DARPA Challenges

DARPA Grand Challenges

DARPA = Defense Advanced Research Projects Agency

Images, videos, texts by DARPA

1. DARPA Grand Challenge (desert): 13.3.2004
2. DARPA Grand Challenge (desert): 8/9.10.2005

DARPA Urban Challenge (urban area): 3.11.2007

DARPA Robotics Challenge (desaster area): 2012-14

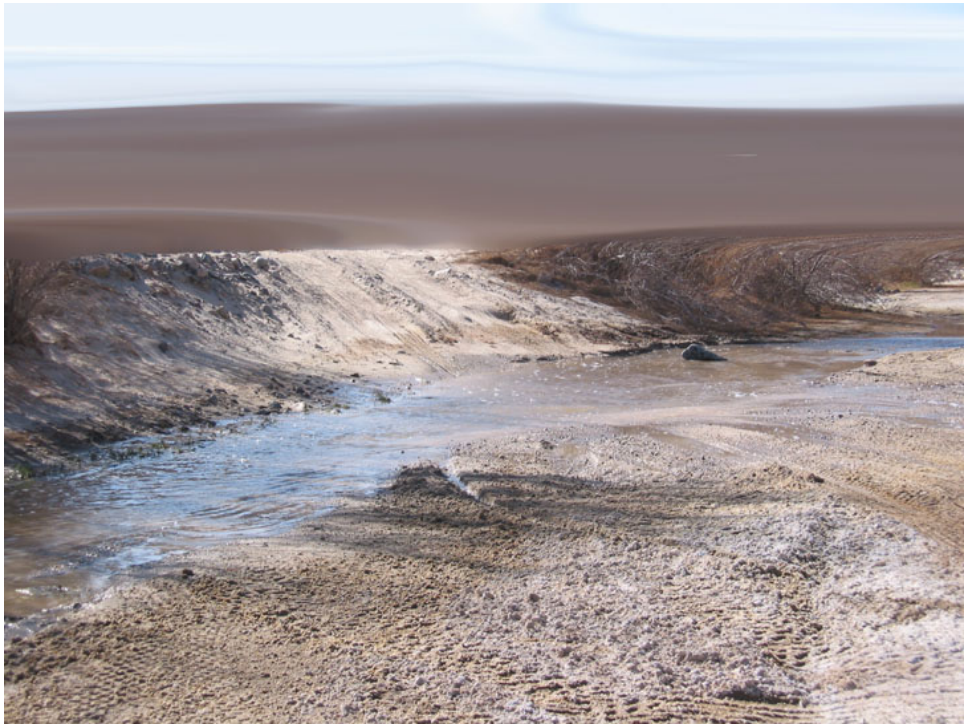
1. DARPA Grand Challenge 13.3.2004

- 142 miles = 230 km (originally 300 miles)
  with autonomous car
  in 10 hours
  on rough terrain through California desert

