robotic vehicle technologies. Similar in scope to the first, the October 2005 event required vehicles to complete a 132-mile desert route in southern Nevada in less than 10 hours.

“We had 195 entrants and had five finishers cross 132 miles of desert,” Whitaker said. “A tremendous amount of energy was built as a result of that event.”

“These are vehicles that are fully self-contained,” he noted. “You put them on the starting line, push the button and they go. There’s no remote control. It is totally under the control of its own computer.”

In determining the path forward, DARPA planners shifted focus from an autonomous cross-country desert venue to a course that would introduce aspects of modern urban operational environments.

“I was out here in January when we discovered this area as a place where we could run vehicles down the street; if they crashed into a building or ran off the road, they would not cause any damage,” Whitaker said. “This area is a closed military base that is used for MOUT (military operations in urban terrain) training, so it closely resembles the type of environment our troops face overseas.”

Initial DARPA solicitations drew 89 applicants for Urban Challenge, a figure that was later reduced to 36 after DARPA site visits and analysis.

“For the past week or so, we have had 35 teams here [one of the 36 selected semifinalists subsequently withdrew] at the former George Air Force Base, where we have been testing them on the rudiments of urban driving,” Whitaker said. “The problem of urban driving is difficult because basically every mission ends or begins somewhere where there are people, vehicles, buildings and roads nearby. In order to build truly safe systems, we decided to provide metrics by which they would be judged.”

He added that those performance metrics were roughly based on the California Driver Handbook.

“We have taken that handbook and looked at what human drivers were required to do: 15-year-olds—how well can they drive? And we have tried to impose that level of skill on the robots,” he said.

Once at the Victorville site, the 35 teams participated in a national qualification event (NQE) from October 26–31.

Whitaker explained that the NQE involved different test areas.

“One test area included left turns across traffic. The vehicle had to be able to pull into a busy two-lane road with traffic coming in both directions. It was challenging for a vehicle to be looking in both directions at the same time, predicting when the other vehicles would arrive at the intersection and then determining when it was safe to pull in. That’s very tough,” he said.

He noted that another test area mandated that the autonomous vehicles enter a large parking lot through an open gate.

“There was a fence there—they didn’t know there was a fence—and there was a gate that was open, but they didn’t
know where that was. They had to use their sensors to detect that and go through it,” he added.

Other qualifying events ranged from movement down a narrow, winding street populated by other vehicles to actions involving both manned and other unmanned vehicles arriving at a four-way stop.

“We were assessing whether they acted too aggressively and went early or whether they were not aggressive enough and just sat there and stared for a while and then waited for everything to clear,” he said.

“After all that testing we had a sense of ‘who’ was able to do all the skills correctly,” he added.

Eleven of the autonomous vehicle teams survived the NQE process and started the final event. Although the majority of the finalists were university teams that relied on robotic modifications to small commercial vehicle platforms, at least one industry finalist, Team Oshkosh Truck, had developed a new autonomous variant of its Marine Corps MTVR (medium tactical vehicle–replacement) logistics vehicle.

DARPA representatives noted that one of the most significant milestones represented by Urban Challenge involved the interaction between autonomous vehicles.

“The vehicles that are going to go out today have been extensively tested against human drivers, to see if they could merge safely, yield turns, handle intersections, park themselves between cars and generally behave well on streets with other traffic being driven by humans,” explained Dr. Tony Tether, DARPA director. “What we really don’t know is what they are going to do when robot meets robot. We haven’t tested that, and today is going to be the first time in the whole world, that I know of, that not only are these autonomous vehicles going to perform against human drivers but perform against each other. I’m holding my breath, quite frankly.”

To mark the start of the final event, Tether then released several dozen background vehicles—manned vehicles that were operated on the closed course—to further expand the decision-making challenges for the autonomous participants. The background vehicles were soon followed onto the course by the 11 autonomous finalists, with each of those platforms. Each of those robotic systems was accompanied by a manned chase vehicle that could trigger an emer-
emergency kill switch in the event of serious malfunction.

As the vehicles entered the course, they moved around a large traffic circle before heading out on particular roads to perform a specific series of missions and sub-missions that had been introduced through a mission data file that was downloaded to the vehicle computer before each mission.

