

## WEB EXCLUSIVE

### PopSci's Darpa Grand Challenge Preview

Elizabeth Svoboda

In this, the first of a series, Popular Science profiles one of the favored teams competing to win the Darpa Grand Challenge autonomous vehicle race, which will take place on Saturday (October 8) near Primm, Nevada. Today we look at the Blue Team's autonomous motorcycle. Stay tuned to [popsci.com](http://popsci.com) for more previews throughout the week, and for minute-by-minute videos and updates on race day.

#### The Blue Team

University of California at Berkeley and Texas A&M

#### Players

A cultlike group of engineering students and recent grads, including 25-year-old team leader Anthony Levandowski, 25-year-old Charlie Smart, 19-year-old Bryon Majusiak and 23-year-old Howard Chau.

#### Rig

The Ghost rider, a 90cc off-road motorcycle that's stripped down to its metal skeleton and tricked out with two cameras, 12 optical encoders and a GPS module. These sensors feed information about the surrounding terrain to two on-board 2.2GHz Opteron processors, which synthesize the data and steer the bike accordingly. "Most people are entering trucks and Hummers, but there's a lot of potential for a lighter unmanned vehicle to be used in the field—one that can go through narrow or tight spaces," Levandowski says.

#### Backstory

Last year's Ghost rider collapsed at the starting line when Levandowski forgot to turn on a critical balance controller. "It was so frustrating," Smart says. "It's like if you call tech support and say your computer's not working, and they say, 'Did you turn it on?' " Chasing redemption, Blue Team members regrouped, refueled their budget with contributions from companies like Agilent and Raytheon, and set their sights on 2005.

#### Spotlight tech

Engineering an unmanned motorcycle presents unique challenges—unlike its four-wheeled competitors, the Ghost rider must be able to balance on a single axis. To help stabilize the bike, Chau has designed a pair of robotic arms, one on each side, that muscle it back into a standing position if it tips over. "They're like glorified kickstands," he says. Self-adjusting camera mounts ensure that the vehicle's visual sensors stay level and pointing straight ahead, even as the bike leans into tight turns and rumbles over obstacles.

#### Working style

Very intense. Most team members put in 12 to 16 hours every day at a corrugated-metal warehouse a few miles from the Berkeley campus. Often they don't finish tinkering and typing until 2 or 3 a.m.—if they go home at all. "Sometimes I leave at night and come back the next morning, and Anthony's still there," Majusiak says.

#### Piggy bank

The University of California at Berkeley and corporate sponsors have chipped in several thousand dollars apiece, but Levandowski, who moonlights as a successful online entrepreneur, has contributed over \$100,000 of his own savings to the effort.

#### Odds of winning 20:1.

We like Levandowski and co.'s innovative approach, but a wobbly two-wheeler might not make the grade in this year's race, where reliability and endurance will be the key deciding factors.

For more coverage of this year's Darpa Grand Challenge, including up-to-the-minute field reports and videos, check out our Darpa Grand Challenge headquarters. You can also visit Darpa's official site [here](http://here).

## WEB EXCLUSIVE

### PopSci's Darpa Grand Challenge Preview: Update #2

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In this, the second of a series, *Popular Science* profiles one of the favored teams competing to win the Darpa Grand Challenge autonomous-vehicle race, which will take place on Saturday, October 8, near Primm, Nevada. Today we look at Team DAD's Toyota truck, equipped with an innovative laser-based navigation system. Stay tuned to [popsci.com](http://popsci.com) for more previews throughout the week and for minute-by-minute videos and updates on race day.

**Team DAD (Digital Auto Drive)**  
**Morgan Hill, California**

#### Players

Three years ago, engineer Dave Hall grew bored with his day job—creating distortion-free speakers for Velodyne Acoustics—and decided to make a Grand Challenge run on the side. He convinced his business-manager brother Bruce, electronics engineer Tri Luong, mechanic Rick Yoder and design engineer Chris Kallai to join him.

#### Rig

A 2003 Toyota Tundra truck with some serious navigational headgear. Its top-mounted "nervous system" features nine one-gigahertz digital-signal processors, which generate a constantly changing internal map of surrounding obstacles. The vehicle's entire roof unit weighs just 300 pounds, which recommends it from a practical standpoint. "If you're going to be carrying supplies in the field, you can't be loaded down with heavy computer equipment," Bruce Hall says.

#### Backstory

So much for capitalizing on another team's mistakes—DAD's 2004 Grand Challenge entry actually bit the dust >because< of an opponent's mishap. "The officials paused us at the six-mile mark so a tow truck could take away the Red Team's [broken-down] vehicle," Bruce says. "They stopped us against a big rock, and when we started again, the system couldn't accelerate enough to get over it." The fluke failure only whetted the team's appetite for more action.