- $ 1 million price

- 27 applicants
- 15 qualified teams

Grand Challenge

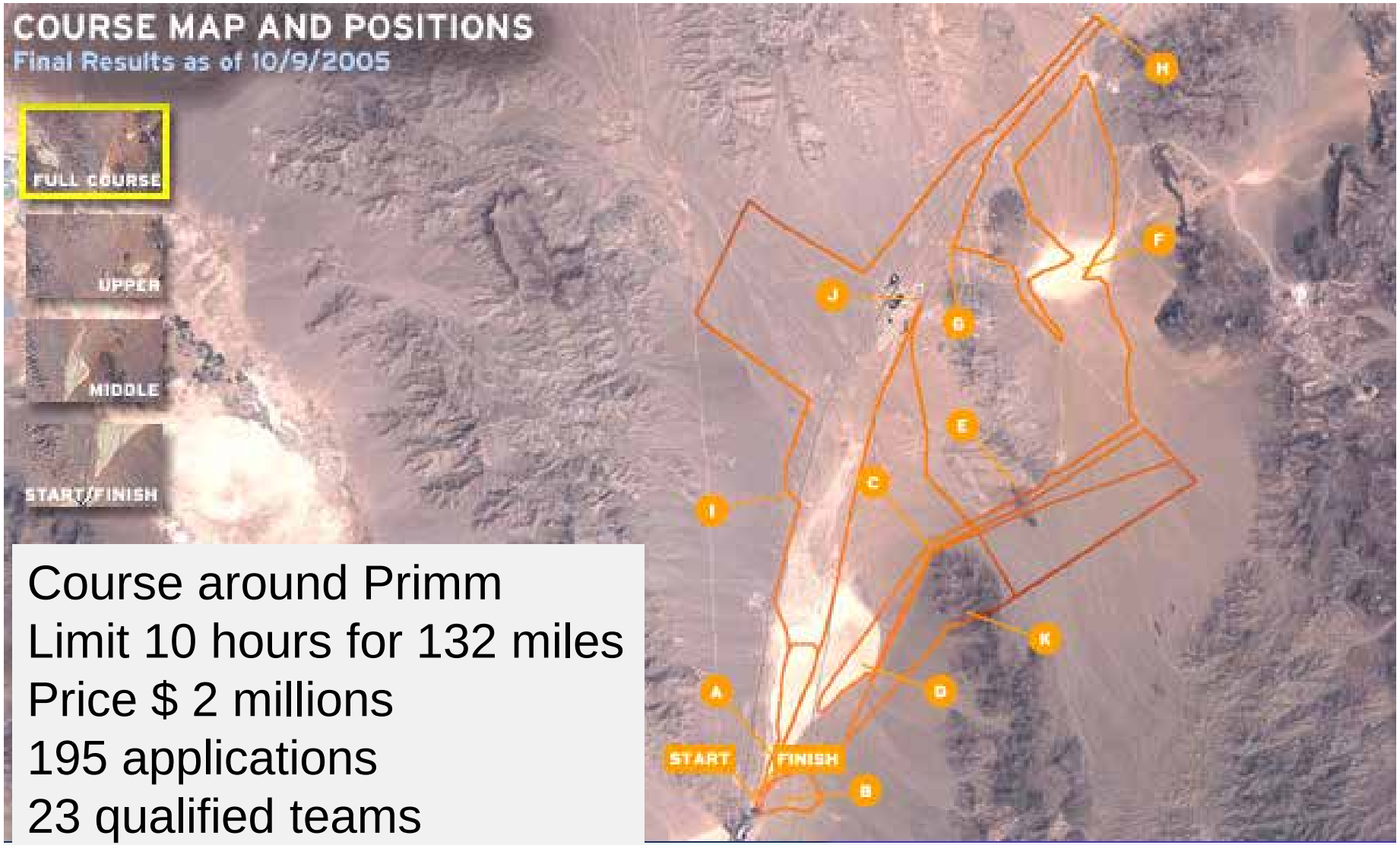


Grand Challenge

1.DARPA Grand Challenge 13.3.2004

Best: Red Team (Carnegie Mellon University) stopped with burning tires after 12 km

2. DARPA Grand Challenge 8./9.10.2005



Course around Primm
Limit 10 hours for 132 miles
Price $ 2 millions
195 applications
23 qualified teams

Grand Challenge

2. DARPA Grand Challenge 8./9.10.2005

Champion: „Stanley“ 6:53:58
Stanford Team (Sebastian Thrun)
VW Touareg

The vehicle that completed the course in the shortest amount of time was “Stanley,” entered by Stanford University. The team wins the $2 million prize because it finished the entire course in the shortest elapsed time under 10 hours – six hours, 53 minutes and 58 seconds (6:53:58).

Two vehicles entered by Carnegie-Mellon University, Red Team’s “Sandstorm” (7:04:50) and Red Team Too’s “H1ghlander” (7:14:00) finished close behind. The Gray Team’s “KAT-5” finished at 7:30:16. Oshkosh Truck’s 16-ton robot, TerraMax, also finished the course, on Sunday. Its official elapsed time was not available at press time, but the vehicle will not be eligible for the cash prize because the time will exceed the 10-hour limit.

The first four finishers entered the history books as being the first ground vehicle robots to travel a great distance at relatively high speed within a specified time frame. Stanley’s average speed over the 131.6-mile desert course was 19.1 mph. Sandstorm averaged 18.6 mph, H1ghlander 18.2 mph, and KAT-5 17.5 mph.

Stanley

The Stanford Vehicle (nicknamed "Stanley") is based on a stock, Diesel-powered Volkswagen Touareg R5, modified with full body skid plates and a reinforced front bumper. Stanley is actuated via a drive-by-wire system developed by Volkswagen of America's Electronic Research Lab.

All processing takes place on **seven Pentium M computers**, powered by a battery-backed, electronically-controlled power system. The vehicle incorporates measurements from **GPS**, a **6DOF inertial measurement** unit, and wheel speed for pose estimation.

