



# DRC Trials Rules

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# Revision History

This section captures changes to this document.

Version	Date	Author	Section	Description
Release 3	10/15/2013	E.Krotkov	Run Termination Criteria	Deleted paragraph about person touching robot. Now covered in Interventions section

## 1 Introduction

This document defines the rules for the DRC Trials.

Related documents include the following:

- DRC Trials Task Description - Describes the tasks to be performed by the human/robot system at the DRC Trials
- DRC Trials Operations Guide - Describes the operations of the DRC Trials
- DRC Trials Documents Roadmap - Lists the documents planned and their expected publication dates

## 2 Scope and Precedence

The rules apply to all participants in the DRC Trials. 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 may 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](http://www.TheRoboticsChallenge.org).

## 3 Rule Modifications

The development of revolutionary technologies is a primary objective of the DARPA Robotics Challenge. Entrants may 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 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 the DRC forum at [TheRoboticsChallenge.org](http://TheRoboticsChallenge.org). Questions about proprietary or sensitive matters should be sent to the [TheRoboticsChallenge@darpa.mil](mailto:TheRoboticsChallenge@darpa.mil). DARPA will ensure that answers do not give any team an unfair advantage.

Decisions of the Chief Judge are final.

## 4 Ranking

This section defines the ranking approach for the DRC Trials. In principle, we consider task completion to be the most important criterion, and consider number of interventions to be the next most important criterion, and consider task completion time to be the next most important criterion. We adopt an approach similar to that used for the Virtual Robotics Challenge, with rankings based on the primary criterion and ties broken by secondary and tertiary criteria. Unlike the Virtual Robotics Challenge approach, the ranking approach does not consider communication bits.

### 4.1 Task Completion

Let  $N$  represent the number of tasks to be performed by the human/robot system. For the DRC Trials,  $N=8$ .

Let  $M_i$  represent the number of sub-tasks of the  $i$ -th task to be performed by the human/robot system. Appendix B lists the sub-tasks. Note that different tasks may have different numbers of sub-tasks.

Let  $C_{ij}$  represent the number of points for completing the  $j$ -th sub-task of the  $i$ -th task. The Sub-Task Points column of Appendix B lists the number of points for each sub-task.

The task completion rating  $C$  shall be the sum of the sub-task completions for each of the tasks:

$$C = \sum_{i=1}^N \sum_{j=1}^{M_i} C_{ij} \quad (1)$$

## 4.2 Number of Interventions

Let  $l_i$  represent the number of interventions for the  $i$ -th task.

The number of interventions rating  $I$  shall be the sum of the number of interventions for each task:

$$I = \sum_{i=1}^N l_i \quad (2)$$

## 4.3 Task Completion Time

Let  $T_{given_i}$  represent the time available for the  $i$ -th task. Appendix C lists the current values of the given times (subject to change).

Let  $T_i$  represent the time taken to complete the  $i$ -th task. If the task is not completed, then set  $T_i = T_{given_i}$ . In other words, if the human/robot system does not accomplish all of the sub-tasks, then the time for the task shall be assessed as the given time. The time taken must be strictly greater than zero, because it is not possible to complete the tasks instantaneously. It follows that  $0 < T_i \leq T_{given_i}$ .

Example: The human/robot system completes all sub-tasks of the  $i$ -th task in twenty (20) minutes. Then  $T_i = 20$ .

Example: The human/robot system completes the first sub-task in five (5) minutes, but does not complete the final sub-task. Then  $T_i = T_{given_i}$ .

The task completion time rating  $T$  shall be the sum of the task completion times:

$$T = \sum_{i=1}^N T_i \quad (3)$$

It follows that  $0 < T \leq \sum_{i=1}^N T_{given_i}$

## 4.4 Ranking

Teams shall be ranked by task completion  $C$  (Equation 1), with larger values of  $C$  considered more favorable.

Teams with equal  $C$  values shall be ranked by  $I$  (Equation 2), with smaller values of  $I$  considered more favorable.

Teams with equal  $T$  values shall be ranked by  $T$  (Equation 3), with smaller values of  $T$  considered more favorable.

Cases in which teams have equal values shall be referred to the Chief Judge for resolution, possibly by conducting re-runs.

## 5 Communications

A basic principle of the DRC Program is for the teams to focus on robotics, and not focus on communications for reliable packet delivery. For the DRC Trials, the approach will follow this principle and simplify the communications by providing a channel that is error-free, but with limited bandwidth and non-negligible latency.