#### Spotlight tech

At the beginning of the year, Dave started working on a completely new navigation system: a spinning array of 64 laser beams that's unaffected by bright light, fog or darkness (many ordinary camera-based systems, in contrast, tend to succumb to harsh glare or inclement weather). By recording when the beams bounce back off surrounding objects, the array's sensors can determine how far away the objects are, providing onboard computers with 640,000 navigational data points per second.

#### Working style

While the team has been frantically revising the code that dictates how the vehicle responds to unfamiliar situations, it can afford to be a little laid-back in other areas. The mechanics of the truck, for instance, haven't changed much in the past few months. "Our recent work has been 5 percent hardware, 95 percent software," Bruce says. "We know the gas, brakes, and steering work. Now we just have to figure out how to handle all the obstacles, all the exceptions."

#### Piggy bank

Primary sponsor Texas Instruments has contributed handsomely (the team won't release specific numbers), and Bruce and Dave's jobs at Velodyne haven't hurt, either—as president and CEO, respectively, they've never felt bad about putting equipment purchases on the company tab.

#### Odds of winning

10:1. With a foolproof vision system and hundreds of miles of road testing under its belt, Team DAD's entry should stand out as one of the sturdiest vehicles in the race.

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## WEB EXCLUSIVE

### PopSci's Darpa Grand Challenge Preview: Update #3

Elizabeth Svoboda

In this, the fourth of a series, *Popular Science* profiles one of the favored teams competing to win the Darpa Grand Challenge autonomous-vehicle race, which will take place on Saturday, October 8, near Primm, Nevada. Today we look at the Virginia Tech team's two entries, each of which takes a different approach to the problem. Stay tuned to [popsci.com](http://popsci.com) for more previews throughout the week and for minute-by-minute videos and updates on race day.

**Virginia Tech Team**  
**Blacksburg, Virginia**

#### Players

Engineering professors Charles Reinholtz and Al Wicks; graduate student mentors Brett Leedy, Art Bloomer, Dave Anderson, Ernie Velasquez and Joe Putney; and about 40 undergraduates, who—despite participating to fulfill a senior requirement—approach the project with missionary zeal. "Sometimes I actually have to tell them not to work so hard," Reinholtz says.

#### Rig

Virginia Tech is entering this year's Grand Challenge with a one-two punch: Cliff and Rocky, two four-wheel-drive utility carts. Each has drive-by-wire systems that use motors to control the steering, the throttle, and the electrohydraulic actuators for braking. And each vehicle compresses hardcore features like stereo vision and lidar sensors into a surprisingly lightweight package—both weigh in at about 2,500 pounds. Mechanically similar, Cliff and Rocky differ dramatically in their data-processing styles. More on this below.

#### Backstory

The team's 2004 entry made it about 100 yards past the starting line before skidding to a halt as a result of too-enthusiastic braking for obstacles. "There wasn't anything in our code that said, 'If you're trying to go faster, don't put on your brakes,'" Leedy says. "This year we made sure to correct that."

#### Spotlight tech

Cliff and Rocky's software-controlled computer brains interpret the surrounding landscape very differently. Cliff interprets obstacles as it approaches them but keeps no internal record of its past observations. "It can react to what it sees, but then it instantly forgets," Leedy says. Rocky, in contrast, has a memory like an elephant—every time its laser range finders glimpse a nearby tree or rock, it squirrels that tidbit away into its data bank, to be retrieved later if needed. Although Rocky's strategy might seem superior, Cliff's short memory has benefits as well: It enables the 'bot to ignore superfluous details, such as a deer darting across the landscape.

#### Working style

Focused and methodical. Whereas the modus operandi of some other teams includes free-for-all brainstorming sessions and impromptu duct-tape fixes, the Virginia Tech team is fairly regimented in its approach to the task at hand. This >is<, after all, a class project. "First we defined the problem, then we figured out step-by-step how to solve it," Reinholtz says.

#### Piggy bank

Sponsors—among them Ingersoll-Rand, Honeywell and National Instruments—donated about \$150,000 worth of equipment, so the team didn't need much of a cash budget. "Most of the time we'd just approach a sponsor and say, 'Hey, we need this part for our vehicle. Do you have any we can use?'" Leedy says.

#### Odds of winning 20:1.

15:1. In a matchup in which, as Reinholtz observes, "the only acceptable failure rate is zero," entering two similar vehicles is strategic genius. Whether the golf-cart-like cruisers will withstand the rigors of desert terrain, however, remains to be seen.

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## WEB EXCLUSIVE

### PopSci's Darpa Grand Challenge Preview: Update #4

Elizabeth Svoboda

In this, the fourth of a series, *Popular Science* profiles one of the favored teams competing to win the Darpa Grand Challenge autonomous-vehicle race, which will take place on Saturday, October 8, near Primm, Nevada. Today we look at Stanford's entry, affectionately dubbed Stanley, which is designed to automatically choose the best route. Stay tuned to [popsci.com](http://popsci.com) for more previews throughout the week and for minute-by-minute videos and updates on race day.