While the vehicle is in motion, the environment is perceived through **four laser range finders, a radar system, a stereo camera pair, and a monocular vision system.** All sensors acquire environment data at rates between **10 and 100 Hertz.** Map and pose information are incorporated at 10 Hz, enabling Stanley to avoid collisions with obstacles in real-time while advancing along the 2005 DARPA Grand Challenge route.

The development of Stanley began in July 2004. At the time of the initial team application, the vehicle is largely functional and has logged dozens of autonomous miles along the 2004 DARPA Grand Challenge course.

DARPA Urban Challenge 3.11.2007

Urban Course on training area in Victorville/CA
60 miles (100 km) with given points in 6 hours

Urban traffic manouvers by Californian rules
Participants + 50 other cars

Special Qualification rounds

1. price: $ 2 Mio.
2. price: $ 1 Mio.
3. price: $ 0,5 Mio.

Special funding ($ 1 Mio.)
for 6 selected teams

Urban Challenge

Images von DARPA bzw.
Telepolis (H.A. Marsiske)

Images, Video von http://www.darpa.mil/grandchallenge/gallery.as

National Qualification Events (NQE) 2007

The NQE A test course required robots to safely merge into and out of two-way traffic in a tight, circulating course. Needless to say, this led to some hair-raising moments for some of the traffic drivers. Besides the complex timing and scoring being recorded by course officials, traffic drivers would alert officials to aggressive behavior with an ever-popular horn blast. Amazingly, in eight days of testing, only one traffic vehicle was actually struck by a robotic vehicle, a testament to the progress of the teams and DARPA's focus on safety.

National Qualification Events (NQE) 2007

The meandering NQE B course tested robots on their ability to **stay within a lane** as they traversed this 2.8-mile course. One section, affectionately termed “The Gauntlet” required the robots to delicately **maneuver through a series of parallel parked cars and road obstacles**. A final test on the NQE B course required the robots to **find an assigned parking spot between adjacent parked cars**, then **safely pull into and back out of the spot** before proceeding on its mission.

National Qualification Events (NQE) 2007

NQE C was traffic intensive, consisting of a series **of four-way stop intersections** for the robot to negotiate, each with its own arrangement of traffic. Robots had to recognize the other vehicles at these intersections, **determine the order of precedence and then safely proceed** through the intersection when it was their turn. For the second half of the NQE C course, various road blocks were emplaced and the robots were tested on their ability to **recognize the road block, execute a U-turn and dynamically replan a new route** to complete their mission.

National Qualification Events (NQE) 2007

21 teams passed the NQEs,
but only 11 were admitted to the finals (for safety reasons)

Team AnnieWay (Karlsruhe)
Ben Franklin Racing Team (Philadelphia/PA))
CarOLO (Braunschweig)
Team Cornell (Ithaka/NY)
Honeywell/Intelligent Vehicle Systems (Troy,Dearborn/MI,…)
MIT (Cambridge/MA)
Team Oshkosh Truck (Oshkosh/WI)
Stanford Racing Team (Stanford/CA)
Tartan Racing (CMU, Pitsburgh/PA)
Team UCF (Orlando/FL)
VictorTango (Blacksburg/VA)

Finals

The course for the final event was communicated to the teams in the form of two files, analogous to a map and a specific mission. Upon announcing the finalist selections on November 1, teams were given the 'map' file of the final course (Route Network Definition File). However, each team didn't receive their Mission Definition File, which lists the order of checkpoints they had to visit, until five minutes before they launched on race day. With this approach, the teams had no a priori knowledge of their missions, creating a truly autonomous driving test. Thirty manned traffic vehicles were also released onto the course to increase traffic density. This fleet of Ford Tauruses were retrofitted with safety cages, race seats, fire systems, radios and tracking systems, and were driven by professional drivers. In all, over 50 vehicles, both manned and unmanned, were navigating the city streets simultaneously during the final event.


Start

Champion: Tartan Racing (CMU)

6 vehicles reached the goal, 3 below 5:30h

1.: Tartan Racing, (CMU) Pittsburgh, PA (flawless)
2.: Stanford Racing Team, Stanford, CA (fastest, but error while overtaking)
3.: Victor Tango, Blacksburg, VA (leaves the course for short time)

Technique

Mostly standard vehicles (like VW)

Sensors:

- GPS
- Laser
- Radar
- Camera (not intensively used!)

