Virtual Robotics Challenge Rules

Release 2 on March 30, 2013

DISTAR Case 21064

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Change Control Page

This section provides control for the development and distribution of revisions to the Virtual Robotics Challenge Rules.

Version	Date	Author	Section	Description
Release 2	3/30/2013	E. Krotkov	Checkpoint Completion	Revise number of checkpoints, Must complete checkpoints in order
			Allotments	Added statement about counting only “useful payload” bits
			Allotments	Updated table with uplink bit allotment (fixed cut and paste error)
			Schedule	Added dress rehearsal

1 Introduction

The DARPA Robotics Challenge (DRC) program plans to conduct three competitions (contingent on continued funding):

- The Virtual Robotics Challenge (VRC) in June 2013
- The DARPA Robotics Challenge Trials (DRC Trials) in December 2013
- The DARPA Robotics Challenge Finals (DRC Finals) in December 2014

This document contains the official rules of the Virtual Robotics Challenge (VRC), the first of the three competitions. The rules for DRC Trials and DRC Finals will appear later.

In the VRC, competitors will use software to command and control a simulated robot performing simulated disaster response tasks. Top performers in the event become eligible to receive a robot system with which to compete in DRC Trials. DARPA anticipates providing six (6) robot platforms. DARPA will determine at a future date the disposition of these platforms upon completion of the DRC program.

The website http://www.darpa.mil/Our_Work/TTO/Programs/DARPA_Robotics_Challenge.aspx contains links to program documents, including the following:

- The Broad Agency Announcement (BAA) solicitation and amendments
- The BAA questions and answers
- Proposers' Day briefings and transcripts
- Kickoff briefings and transcripts
- Program information

The website TheRoboticsChallenge.org contains links to key documents, including the following:

- Program information, discussion forums, and frequently asked questions
- Pre-registration for Track C and Track D
- Registration for Track C

Related documents include the following:

- Virtual Robotics Challenge Technical Guide – Describes the computing environment, how runs will be conducted, and what parameters will be varied for the VRC
- Virtual Robotics Challenge Qualification Guide – Defines procedures and schedule for qualifying for the VRC
- Virtual Robotics Challenge Practice – Defines procedures and schedule for conducting practice runs after qualification and before the VRC – Not yet available

2 Scope and Precedence

The rules apply to all participants in the VRC. Nothing in these rules, to include this document and all subsequent rules documents, may be interpreted as modifying the statement of work or authorizing work outside the terms and conditions of any existing agreements or contracts with DARPA.

DARPA will release additional documents with rules updates, procedures, and other information for teams as needed. These additional documents carry the full authority of the rules in this document.

All documents will be posted on the DARPA Robotics Challenge website, www.TheRoboticsChallenge.org.

3 Rule Modifications

The development of revolutionary technologies is a primary objective of the VRC. Entrants are invited to communicate directly with DARPA regarding any rule that restricts their ability to demonstrate technical achievement and innovative solutions to robotics for disaster response.

The Chief Judge has the authority to modify the rules at any time. Rules may be modified for many reasons, including accommodation of a promising technical approach that would have been prohibited by the rules. DARPA will communicate any modifications to the rules with an e-mail to all entrants and a statement on the DARPA Robotics Challenge website.

The Chief Judge may revise the schedule at any time and interpret the rules in any manner to best meet DARPA's objectives. The Chief Judge's decisions are based on a number of factors such as fairness, safety, statutes, program goals, and efficient operations.

Requests for rules clarifications should be sent to TheRoboticsChallenge@darpa.mil. DARPA will hold confidential any questions that are designated as team proprietary. DARPA will ensure that answers do not give any team an unfair advantage.

Decisions of the Chief Judge are final.

4 Eligibility

All responsible sources capable of performing the VRC tasks are eligible to participate in the VRC. The VRC is open to individual participants, and teams of participants, of all nationalities and of all ages. However, in order to receive the cash prize (after successfully competing in the VRC, the DRC Trials, and the DRC Finals), the winner must provide a U.S. taxpayer identification number (TIN, for example, a social security number). Information on how to obtain a TIN is available on the U.S. Internal Revenue Service website at www.IRS.gov.

Participants who are U.S. citizens or lawful permanent residents under 18 years of age may be required to obtain the consent of a guardian and/or meet other applicable legal requirements as a prerequisite to accepting the prize under this Challenge.

An individual or entity is not eligible to register or otherwise participate if he or she is on the Specially Designated Nationals list promulgated and amended by the Office of Foreign Assets Control of the United States Department of the Treasury (http://www.treasury.gov/resource-center/sanctions/SDN-List/Pages/default.aspx). Participants are solely responsible for compliance with all applicable laws and regulations. DARPA expressly disclaims any liability or responsibility thereto. In case of doubt about applicable laws and regulations, interested parties may choose to consult their legal counsel.