**Stanford Racing Team, Stanford University**  
**Palo Alto, California**

#### Players

Computer science professor and [October 2005] honoree Sebastian Thrun mans the ship, joined by engineer Sven Strohband of Volkswagen, eight other Stanford faculty members and more than 50 students.

#### Rig

A rugged 2004 Volkswagen Touareg dubbed "Stanley," outfitted with GPS capability and a complete suite of radar, stereo, video sensors and lasers. A sign on the side reads "Drivers not required," a play on the VW slogan "Drivers wanted."

#### Backstory

After watching last year's race, Thrun got excited about the competition's teaching potential and organized a fall 2004 computer science course called "Darpa Grand Challenge." Although the initial prototype for Stanley was built in class, many students stayed to see the project through after the semester had ended.

#### Spotlight tech

The team's de facto design philosophy is "Redundancy is key." To that end, Stanley's electronic brain consists of six networked Pentium M computers. This array includes multiple copies of every necessary program so that even if one or two of the computers malfunction, the vehicle will be able to continue the race. The team recently perfected control software that ensures that Stanley will automatically choose the most direct path that avoids obstacles and stays on the road. "It looks at many possible routes and picks the best one," Thrun says.

#### Working style

Unconventional and playful. The off-road biker bar Slash-X, south of Barstow, California, is one of the team's favorite haunts. After a long road-testing stint, the team stakes out a corner of the bar and starts programming on laptops to correct any operational mistakes that have cropped up during the day.

#### Piggy bank

Although the team is appearing in the race for the first time, sponsors Android, Red Bull and Volkswagen have already jumped on its bandwagon, contributing tens of thousands of dollars in money and supplies.

#### Odds of winning 20:1.

10:1. In a race as long and tough as this one, equipment is bound to backfire from time to time. Because Thrun's team has made allowances for this possibility in its design, its vehicle should go far. "The field is very strong this year, so somebody is going to win it," Thrun says. "I'm optimistic about our chances."

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## WEB EXCLUSIVE

### **PopSci's Darpa Grand Challenge Preview: Update #5**

Elizabeth Svoboda

In this, the fifth of a series, *Popular Science* profiles one of the favored teams competing to win the Darpa Grand Challenge autonomous-vehicle race, which will take place on Saturday, October 8, near Primm, Nevada. Today we look at the Red Team's next-generation Hummer, which features a sophisticated system of integrated sensors. Stay tuned to [popsci.com](http://popsci.com) for more previews throughout the week and for minute-by-minute videos and updates on race day.

**Red Team, Carnegie Mellon University  
Pittsburgh, Pennsylvania**

#### **Players**

Team leader and maverick robotics professor William "Red" Whittaker, project manager Michele Gittleman, and more than 50 seriously obsessed CMU undergraduate and graduate students.

#### **Rig**

Sandstorm, the battle-hardened 1986 Hummer that was the Red Team's sole entry in 2004, will be returning to the starting line with a mechanical facelift. It boasts a fresh engine, new suspension, and a gimbaled platform that insulates delicate sensors from bumps and jostles. The Red Team isn't stopping there, though. It will also enter a next-generation modified Hummer called H1ghlander, which is threatening to leave its older sibling in the dust. H1ghlander features a speedy networking capability known as CANbus that allows its multiple microcontrollers to communicate with one another.

#### **Backstory**

Although none of last year's 'bots came close to completing the entire 150-mile course, Sandstorm was the nominal winner. It effortlessly chewed up seven miles of terrain before getting stuck in a rocky, switchback-riddled part of the course, nearly plunging off a cliff. "We've been in the shop for a year and a half now," Whittaker says, "and the team's been champing at the bit to get back out there."

#### **Spotlight tech**

The team's sensor-integration methods—installed on both vehicles—are unsurpassed. Sensors fuse laser and radar data into a composite model of the surrounding terrain that highlights less-navigable areas. The icing on the cake: a separate array of moving sensors that can probe hard-to-see areas that the fixed sensors miss.

#### **Working style**

Exceedingly thorough. Over months of tinkering and road-testing, team members have tried to anticipate every possible race-day scenario in hopes of staving off a potential disaster. "The question isn't just 'Can you do it?' " Whittaker says. "It's 'Can you do it on any given day, in any circumstances, under any conditions, on any route?' "

#### **Piggy bank**

Thanks to last year's success, sponsors such as Caterpillar, Boeing and Intel have been clamoring to have their names associated with the team, and these agreements have translated into a rumored several-million-dollar budget. The team's high profile has opened up another revenue stream as well—for less than \$20, fans can pick up a Red Team T-shirt, khaki hat or 11"x17" poster at the team's official Web site.

#### **Odds of winning 20:1.**

3:1. Sandstorm has logged more than 4,000 off-road miles and probably has the best shot of any vehicle at winning this race, although Whittaker, known for his military-style rigor, insists otherwise. "Being a favorite doesn't buy you coffee," he says. "It doesn't mean anything on race day."

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