Tartan Racing (CMU, Pitsburgh/PA)

Stanford Racing Team (Stanford/CA)

MIT (Cambridge/MA)

Sting (Georgia Tech)

Problems

- Collisions
- Deviations from road
- Risky maneuvers

Caused by

- Missing sensor data (GPS, inertial sensor, …)
- Software

Collisions

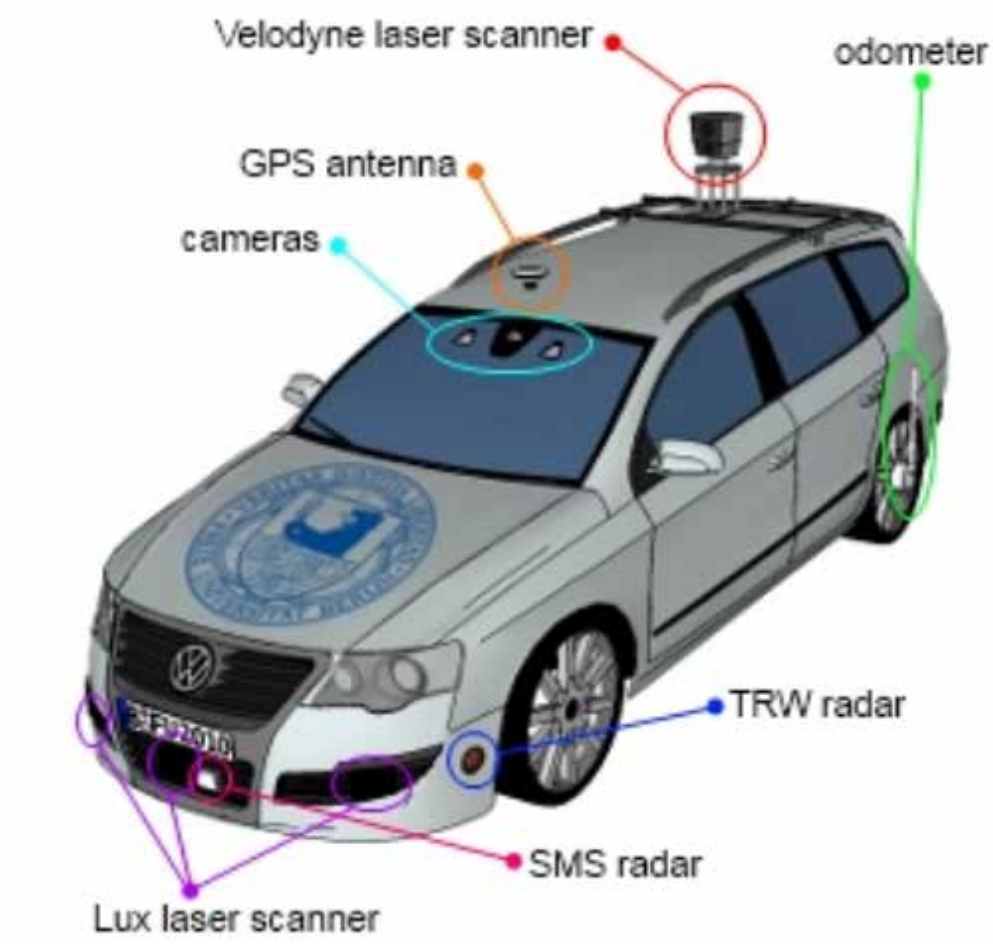
First Team AnnieWAY's autonomous VW Passat froze at the entrance to a traffic circle, then IVS's F-250 followed suit at an intersection, creating a traffic jam. Then Team Oshkosh's MTVR lost a shoving match with a building. All three vehicles have been driven back to the autonomous vehicle graveyard, a side lot near the team pits where race officials are parking cars that have been cut from the race. Just now UCF's Subaru Outback plowed into a house, so it's likely that team is out too. Sorry, that area's off limits to press, and I can't get a photo of that one.

Collisions

Two bots collided about an hour ago here at the DARPA Urban Challenge robot car race in Victorville, CA. Team Cornell's Skynet turned into a traffic circle a bit too sharply, and stopped before scraping the concrete K-rail bordering the course. After thinking for a moment, it backed up. Went forward again. Stopped. That's when MIT's vehicle came nosing along on the same road feeding into the traffic circle. After considering the motionless Cornell vehicle for a second or two, MIT apparently decided it was safe to pass--just as Cornell nudged forward.