Federal entities and Federal employees acting within the scope of their employment are not eligible to participate.

Federal employees acting outside the scope of their employment should consult their ethics official before participating in the Challenge.

To avoid the appearance of unfairness, DARPA employees and DARPA support contractors and their spouses, dependents, and household members are not eligible to participate.

Teams funded under Track A are not eligible to participate.

DARPA reserves the right to disqualify a participant whose actions are deemed to violate the spirit of the competition for any reason, including but not limited to, the violation of laws or regulations in the course of participation in the Challenge.

5 Registration

Registration for the VRC takes place at the website www.TheRoboticsChallenge.org. Section 12 documents the registration schedule (late registrations are being considered).

Track B teams must register for the VRC.

Teams that register and are not on Track B are by definition on Track C.

DARPA aims to accommodate all registrants. Because the process of conducting runs will be automated, and therefore does not require personnel, DARPA does not anticipate limiting registration.

In the highly unlikely case that the number of registrants exceeds the computing resources available, DARPA may at the discretion of the Chief Judge conduct a random drawing to select registrants.

DARPA will not use order of registration as a selection criteria. Registration is not on a “first come first served” basis.

In exceptional circumstances, DARPA may accept registration requests after the Registration Closes date.

Registration for or participation in the challenge does not create or imply any contract with DARPA or the United States Government.

6 Qualification

Registered entrants must qualify for the VRC by demonstrating basic functionality prior to the competition.

Each team will be assigned a time slot in which to demonstrate basic robot functionality, such as walking in a straight line. Teams may make any number of attempts within the given time.

Failure to meet this objective by the end of the allotted time slot will result in disqualification from participation in the VRC competition.

Section 12 identifies the overall schedule for the qualification period. The *Virtual Robotics Challenge Qualification Guide* provides details about the qualification process.

7 Practice

DARPA will provide teams with the opportunity to run their systems using the software and services to be used in the VRC competition, to include access to the cloud service running the onboard robot code and DRC simulation code.

Variants of the VRC arenas will be released on which teams can practice before the official practice period with funded use of the CloudSim service. These arenas will be representative of the final VRC arenas in that they will reflect the same tasks and approximately the same configuration. However, parameters in the final VRC arenas will be altered from those of the practice arenas such that the exact road or path configuration, fixture sizes and geometries, friction coefficients, the communications parameters described in the VRC Technical Guide, and a variety of other minor adjustments will not be known in advance.

Section 12 identifies the overall schedule for the practice period. DARPA will announce detailed practice schedules and procedures at a later date.

8 Competition Tasks

The VRC competition will comprise three[1] tasks that are representative of the challenges planned for the DRC Trials and DRC Finals:

1. Walk a short distance to and climb into a utility vehicle, drive along a roadway at no greater than 16 kph (10 mph), climb out of the utility vehicle, and walk to the finish area.
2. Walk across progressively more difficult terrain; for example, progressing from parking lot to short grass to tall grass to tall grass on slope to ditch to rock field. In the earlier terrain, the supplied GFE Platform balancing and walking behaviors will suffice. In the later terrain, DARPA expects perception and footstep planning will be needed.
3. Connect a hose to a spigot and open the spigot by way of turning a valve. This is purely a manipulation task, that is, the robot does not need to travel more than a few steps to the work site.

Further details about these tasks will be provided in the *Virtual Robotics Challenge Technical Guide.*

9 Competition Runs

For each of the three (3) tasks described in Section 8, entrants will perform five (5) runs, for a total of fifteen (15) runs.

[1] Ideally, one would simulate all of the tasks in DRC-13 and DRC-14. However, in practice, simulating all of the tasks would require excessive time and effort, because of the need for multiple runs of the same task with different configuration settings.

Each run will take place with a unique *configuration* specifying the location of all objects in the environment, the starting position of the robot, the communications parameters (latency), contact friction properties, obstacle placement, object geometry, and other relevant parameters.

The five configurations will be distinct from each other. However, each team will have the same five configurations.

The following pseudo-code describes how the runs will take place for a given *team* performing a given *task*:

```
Simulate (team, task)
   For configuration (1: 5)
      Spawn simulation in cloud of robot performing task with
         configuration settings
      Spawn instance in cloud of Field Computer running Field Code
      Start scoring (configuration)
      Team simulates execution of task
      Stop scoring (configuration)
      Compute scores, log results
   Next
End Simulate
```

The expected completion time for a run of any of the three tasks is ten (10) minutes. The time limit for a run of any of the three tasks is thirty (30) minutes. For purposes of estimating the scope of VRC testing, runs will not exceed thirty (30) minutes.

Time starts when the team initiates the run. As the system initializes, the robot will not be able to view the terrain, but the team will be able to make the robot move so that the team is satisfied that all of their hardware and software processes are up and running. When the team initiates the run the robot will be "teleported" to the start area, and the run time clock will start.

