

DARPA Grand Challenge

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(Redirected from Darpa grand challenge)

The **DARPA Grand Challenge** is a prize competition for driverless vehicles, funded by the Defense Advanced Research Projects Agency, the most prominent research organization of the United States Department of Defense. Congress has authorized DARPA to award cash prizes to further DARPA's mission to sponsor revolutionary, high-payoff research that bridges the gap between fundamental discoveries and military use. DARPA has technologies needed to create the first fully autonomous ground vehicles capable of completing a substantial off-road course within a limited time. The third event, The DARPA Urban Challenge, which took place on November 3, 2007 and was broadcast via webcast,^[1] further advanced vehicle requirements to include autonomous operation in a mock urban environment.



The site of the DARPA Grand Challenge on race day, fronted by the Team Case vehicle, DEXTER

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History and Background

See also: History of driverless cars

Fully autonomous vehicles have been an international pursuit for many years, from endeavors in Japan (starting in 1977), Germany (Ernst Dickmanns and VaMP), Italy (the ARGO Project), the European Union (EUREKA Prometheus Project), the United States of America, and other countries.

The Grand Challenge was the first long distance competition for driverless cars in the world; other research efforts in the field of Driverless cars take a more traditional commercial or academic approach. The U.S. Congress authorized DARPA to offer prize money (\$1 million) for the first Grand Challenge to facilitate robotic development, with the ultimate goal of making one-third of ground military forces autonomous by 2015. Following the 2004 event, Dr. Tony Tether, the director of DARPA, announced that the prize money had been increased to \$2 million for the next event, which was claimed on October 9, 2005. The first, second and third places in the 2007 Urban Challenge received \$2 million, \$1 million, and \$500,000, respectively.

The competition was open to teams and organizations from around the world, as long as there were at least one U.S. citizen on the roster. Teams have participated from high schools, universities, businesses and other organizations. More than 100 teams registered in the first year, bringing a wide variety of technological skills to the race. In the second year, 195 teams from 36 US states and 4 foreign countries entered the race.

2004 Grand Challenge

Main article: DARPA Grand Challenge (2004)

The first competition of the DARPA Grand Challenge was held on March 13, 2004 in the Mojave Desert region of the United States, along a 150-mile (240 km) route that follows along the path of Interstate 15 from just before Barstow, California to just past the California–Nevada border in Primm. None of the robot vehicles finished the route. Carnegie Mellon University's Red Team and car Sandstorm (a converted Humvee) traveled the farthest distance, completing 11.78 km (7.32 mi) of the course. But the vehicle got hung up on a rock, after making a switchback turn. No winner was declared, and the cash prize was not given. Therefore the second DARPA Grand Challenge event was scheduled for 2005.

2005 Grand Challenge

Main article: DARPA Grand Challenge (2005)

The second competition of the DARPA Grand Challenge began at 6:40am on October 8, 2005. All but one of the 23 finalists in the 2005 race surpassed the 11.78 km (7.32 mi) distance completed by the best vehicle in the 2004 race. Five vehicles successfully completed the race:

Vehicle	Team Name	Team Home	Time Taken (h:m)	Result
Stanley	Stanford Racing Team (http://cs.stanford.edu/group/roadrunner//old/index.html)	Stanford University, Palo Alto, California	6:54	First place
Sandstorm	Red Team (http://www.redteamracing.org/)	Carnegie Mellon University, Pittsburgh, Pennsylvania	7:05	Second place
H1ghlander	Red Team (http://www.redteamracing.org/)	Carnegie Mellon University, Pittsburgh, Pennsylvania	7:14	Third place
Kat-5	Team Gray (http://www.graymatterinc.com/)	The Gray Insurance Company, Metairie, Louisiana	7:30	Fourth place
TerraMax	Team TerraMax (http://www.terramax.com/)	Oshkosh Truck Corporation, Oshkosh, Wisconsin	12:51	Over 10 hour limit, fifth place

Vehicles in the 2005 race passed through three narrow tunnels and negotiated more than 100 sharp left and right turns. The race concluded through Beer Bottle Pass, a winding mountain pass with a sheer drop-off on one side and a rock face on the other.^[2] Although the 2004 course required more elevation gain and some very sharp switchbacks (Daggett Ridge) were required near the beginning of the route, the course had far fewer curves and generally wider roads than the 2004 course.