Recent developments

MadeInGermany, FU Berlin



DARPA Robotics Challenge 2012-14

Robots in desaster response scenario

Scenario

for the first competition Dec. 2013:

The robot has to

1. use an unmodified vehicle to drive to desaster area
2. traverse through devasted area
3. remove debris blocking an entry
4. open a door and enter a building
5. climb a ladder and traverse industrial walkway
6. break through wall using appropriate tools
7. locate and close a valve near a leaking pipeline
8. replace a defect component

1) Drive a utility vehicle at the site – this will include getting in and out of an unmodified vehicle, along with steering, accelerating and braking on a moderately curving road (maximum speed will be 15 km/h, or 9.3 mph)
2) Travel dismounted across rubble – after leaving the vehicle, robots will have to traverse a variety of terrains, along with avoiding insurmountable obstacles
3) Remove debris blocking an entryway – that debris will likely be a solid object such as a rock or cinder block, not weighing more than 5 kg (11 lbs)
4) Open a door and enter a building
5) Climb an industrial ladder and traverse an industrial walkway
6) Use a power tool to break through a concrete panel – the tool will probably be an air or electric impact hammer and chisel, or an electric reciprocating saw
7) Locate and close a valve near a leaking pipe – there will be multiple pipes present, but the leaking one should be identifiable by its hissing sound and escaping smoke
8) Replace a component such as a cooling pump – besides locating the pump, this will involve loosening one or more fasteners, extracting the faulty pump, then reversing the steps to replace it with another

DARPA Robotics Challenge

- Semi-autonomy
- Control by non-expert operators
- Acting in normal environment after a catastrophe
- Usage of standard tools
- Extern power supply allowed as far as conform with tasks

ATLAS

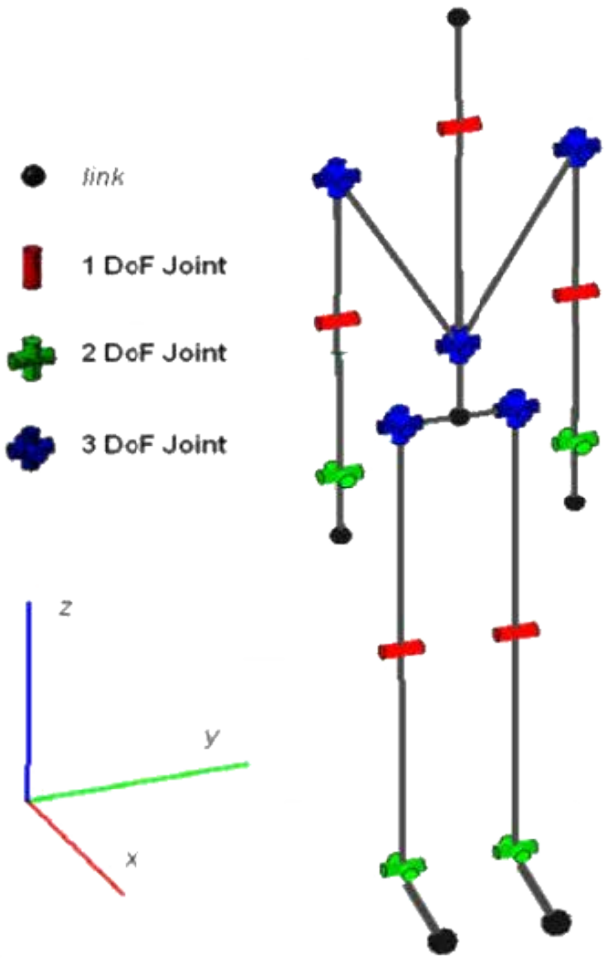
DARPA provides robot platform ATLAS (Boston Dynamics)
for selected teams

Boston Dynamics now owned by Google
– with consequences for cooperation with DARRA

ATLAS

- On-board real-time control computer;
- Hydraulic pump and thermal management;
- Two arms, two legs, a torso and a head;
- 28 hydraulically actuated joints;
- Carnegie Robotics sensor head with LIDAR and stereo sensors;
- Two sets of hands,
  one provided by iRobot and
  one by Sandia National Labs.