Time ends when the task is achieved or when the maximum allowed time is reached.

If the robot must be reset during a run, for example due to a software process crashing, time continues to accrue and is not reset with the robot. However, runs ended by software process crashes will not count if the crash occurred for reasons outside team control.

If the robot must be reset during a run, the robot location and state shall remain unchanged for the resumption of the run (no "teleportation").

Teams will be allowed to successfully complete a run only once; teams may not perform a run multiple times to obtain a better score.

10 Competition Scoring

10.1 Communications

The VRC will add latency to the communications link between the OCU and the Field Computer to create a roundtrip latency of 500 ms. All teams shall have equal latency, except for teams

with underlying roundtrip internet latency in excess of 500 ms. We suggest such teams find a location to compete from without excessive latency.

The communications bandwidth between the OCU and the Field Computer shall not be limited by the VRC. However, the total number of bits will be limited (see Section 10.2).

Teams may use any communications protocol they desire for communications between the OCU and the Field Computer, including UDP and TCP. The VRC will not impose or require exclusive use of particular protocols.

10.2 Allotments of Time and Communications

Every run shall begin with, and may not exceed, the following allotments of time, uplink bits, and downlink bits:

- Time. The time for each run shall be 30 min (1,800 sec).
- Bits. The number of bits allotted per run shall include only "useful payload" bits, and not include header bits from the transport protocol layer or internet protocol layer or VPN.
- The number of bits allotted per run shall be the product of the time available (1,800 sec) and an assumed average bandwidth over the entire run time. Teams may use the bits at any instantaneous rate they choose (limited only by the internet). The assumed average bandwidth shall differ for each of the five (5) runs for a given task.
- Uplink Bits (from the OCU to the Field Computer): The following table shows the assumed average uplink bandwidths, and the corresponding number of uplink bits allotted.

Assumed Average Uplink Bandwidth (bps)	Number of Uplink bits allotted
16,384	29,491,200
4,096	7,373,800
1,024	1,843,200
256	460,800
64	115,200

Note that the table lists the cases in descending order from least challenging to most challenging. Each case differs from neighboring cases by a factor of four. Note that the table does not list the actual run order for the VRC Competition. Note that the Shannon Entropy Rate for human speech is approximately 10 bps.

- Downlink Bits (from Field Computer to OCU): The following table shows the assumed average downlink bandwidths, and the corresponding number of downlink bits allotted.

Assumed Average Downlink Bandwidth (bps)	Number of Downlink bits allotted
524,288	943,718,400

262,144	471,859,200
131,072	235,929,600
65,536	117,964,800
32,768	58,982,400

Note that the table lists the cases in descending order from least challenging to most challenging. Each case differs from neighboring cases by a factor of two. Note that the table does not list the actual run order for the VRC Competition.

Shortly in advance of each run, teams will be told what bandwidth limitations will be in place for the run.

The run shall end upon completion of the task, or upon expiration of the allotted time.

Run time shall be calculated according to simulation time, not according to "wall clock" time. The rationale is to ensure fairness, since simulation time is the same for all teams, but the ratio of simulation time to wall clock time may not be the same for all teams.

The uplink shall be halted upon depletion of the Uplink Bits allotment. Halting the uplink means that bits sent from the OCU to the Field Computer will be prevented from reaching the Field Computer. Halting the uplink is not the same as halting the run; for example, an autonomous system may be able to complete the task despite halting the uplink.

The downlink shall be halted upon depletion of the Downlink Bits allotment. Halting the downlink means that bits sent from the Field Computer to the OCU will be prevented from reaching the OCU. Halting the downlink is not the same as halting the run.

10.3 Checkpoint Completion

The driving task shall consist of four (4) checkpoints defined in the *Virtual Robotics Challenge Technical Guide*: getting into the vehicle after walking from the starting pen, driving the first half of the road course, driving the second half of the road course, and walking to the finish gate after getting out of the vehicle.

The walking task shall consist of four (4) checkpoints defined in the *Virtual Robotics Challenge Technical Guide*: crossing level ground, crossing the mud pit, crossing uneven ground, and crossing the rubble pile.

The hose task shall consist of four (4) checkpoints defined in the *Virtual Robotics Challenge Technical Guide*: lifting the hose connector off of the surface on which it is at rest, aligning the hose connector to the standpipe, threading the hose connector all the way onto the standpipe, and opening the valve fully. Unlike the driving and walking tasks, these checkpoints do not appear as physical gates.

The robot must complete the checkpoints in the order given. The robot must pass through all gates placed along the course.

10.4 Damage

The rationale for considering damage is to reward operation that results in minimal harm to the robot, thus enabling functionality longer in austere or hazardous environments. Falls and similar high-shock events exhibit large accelerations that are potentially dangerous to personnel and to the robot.