An error-free channel means no packet loss and no packet corruption, which in turn means that teams need not develop strategies for dealing with loss or corruption. The network equipment will be designed to queue rather than drop packets. However, it is not possible to guarantee that no packets will be dropped.

For the DRC Trials, the approach may limit bandwidth by the minute, with bandwidth values in the range of 100 Kbps (one hundred kilobits per second) and 1 Mbps (one megabit per second). The rationale for alternating minutes is implementation simplicity and equal treatment of all teams in all tasks. The rationale for the range of values is that they are intermediate values, between cell phone and 802.11 networks. The actual values for the DRC Trials will be determined based on team experience. DARPA reserves the right to announce the bandwidth values at the DRC Trials.

For the DRC Trials, the approach may vary round-trip latency by the minute, with latency values in the range of 100 and 1,000 ms. The rationale for alternating minutes is implementation simplicity and equal treatment of all teams in all tasks. The rationale for the range of values is, as for bandwidth, that they are intermediate values. The actual values for the DRC Trials will be determined based on team experience. DARPA reserves the right to announce the latency values at the DRC Trials.

When latency decreases for odd minutes, packets will not intentionally be dropped.

## 6 Run Termination Criteria

A run terminates upon any of the following conditions:

- Task Completion - The human/robot system completes the task within the given time
- Run Cancellation - A Trials Official cancels the run due to an external factor such as weather
- Time Expiration - The given time expires before the human/robot system completes the task

- E-Stop - A Trials Official activates the e-stop because of an unsafe condition
- By Request - The Team Lead requests that the run end
- Team Member touches robot (excluding the tether, excluding interventions)

A team may be eligible for a re-run if a run was cancelled. The Chief Judge shall review eligible cases and determine the course of action.

If a robot falls during a run, it may continue on its own, that is, if it can resume the task without physical intervention.

## 7 Conducting Runs

Appendix C defines the given times for the eight tasks. The appendix shows that each task will have a given time of thirty (30) minutes (subject to change).

The Vehicle, Obstacle, and Ladder tasks will take place in blocks of duration seventy-five (75) minutes. The first 30 minutes is expected to be dedicated to setup, and the next 30 minutes is expected to be dedicated to the run. The final 15 minutes shall be dedicated to moving to the next station; no portion of a run may take place during the final 15 minutes.

For the Vehicle, Obstacle, and Ladder tasks, teams may begin runs at any time during the first 60 minutes. If a team begins their run in the first 30 of the 60 minutes, then they will be able to run for a full 30 minutes. If a team begins their run after the first 30 of the 60 minutes, then they will not be able to run for a full 30 minutes.

The Debris, Wall, Hose, Door tasks will take place in blocks of duration sixty (60) minutes. The first 15 minutes is expected to be dedicated to setup, and the next 30 minutes is expected to be dedicated to the run. The final 15 minutes shall be dedicated to moving to the next station; no portion of a run may take place during the final 15 minutes.

For the Debris, Wall, Hose, Door, and Valve tasks, teams may begin runs at any time during the first 45 minutes. If a team begins their run in the first 15 of the 45 minutes, then they will be able to run for a full 30 minutes. If a team begins their run after the first 15 of the 45 minutes, then they will not be able to run for a full 30 minutes.

The durations for Vehicle, Obstacle, and Ladder tasks differ from the durations for the Debris, Wall, Hose, Door, and Valve tasks because of greater setup time needed, including delays on the Ladder and Obstacle tasks and travel to the site of the Vehicle task.

## 8 Interventions

During a run, a robot may stop working. The cause might be the robot falling, or software crashing, or many other factors.

If the robot stops working during a run, the Team Representative in the field with the robot may call for an intervention, during which the team may attempt to get the robot working again. The Team Representative in the field with the robot is the only individual who may request an intervention. The intent is to enable teams to perform quick “reset” functions, but not to allow substantial repairs.

When an intervention is called, the count of the number of interventions increments by one.

During an intervention, team personnel may perform the following actions:

- Physically re-position limbs or appendages of the robot, for example, by moving an arm or a leg
- Physically press a button or switch on the robot

During an intervention, team personnel may NOT perform the following actions:

- Approach the robot in the field without the permission of the judge
- Enter a keep-out zone in the field
- Use mechanical devices (for example a hoist) to re-position the robot
- Swap a new robot for the broken robot
- Swap a new component for a broken component
- Disassemble the broken robot or any of its components

The maximum number of personnel that may deploy into the field for an intervention is three (3).