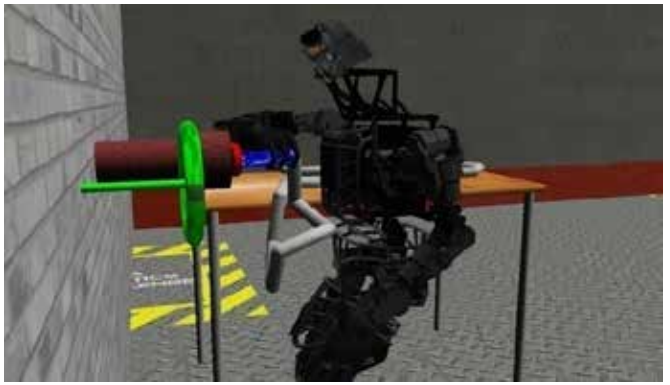
ATLAS



Weight (incl. powerpack): 150 kg
Height: 1.88 m
Chest Depth: 0.56 m
Shoulder Width: 0.76 m
Required Power: 480V 3-phase at 15 kW
Interface:10 Gbps Fiber Optic Ethernet
C++ and ROS APIs

DRC SIMULATOR

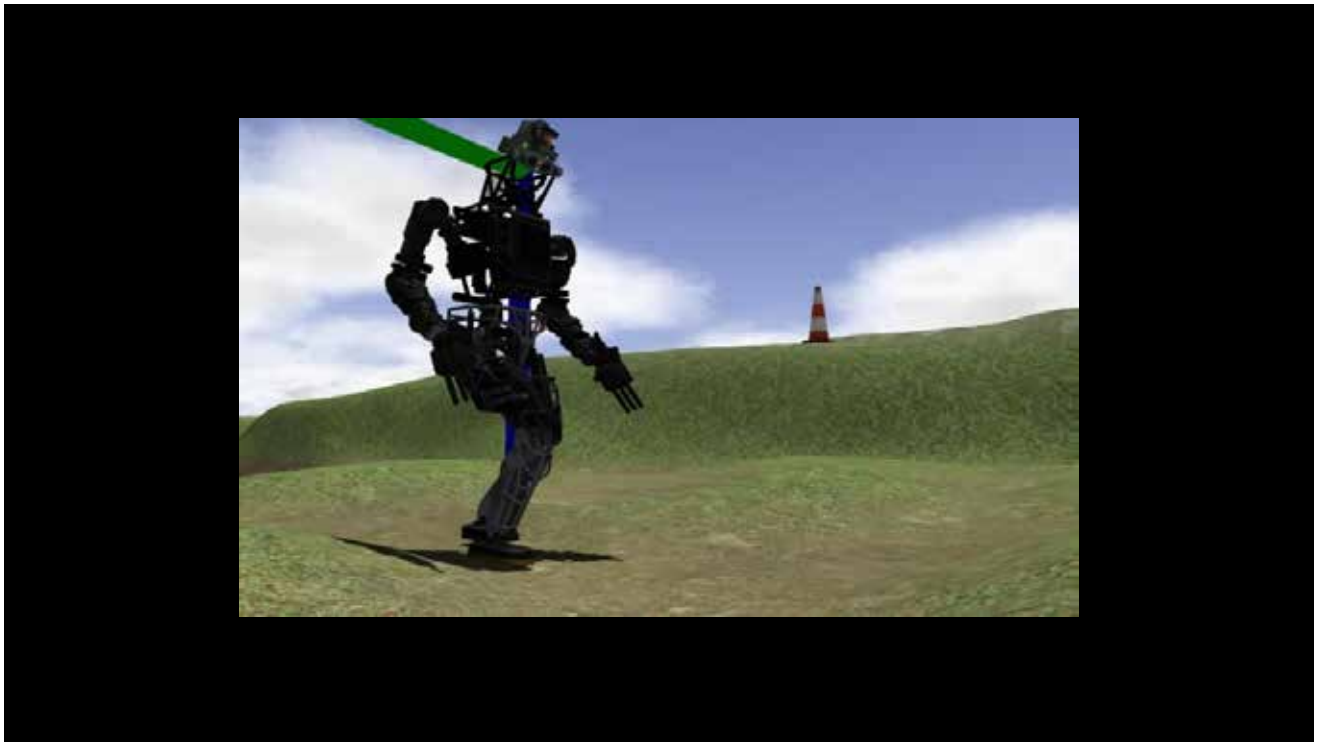
Open-source simulator with robots, robot components, field environments



"Open Source Robotics Foundation" was selected to develop the simulator and stimulate open source efforts throughout the world.

DRC SIMULATOR

DARPA: http://www.youtube.com/watch?v=C32dq-iBLwc



“Open Source Robotics Foundation” was selected to develop the simulator and stimulate open source efforts throughout the world.