A run shall terminate if the robot sustains damage. In this context, damage shall be defined as three (3) occurrences of exceeding a threshold value for the maximum absolute acceleration of the center of mass. The determination of damage will take care to disregard spurious acceleration spikes.

10.5 Ranking

Let *C* represent the total number of checkpoints a team achieves over all 15 runs. Larger values of *C* indicate greater proficiency in completing the challenge tasks, which is considered more favorable.

Let *B* represent the percentage of uplink bits remaining after all 15 runs. Larger values of *B* indicate that the operator transmitted less information, which is considered more favorable in situations with limited communications bandwidth.

Let *T* represent the total number of seconds remaining from the initial allotment after all 15 runs. Larger values of *T* indicate that the system completed the challenge tasks more rapidly, which is considered more favorable. The rationale for using run time as a scoring criterion is that timely disaster response is typically more effective than tardy disaster response.

Teams shall be ranked initially by their *C* values. A team with a higher *C* value shall be ranked higher (more favorably) than a team with a lower *C* value. If all teams have a unique *C* value, then the ranking process is complete.

Teams with the same *C* value shall be ranked in an alternating pattern. The team with the largest *B* value shall rank first; that team will then be considered no further. The team with the largest *T* value of all remaining teams shall rank second; that team will then be considered no further. The team with the largest *B* value of all remaining teams shall rank third; that team will then be considered no further. The team with the largest *T* value of all remaining teams shall rank fourth; that team will then be considered no further. This alternating pattern shall repeat until all teams have been ranked.

If two or more teams have equal rank, then the Chief Judge will determine how to resolve the matter, possibly by conducting additional runs.

11 Competition Non-Disclosure

The Competition Non-Disclosure Period is the period beginning when an entrant begins their first competition run, and ending when the VRC results are announced.

During the Competition Non-Disclosure Period, entrants may not disclose the configuration settings used for the competition runs.

Violation of the non-disclosure rule will result in disqualification of the entrant who disclosed the configuration settings, and may result in re-runs or disqualification of the entrant who received the disclosed information.

12 Schedule

Table 2 identifies significant VRC dates.

Event	Date	Remarks
VRC Pre-Registration Opens	October 24, 2012	Used for purposes of sizing cloud resources
VRC Rules Drafted	November 12, 2012	
VRC Registration Opens	December 3, 2013	Used for official entry
VRC Registration Closes	December 14, 2012	Extended to Dec 18, 2012
VRC Registration Notification	December 31, 2012	
VRC Rules Release 1	December 31, 2012	
VRC Qualification	May 1, 2013 – May 15, 2013	
VRC Practice	May 28, 2013 – June 7, 2013	
VRC Dress Rehearsal	June 14, 2013	Runs during team local time
VRC Competition	June 17, 2013 – June 28, 2013	Dates planned for runs: June 18 – 20 (local time)

Table 2. VRC Schedule

Teams should plan on conducting runs on the three days specified. Teams should be available to conduct runs for the entire two weeks specified, in case the runs on the three days are not possible as planned. See the VRC Tech Guide for details.

Appendix 1: Definitions

Checkpoint

A progress marker that defines accomplishment of a sub-task.

Chief Judge

The Chief Judge is the DARPA Program Manager or an official designated by the DARPA Program Manager. The Chief Judge is the final authority on all matters referred to in the rules and on all matters pertaining to the VRC that are not explicitly referred to in the rules.

DARPA Robotics Challenge Website

Application forms and the most authoritative and up-to-date information about the DARPA Robotics Challenge program in general, and the VRC in particular, can be obtained at TheRoboticsChallenge.org.

Entrant

An entrant is a team on Track B or Track C that has not been disqualified.

Media Representative

A media representative is anyone who is accredited by DARPA as such.

Official

An official is a person designated by DARPA for the purpose of administering or monitoring any aspect of the VRC.

Qualification

The qualification process performs an initial check in advance of VRC to guarantee that teams can demonstrate basic functionality in order to be allocated resources on the cloud.

Rules

The rules posted on the DARPA VRC website are the official governing set of regulations and guidelines of the DARPA VRC and apply to all participants. The rules include this document as well as subsequent procedure documents and rules updates that are released on the website. The Chief Judge is the final authority on all rules and all aspects of the DARPA VRC.

Run

A trial of a simulated task with a particular configuration (including but not limited to starting position, starting orientation, and communication parameters)

Team Leader

A team leader is the individual identified to DARPA during the application process and is responsible for acting as the primary point of contact for team communication with DARPA.

Team Member

A team member is a team leader or individual who has been designated by the team leader as a team member.

Team Sponsor

A team sponsor is an organization that contributes labor, materials, services, equipment, or funds to a team.

VRC

Virtual Robotics Challenge