The natural rivalry between the teams from Stanford and Carnegie Mellon (Sebastian Thrun, head of the Stanford team was previously a faculty member at Carnegie Mellon and colleague of Red Whittaker, head of the CMU team) was played out during the race. Mechanical problems plagued H1ghlander before it was passed by Stanley. Gray Team's entry was a miracle in itself, as the team from the suburbs of New Orleans was caught in Hurricane Katrina a few short weeks before the race. The fourth finisher, Terramax, a 30,000 pound entry from Oshkosh Truck, finished on the second day. The huge truck spent the night idling on the course, but was particularly nimble in carefully picking its way down the narrow roads of Beer Bottle Pass.

2007 Urban Challenge

Main article: DARPA Grand Challenge (2007)



A vehicle that was developed for the 2007 DARPA Urban

The third competition of the DARPA Grand Challenge,^[3] known as the "Urban Challenge", took place on November 3, 2007 at the site of the now-closed George Air Force Base (currently used as Southern California Logistics Airport), in Victorville, California (Google map (<http://maps.google.com/maps?f=q&hl=en&geocode=&q=victorville&ie=UTF8&ll=34.590718,-117.374325&spn=0.033527,0.035877&t=k&z=15&om=1>)).^[1] The course involved a 96 km (60 mi) urban area course, to be completed in less than 6 hours. Rules included obeying all traffic regulations while negotiating with other traffic and obstacles and merging into traffic.

Unlike previous challenges, the 2007 Urban Challenge organizers divided competitors into two "tracks," A and B. All Track A and Track B teams were part of the same competition circuit, but the teams chosen for the Track A program received US \$1 million in funding. These 11 teams largely represented major universities and large corporate interests such as CMU teaming with GM as Tartan Racing, Stanford teaming with Volkswagen, Virginia Tech teaming with TORC Technologies as VictorTango, Oshkosh Truck, Honeywell, Raytheon, Caltech, Autonomous Solutions, Cornell, and MIT. One of the few independent entries in Track A was the Golem Group (<http://www.golemgroupp.com>). DARPA has not publicly explained the rationale behind the selection of Track A teams.

Teams were given maps sparsely charting the waypoints that defined the competition courses. At least one team, Tartan Racing, enhanced the maps through the insertion of additional extrapolated waypoints for improved navigation. A debriefing (<http://www.teamjefferson.com/files/duc/Debrief-Complete-TeamJefferson-DRAFT.pdf>) published by one of the teams illustrates graphically the contrast between the course map it was given by DARPA and the course map used by Tartan Racing^[4].

Tartan Racing claimed the \$2 million prize with their vehicle "Boss", a Chevy Tahoe. The second place finisher earning the \$1 million prize was the Stanford Racing Team with their entry "Junior", a 2006 Volkswagen Passat. Coming in third place was team VictorTango, winning the \$500,000 prize with their 2005 Ford Escape hybrid, "Odin".^[5] MIT placed 4th, with Cornell University and University of Pennsylvania/Lehigh University also completing the course.

The six teams that successfully finished the entire course:

Team Name	ID#	Vehicle	Type	Team Home	Time Taken (h:m:s)	Result
Tartan Racing (http://www.tartanracing.org/)	19	Boss	2007 Chevy Tahoe	Carnegie Mellon University, Pittsburgh, Pennsylvania	4:10:20	1st Place; averaged approximately 14 mph (22.53 km/h) throughout the course ^{[6][7]}
Stanford Racing (http://cs.stanford.edu/group/roadrunner/)	03	Junior	2006 Volkswagen Passat Wagon	Stanford University, Palo Alto, California	4:29:28	2nd Place; averaged about 13.7 mph (22.05 km/h) throughout the course ^[8]
VictorTango (http://www.me.vt.edu/urbanchallenge/)	32 ^[9]	Odin	2005 Ford Hybrid Escape	Virginia Tech, Blacksburg, Virginia	4:36:38	3rd Place; averaged slightly less than 13 mph (20.92 km/h) throughout the course ^[6]
MIT (http://grandchallenge.mit.edu/)	79	Talos	Land Rover LR3	MIT, Cambridge, Massachusetts	Approx. 6 hours	4th Place. ^[10]
The Ben Franklin Racing Team		Little	2006	University of Pennsylvania,	No	One of 6 teams to