“There are roughly 10 miles of roads out there,” Whitaker said. “The vehicles will make use of the highway that goes around the base. At some point all of the vehicles will be required—probably three or four times—to drive down a dirt road, pull safely onto a highway and go 30 miles an hour up the highway. If you haven’t seen these types of vehicles before, you’ll think it looks a lot like a truck with some gear on top, going relatively slowly. But once you’ve watched it for an hour or so you realize that one of these vehicles, going even 10 miles an hour, is really fast, especially if you’re very close to where it’s traveling.”

DARPA also stationed approximately 100 observers out on the course to grade vehicle performance at stop signs and other traffic decision points.

“The unusual behaviors that we have seen so far are things we didn’t imagine,” Whitaker said. “For example, we’ve been surprised in almost every task that the robot decides to plan a different route and go on some other road that we didn’t know the robot knew about. So we’re still learning.”

The final event required the vehicles to complete 60 miles in six hours. The distance was divided into three major missions, with the vehicles returning to the starting point for sensor cleaning and new mission data file downloads after the first two phases.

Five of the teams had been pulled off the course by the start of the second mission, leaving six teams to conduct the last two series of missions: Team Stanford, Team Victor Tango (Virginia Tech), Team Ben Franklin, Team Cornell, Tartan Racing (Carnegie Mellon Robotics Institute/General Motors) and Team MIT.

As if echoing the ancient biblical observation that “the race is not to the swift,” DARPA representatives repeatedly stressed that Urban Challenge
was not a race, but rather an event in which the winner would be predicated on a long list of criteria and very complex scoring procedures conducted by observers.

Just as DARPA had its own representatives observing and scoring around the course, the crowds also included a smattering of requirements planners in Army combat uniforms, backing U.S. Army Training and Doctrine Command patches, seeking their own ground truth regarding the applicability of autonomous vehicle technologies for today’s warfighters.

As for Urban Challenge, DARPA announced Tartan Racing’s “Boss” won the $2 million cash prize as the competition’s first-place winner, Stanford Racing’s “Junior” won the $1 million second-place prize and Victor Tango’s “Odin” won $500,000 for finishing third.

“Every time we have had one of these, we do a big analysis at DARPA to decide what is the next [step],” Whitaker observed. “How do we move the field forward?”

Referring to the congressional guidance to convert one-third of the logistics fleet to autonomous operation by 2015, Whitaker acknowledged that this would be “a ‘stretch goal’ for the agency.”

“Replacing a third of the vehicles in the fleet— just that, never mind making autonomous vehicles—is a very, very aggressive goal,” he said.

Convoy Automation

While fully autonomous operation may still be a “stretch goal” for near-term implementation, other Joint service organizations have been exploring other options for near-term/low-cost application of semiautonomous technologies in support of the warfighter.

One recent example of this exploration took place just two days before Urban Challenge, when the U.S. Army Research, Development and Engineering Command’s (RDECOM) Tank Automotive Research, Development and Engineering Center (TARDEC) hosted a demonstration of its convoy active safety technologies (CAST) integrated onto the family of medium tactical vehicles (FMTV) at Fort A.P. Hill, Va.

Program descriptions noted that CAST “is designed to develop a low-cost robotic convoy capability for current force tactical wheeled vehicles with the target cost of a robotic retrofit kit under $20,000 per vehicle. Although robotic convoy technology has the potential to increase the capability of current force vehicles, this aggressive goal can be achieved only through extensive research and development of diverse and low-cost sensing modalities. CAST experimentation will develop key robotic convoy technologies that balance capability and cost by taking an objective look at the utilities of a semiautonomous navigation system for sustainment convoys.”

The demonstration was co-sponsored by the Joint Ground Robotics Enterprise and the Joint Center for Unmanned Ground Vehicles in conjunction with the Robotics Systems Joint Program Office and the Combined Arms Support Command’s Support Battle Lab. Additional partners in CAST testing include representatives from the Army Research Laboratory, Air Force Research Lab, PercepTek, DCS, Auburn University and the University of Florida.—S.G.