Annoncement of DRC Simulator in 2012:
http://theroboticschallenge.org/simulator.php
http://gazebosim.org/wiki/InstallDRC

The GFE Simulator is being developed by the Open Source Robotics Foundation (OSRF). Built on the powerful Gazebo software package, the GFE Simulator will function as both a means of controlling the simulated robot and as a pass-through for controlling the physical robot during the 2013 and 2014 DARPA Robotics Challenge. The GFE Simulator supplier will manage an open-source effort where the simulator, robot models, and environment models are developed and improved by the supplier as well as by contributors throughout the world. Features of the simulator (not all implemented yet) include the following:

- Models the three-dimensional environment
- Allows developers to import kinematic, dynamic, and sensor models of a robot
- Allows users to send commands (identical to those sent to a physical robot) over a network to and receive data (similar to that received from a physical robot) from the simulated robot
- Uses physics-based models of inertia, actuation, contact, and environment dynamics to simulate the robot's motion
- Runs in real-time on the "cloud"

  Cloud computing resources will be funded by DARPA for at least 100 teams

Overall Schedule

The challenge is open for teams from all over the world.

1. Phase (2012-13): Qualification events

Teams can enter to 2. phase via 4 alternative tracks.

June 2013: *Virtual Robotics Challenge* on DRC simulator.

Dec. 2013: *First Hardware Challenge*

(scenario as desribed above with points 1-8)

Some selected teams will get funding (money, robots).

2. Phase (2014):

Final robot challenge (not specified yet) for qualified teams

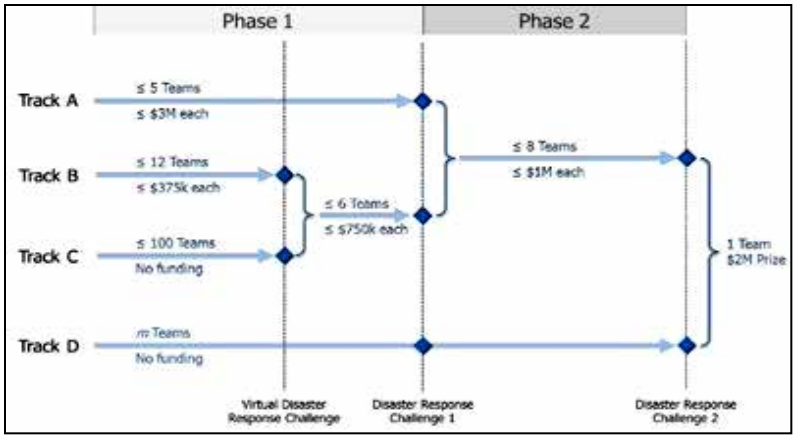
First phase (Oct. 2012 – Dec. 2013)

Track A: Teams propose own robot and software.
Oct. 2012: 7 Selected teams receive funding each up to $3 millions .

Track B and C: Teams propose control software (no hardware) for simulation.
11 selected teams (Track B) receive funding each up to $375,000.
Other teams (Track C) without funding.
June 2013: *Virtual Robotics Challenge* on DRC simulator.
6 teams selected and funded by up to $750,000 and robot ATLAS.

Track D: Teams develop (without funding)
a robot and software for 2. phase.
Application closed Oct.2013

Dec. 2013: *First Hardware Challenge*
(scenario as desribed above with points 1-8)



For second phase:
Up to 8 teams from Tracks A, B, C will be funded each with up to $1 million.
Ongoing use of ATLAS for Track B/C teams (if still in the competition).

Anticipated Schedule 1. Phase

DARPA Virtual Robotics Challenge (VRC)

October 24, 2012	VRC Registration Opens for Track C
March 1, 2013	VRC Registration Closes for Track C
May 1 – 15, 2013	VRC Qualification (Simulation)
	(26 teams from 8 countries qualified)
May 28 – June 7, 2013	VRC Practice (Simulation)
June 10 – 24, 2013	VRC Competition (Simulation)

DARPA Robotics Challenge (DRC) 2013

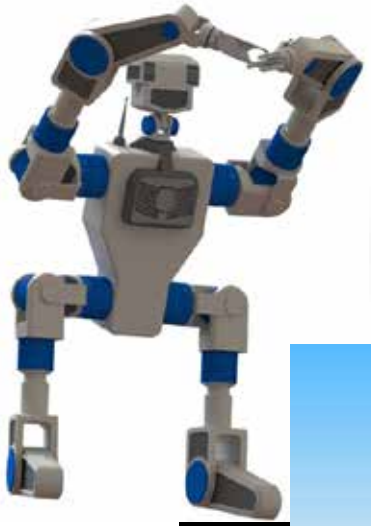
October 24, 2012	DRC 2013 Registration Opens for Track D
July 1, 2013	Detailed DRC 2013 Registration Opens for All Teams, All Tracks
October 1, 2013	DRC 2013 Registration Deadline
November 4 – 22, 2013	Platform Safety Evaluations
December 18 – 19, 2013	Team Practice
December 21, 2013	DRC 2013 Competition
December 22, 2013	Exposition and Awards Day