(http://www.benfranklinracingteam.org/)	74	Ben	Toyota Prius	Lehigh University, Philadelphia, Pennsylvania	official time.	finish course
Cornell (http://www.cornellracing.com/)	26	Skynet	2007 Chevy Tahoe	Cornell University, Ithaca, New York	No official time.	One of 6 teams to finish course

While the 2004 and 2005 events were more physically challenging for the vehicles, the robots operated in isolation and only encountered other vehicles on the course when attempting to pass. The Urban Challenge required designers to build vehicles able to obey all traffic laws while they detect and avoid other robots on the course. This is a particular challenge for vehicle software, as vehicles must make "intelligent" decisions in real time based on the actions of other vehicles. Other than previous autonomous vehicle efforts that focused on structured situations such as highway driving with little interaction between the vehicles, this competition operated in a more cluttered urban environment and required the cars to perform sophisticated interactions with each other, such as maintaining precedence at a 4-way stop intersection.^[11]



Stanford Racing and Victor Tango together at an intersection in the DARPA Urban Challenge Finals.

Technology

2007 Urban Challenge teams employed a variety of different software and hardware combinations for interpreting sensor data, planning, and execution. Some examples:

Team	Language(s)	OS	Hardware	Notes
Cornell	C++, C#		17 dual-core servers	Planning involved Bayesian mathematics.
Insight Racing		Linux	Mac Mini	Mac Minis run on DC power at relatively low power and produce less heat.
Team Case		Windows ^[citation needed]	Mac Minis	
Team Gray			GrayMatter, Inc. AVS.	Embedded hardware system was considerably smaller than that of other teams. ^{[12][13]} Also, the system allows possible expansion with other sensors. ^[14]
Team LUX		Windows XP		embedded version of XP
Team Jefferson	Java	Solaris (Java RTS), Linux (Java SE)	micro-controllers and Sun SPOT (Java ME)	On Perrone Robotics' MAX robotics platform atop Sun Microsystems' Java RTS/SE/ME.
Team Ben Franklin	MATLAB			
Sting Racing	Java	Linux		
VictorTango	a mixture of C++ and LabVIEW	Windows and Linux		
Team Gator Nation (CIMAR)	C, C++, and C#	Windows, Fedora (Linux)		systems communication with the JAUS protocol.
MIT	C	Linux	cluster with	The robotic middleware library Lightweight Communications and Marshaling (LCM) [4]

			40 cores	(http://code.google.com/p/lcm/) was developed for the MIT vehicle.
Austin Robot Technology	C++			software was written and developed by undergraduates from a UT-Austin course (http://www.utexas.edu/news/2007/05/21/comp_sci/) . Used the Player Project as an infrastructure.
Tartan Racing (winner) ^[15]				Employed a hierarchical control system, with layered mission planning, motion planning, behavior generation, perception, world modelling, and mechatronics. ^[16]

Related pages

- Best of Biotech
- Entrepreneurs' Challenge
- Tournament In Management and Engineering Skills

See also

- Centennial Challenges
- Driverless car
- Multi Autonomous Ground-robotic International Challenge
- European Land - Robot Trial
- General Motors EN-V
- Global Security Challenge
- Google driverless car
- MIT Media Lab CityCar
- Robot competition
- VisLab Intercontinental Autonomous Challenge