Time spent resetting the robot counts against the time given for the run. In other words, the intervention time is “on the clock.”

The run may not resume until at least five (5) minutes have elapsed from the beginning of the intervention. This prevents field personnel from hurrying and potentially creating an unsafe condition.

Once the run duration reaches or exceeds the given time less five (5) minutes, an intervention may not take place.

If the reset is successful, then the run will resume from the location of the intervention, if that location is a safe location. For example, if an intervention occurred with the robot partway through a doorway, the run will resume not in that exact spot in the doorway, but at a designated spot shortly before the doorway.

If the reset is not successful, then the run will terminate.

## **9 Tether Management**

One Team Member shall manage the power/communications tether during runs. DRC Officials will not manage the tether.

The tether manager may not be used to assist the robot in performing the tasks. This includes assistance of locomotion, manipulation, perception, and all other functions.



## Appendix A. Definitions

### *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 DRC 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 DRC Trials in particular, can be obtained at [www.TheRoboticsChallenge.org](http://www.TheRoboticsChallenge.org).

### *Entrant*

An entrant is a team 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 DRC.

### *Qualification*

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

### *Rules*

The rules posted on the DARPA Robotics Challenge website are the official governing set of regulations and guidelines of the DARPA DRC Trials 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 DRC Trials.

### *Run*

A trial of a task (see the *Task Description* document for descriptions of the practice tasks, which are similar to but not necessarily the same as the Trials tasks).

### *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.

## Appendix B. Sub-Tasks

The assignment of points to tasks reflects the reality that for disasters, all of the capabilities are necessary for effective response. The Vehicle, Obstacle, Debris, Ladder, and Door capabilities enable movement from a sanctuary area to the danger zone. The Wall, Hose, and Valve capabilities enable effective work in the danger zone.

At this stage, the capabilities are weighted equally because they are viewed as equally necessary for disaster response. However, these values may be updated based on experience with the setups in the *Task Description* document.

Teams will receive a “bonus” for completing all of the sub-tasks with no interventions.

Task	Sub-Tasks	Sub-Task Points	Task Points	Sub-Tasks Must Take Place In Sequential Order
1. Vehicle	Drive past finish line Egress from vehicle Complete all sub-tasks w/no interventions	1 2 1	4	Yes
2. Obstacles	Traverse first four segments Traverse second three segments Traverse final three segments Complete all sub-tasks w/no interventions	1 1 1 1	4	Yes
3. Ladder	Two feet on or above first step Two feet on or above fourth step Two feet on or above landing Complete all sub-tasks w/no interventions	1 1 1 1	4	Yes
4. Debris	Remove five pieces Remove additional five pieces Travel through doorway Complete all sub-tasks w/no interventions	1 1 1 1	4	Yes
5. Door	Through Door 1 (Push) Through Door 2 (Pull) Through Door 3 (Weighted pull) Complete all sub-tasks w/no interventions	1 1 1 1	4	No (Note 1)
6. Wall	Cut Segment 1 Cut Segment 2 Cut Segment 3, Create hole	1 1 1	4	No

	Complete all sub-tasks w/no interventions	1		
7. Valve	Close Valve 1 (90 degree)	1	4	No
	Close Valve 2 (mid-size rotary)	1		
	Close Valve 3 (large rotary)	1		
	Complete all sub-tasks w/no interventions	1		
8. Hose	Hose end moves past start line	1	4	Yes
	Hose end moves into hydrant area	1		
	Attach hose to hydrant	1		
	Complete all sub-tasks w/no interventions	1		

*Table 1. Points*

Note 1. The shortest and most obvious path is to go through the three doors beginning with the push door (shortest distance from start), pull door (medium distance from start), and weighted pull door (farthest from start). However, it is not required that the robot follow that sequential order.

The worst possible task completion rating is zero. This rating indicates that the human/robot system accomplished none of the sub-tasks.

The best possible task completion rating, using Equation (1) and the point values in the table, is 32. This rating indicates that the human/robot system accomplished all of the sub-tasks.

In general, the intent is for difficulty to increase from the beginning of the task to the end.

## Appendix C. Times Given for Tasks

Table 2 lists the times given for the tasks (subject to change).

Task	Time Given (min)
1. Vehicle	30
2. Obstacles	30
3. Ladder	30
4. Debris	30
5. Door	30
6. Wall	30
7. Valve	30
8. Hose	30

*Table 2. Given Times*