Selected Teams Track A

- Carnegie Mellon University
- Drexel University
- Raytheon (only until June 2013)
- SCHAFT
- Virginia Tech
- NASA Johnson Space Center
- NASA Jet Propulsion Laboratory

Funding each up to $3 millions .

Teams Selected for Track A



Selected Teams Track B

funded each up to $375,000

- Lockheed Martin – Advanced Technology Laboratories
- RE2
- University of Kansas
- Carnegie Mellon University
- Massachusetts Institute of Technology
- TRAC Labs
- University of Washington
- Florida Institute for Human and Machine Cognition (IHMC)
- Ben-Gurion University
- NASA Jet Propulsion Laboratory
- TORC Robotics

Winners of *Virtual Robotics Challenge*

Competition via cloud
with Teams from tracks B (funded) and C in June 2013

- Team IHMC, Pensacola, Florida
- WPI Robotics Engineering C Squad (WRECS), Massachusetts
- Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts
- Team TRACLabs, Webster, Texas
- Team ViGIR, Blacksburg, Virginia, und TU Darmstadt
- TROOPER, Cherry Hill, New Jersey
- Team HKU (Hong Kong University /Team K /Case Western University), (funded by Hong Kong University)

Funded each by
up to $750,000 and ATLAS robot

Hardware Challenge December 2013

Separate performance of 8 tasks:

1. drive
2. traverse
3. remove debris
4. open door
5. climb ladder
6. break through wall
7. close valve
8. connect hose

Remote control and securing were allowed

Results of Hardware Challenge Dec.2013

1. Team SCHAFT (SCHAFT Inc.): 27 pts. (out of 32 available points)
2. Team IHMC Robotics (Florida Institute for Human & Machine Cognition): 20 pts.
3. Team Tartan Rescue (Carnegie Mellon Univ. and Nat.Robotics Eng.Center): 18 pts.
4. Team MIT (MIT): 16 pts.
5. Team RoboSimian (NASA Jet Propulsion Laboratory): 14 pts.
6. Team TRACLabs (TRACLabs, Inc.): 11 pts.
7. Team WRECS (Worcester Polytechnic Institute): 11 pts.
8. Team Trooper (Lockheed Martin Advanced Technology Labs): 9 pts.
9. Team THOR (Virginia Tech College of Eng., Robotics & Mechanisms Lab.): 8 pts.
10. Team KAIST (Rainbow Co.): 8 pts.
11. Team ViGIR (TORC Robotics, TU Darmstadt): 8 pts.
12. Team HKU (University of Hong Kong): 3 pts.
13. Team DRC-Hubo (Drexel University): 3 pts.
14. Team Chiron (Kairos Autonomi): 0 pts.
15. Team Mojavaton (Mojavaton, LLC): 0 pts.
16. NASA-JSC Team Valkyrie (NASA Johnson Space Center): 0 pts.

Best 8 Teams to be funded with 3 Millions $

Team	Points	Track
SCHAFT	27	A
IHMC Robotics	20	B
Tartan Rescue	18	A
MIT	16	B
RoboSimian	14	A
Team TRACLabs	11	B
WRECS	11	C
TROOPER	9	B

Track A: Using own robot
Track B and C: Using ATLAS after Qualification in Software challenge

After some changes …

Team	Points*	Track
SCHAFT	27	D (A†)
IHMC Robotics	20	B
Tartan Rescue	18	A
MIT	16	B
RoboSimian	14	A
Team TRACLabs	11	B
WRECS	11	C
TROOPER	9	B
THOR	8	B
ViGIR	8	B
KAIST	8	D

… Team SCHAFT switched to track D after Google's acquisition …

Track A: Using own robot
Track B and C: Using ATLAS after Qualification in Software challenge
Track D: Own funding

Winning Team SCHAFT (Japan)

SCHAFT now owned by Google
– with consequences for cooperation with DARRA

See you at ...

RoboCup 2014

Jeao Pessoa Brasil, July, 19-25

GermanOpen 2015:

Magdeburg, Germany, April