References

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3. ^a "The contest, called the Grand Challenge and sponsored by the Defense Advanced Research Projects Agency, or Darpa, featured both robot collisions and robot traffic jams." John Markoff (2007-11-05). "Crashes and Traffic Jams in Military Test of Robotic Vehicles" (<http://www.nytimes.com/2007/11/05/technology/05robot.htm>) . New York Times. <http://www.nytimes.com/2007/11/05/technology/05robot.htm>.
4. ^a Team Jefferson Debriefing [1] (<http://www.teamjefferson.com/?q=debrief>) .
5. ^a Welcome (<http://www.darpa.mil/grandchallenge/index.asp>)
6. ^a ^b Belfiore, Michael (November 4, 2007). "Carnegie Takes First in DARPA's Urban Challenge" (<http://blog.wired.com/defense/2007/11/darpa-names-win.html>) . *Wired*. <http://blog.wired.com/defense/2007/11/darpa-names-win.html>.
7. ^a First-Place Finish - Carnegie Mellon University (<http://www.cmu.edu/homepage/practical/2007/fall/victory.shtml>)
8. ^a Stanford Racing Team (<http://cs.stanford.edu/group/roadrunner/racelog.html>)
9. ^a The Virginia Tech robot carried number 32 to commemorate the thirty-two people killed in the campus massacre on April 16, 2007 [2] (<http://blog.wired.com/defense/2007/11/virginia-tech-r.html>) .
10. ^a Contact (<http://www.darpa.mil/grandchallenge/mediafaq.asp>)
11. ^a http://www.darpa.mil/grandchallenge/docs/urb_challenge_announce.pdf
12. ^a GrayMatter, Inc AVS (<http://www.graymatterinc.com/>)

13. ^ Other teams competing in 2007 Urban Challenge (<http://www.mindfully.org/Technology/2007/DARPA-Urban-Challenge9aug07.htm>)
14. ^ GrayMatter Inc AVS allowing the adding of other sensors and types thereof (<http://www.graymatterinc.com/flexible.php>)
15. ^ [3] (<http://www.darpa.mil/GRANDCHALLENGE/Teams/TartanRacing.asp>) Tartan Racing team description
16. ^ Urmson, C. et al., Tartan Racing: A Multi-Modal Approach to the DARPA Urban Challenge (http://www.darpa.mil/GRANDCHALLENGE/TechPapers/Tartan_Racing.pdf) 2007, page 4

External links

- Official website (<http://www.darpa.mil/About/History/Archives.aspx>)
 - Announcement of the 2007 Grand Challenge (http://www.darpa.mil/grandchallenge/docs/urb_challenge_announce.pdf) (PDF)

Press coverage

- NOVA: The Great Robot Race (<http://www.educatedearth.net/video.php?id=4132>)
- The Register: Final robot grunts picked for \$1million DARPA race (<http://www.theregister.co.uk/content/28/36231.html>)
- The Register: DARPA's Grand Challenge proves to be too grand (<http://www.theregister.co.uk/content/28/36234.html>)
- CNN.com: Robots fail to complete Grand Challenge (<http://edition.cnn.com/2004/TECH/ptech/03/14/darpa.race>)
- SFGate.com: Robot race suffers quick, ignoble end (<http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2004/03/14/ROBOT.TMP>)
- 2004 DARPA Grand Challenge Image Gallery (<http://hobbiton.thisside.net/darpa/>)
- IEEE Computer Society, Special Issue on Unmanned Vehicles: The DARPA Grand Challenge (<http://www.computer.org/portal/web/csd/magazines/computer#3/>)
- Journal of Field Robotics, Special Issue on DARPA Grand Challenge, Part 1 (<http://www3.interscience.wiley.com/cgi-bin/jissue/112753748/>)
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- Wired Magazine article on the DARPA Grand Challenge and Stanley (<http://www.wired.com/wired/archive/14.01/stanley.html>) .
- Popular Mechanics article on the DARPA Grand Challenge (<http://www.popularmechanics.com/science/robotics/2169012.html>) .
- Popular Mechanics article on the UK MoD Grand Challenge (<http://www.popularmechanics.com/science/robotics/4278604.html?page=1>)
- Popular Science article on the DARPA Grand Challenge (<http://www.popsci.com/popsci/darpachallenge/2e1822e204bd6010vgnvcm1000004eeebccdrerd.html>) .
- Scientific American article on the DARPA Grand Challenge (<http://www.sciam.com/article.cfm?articleID=000000A3-4BCC-13A8-8BCC83414B7F0000&sc=I100322>) .

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