



# DRC Trials Operating Procedures

Release 3 on December 17, 2013

DISTAR Case TBD

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## Revision History

This section captures changes to this document.

Version	Date	Author	Section	Description
Release 3	12/16/2013	E. Krotkov	Communications with Operator	Team Field Lead may tell operator that run has begun, intervention has concluded, and tether management pause has begun or concluded

# Introduction

This document describes operating procedures for the DRC Trials in December, 2013.

Related documents include the following:

- *DRC Trials Rules* - Defines the official rules for the DRC Trials
- *DRC Trials Task Description* - Describes the tasks that must be performed by the human/robot teams in the DRC Trials
- *DRC Trials Operations Guide* - Describes operations of the DRC Trials

## Safety

Safety is the highest priority concern for the DRC Trials.

The DRC Trials robots are a risk to human safety and the integrity of their physical surroundings. DRC robots are in the prototype stage and have not been certified in accordance with any safety standards.

DARPA has established minimal safety procedures to be followed by Teams to reduce the probability that a robot will harm a person. The establishment of these minimal safety procedures does not relieve the Teams of their responsibility to ensure safe operation of their robot at all times.

- Teams are responsible for ascertaining the adequacy of DARPA's safety procedures.
- While DARPA has mandated and required a demonstration of an Emergency Stop (E-Stop) for the robots to qualify for participation, it is each team's responsibility to ensure that their robot's Emergency Stop works reliably.
- Teams are responsible for ascertaining all risks associated with their robot.
- Teams are responsible for implementing safety procedures and precautions they deem appropriate (which may go beyond DARPA's safety procedures) to protect against human injury and property damage.
- Teams assume full liability for any personal injury or property damage caused by their robot or by procedures implemented by the Team.

DARPA understands Robot operation to involve a variety of possible safety hazards:

- Electrical Hazards: A robot may electrocute a person.
  - According to international standards, voltages below 50V generally do not pose a serious hazard in dry conditions with small area contact, so robots may leave internal and tether circuits energized at less than 50V and not pose an electrical hazard as long as conditions are dry and contact with people is minimal.
  - It is the responsibility of teams who wish to leave voltages greater than 50V energized inside their robot while humans are in potential contact to ascertain for themselves, and if true assert to DARPA, that insulation is sufficient for these voltage to not pose an electrical hazard.

- It is the responsibility of the team to de-energize robots in wet conditions or when contact with people may not be minimal.
- Thermal Hazards: A robot may burn a person. It is the responsibility of Teams to ensure adequate thermal insulation or mechanical guarding to mitigate this risk.
- Pressure Hazards: A robot may leak a jet of high-pressure fluid and blind or otherwise harm a person. While DARPA may require such also, Teams are ultimately responsible for ensuring that their robot is only pressurized if personnel around their robot are wearing safety glasses.
- Motion Hazards: A robot may cause harm by moving to contact or strike or pinch a person, or throw an object that strikes a person. A robot with motion disabled by a fail-safe circuit is assumed to not pose a motion hazard even if motor amplifier bus voltage is present. Teams must ensure that people are not close enough to a robot to be harmed before enabling the robot. Teams must ensure that motion disabling circuits are fail-safe regardless of incorrect operation of software, for instance by utilizing keep-alive heartbeats, etc.
- Eye Safety Hazards: The robot may cause harm by shining high-power laser light into a person's eye(s). If any team is using a laser that is or might be an eye safety hazard, they must notify DARPA. A robot with lasers disabled does not pose an eye safety hazard. Teams are responsible for ensuring that such disabling will be reliable regardless of incorrect operation of software.
- Gravity Hazards: The robot may cause harm by falling on a person. Teams must ensure that people are not in a location where a robot may fall on them. It is the team's responsibility when working near a robot, whether they use DARPA equipment or their own, to ascertain the adequacy of mechanical support.
- Other Hazards: There may be other hazards; the above list may not be comprehensive. While DAPRA may help, Teams are ultimately responsible for ascertaining and mitigating all hazards.

For the purposes of runs at the DRC Trials, a robot will be considered SAFE if it poses no hazards.

DARPA recognizes that teams use different terminology such as "e-stop," "m-stop," "disable", "pause," "kill," and other words to describe various level of robot shutdown and safety. Teams also use different indicator lights on the robot to show the robot's state.

To mitigate confusion, safety status will be communicated between DARPA and each team using only ONE word : "SAFE", defined as above. If a DARPA task official asks the Team Field Lead "is the robot SAFE?" the only acceptable answers are "Yes - the Robot is SAFE" or "No -

the Robot is NOT SAFE". Replies with other terms like "The robot is e-stopped" or "The robot is disabled" should not be used, as these can cause confusion and potentially lead to unsafe operation. Teams should avoid using the word "SAFE" when communicating with DARPA except as it is defined above.

## **STOP**

A STOP will be triggered if:

1. Any member of the DRC staff observes a condition jeopardizing safety toward people or property (for example, if the robot leaves a task area), and shouts the word "STOP" in any context, including, but not limited to, "STOP the robot!", "E-STOP the robot!", and "STOP!". DRC staff will NOT call for a STOP for other reasons, for example, if a robot has fallen without triggering the indicator described below or is not making progress.
2. The Team Field Lead (possibly on advice from other members of his team) shouts the word "STOP" in any context for any reason, possibly including a robot falling or not making progress.
3. The indicator on the fall limiter or belay line triggers, indicating the robot has tensioned the belay past the indicator's threshold (typically because of a fall).

After hearing or shouting "STOP," the Safety Official will disable the robot, first by using a method specified during task setup by the Team Field Lead, and if such is absent or not working, by activating the E-stop. If for some reason the Safety Official cannot do his/her job and a safety issue exists, the nearest person should attempt to stop the robot. If the E-stop is non-functional and the robot is externally powered, the power cable may be disconnected as a last resort. No one may approach an unsafe robot without explicit direction from the Safety Official or emergency personnel.

## **Run Termination due to Unsafe Operation**

Whether or not STOPS are triggered, the Safety Official may terminate a team's run at any time if he/she believes a robot is unsafe to people or property. The Safety Official's decision to terminate a run for this reason will not be up for debate. Rather, it will automatically trigger a mandatory review with the Chief Official before further robot operation may continue on any task. The robot may not continue in the Trials after such termination without permission from the Chief Official.

## **Intervention**

If a robot is not deemed unsafe to continue by the Safety Official, and sufficient time remains in the run (see below), a STOP triggers an opportunity for human Intervention.

Interventions (which are always preceded by STOPS) are carried out as follows:

- 1) The Team Field Lead will make the robot SAFE and inform the Safety Official when he/she believes the robot to be SAFE (see above).
- 2) If the Safety Official believes the team's declaration is likely correct and no other circumstances (for example, operations nearby) are preventing it, the Safety Official will grant permission for the team to approach the robot. Notice that this does not relieve the team of its responsibility for ensuring the safe operation of the robot at all times. The opinion of the Safety Official never implies this responsibility has shifted away from the team.
- 3) Once the Safety Official allows the team to access the robot, the Scribe will note the beginning time of the intervention.
- 4) The team will then deploy up to three (3) personnel into the field to move the robot to the restart location and to ready the robot to continue the run.
- 5) The run may not resume until at least five (5) minutes have elapsed from the start time noted by the Scribe in Step 3. The Scribe will inform the Task Official when this has occurred.
- 6) Once the robot has been reset, the Team Task Lead will inform the Task Official that the team is ready to continue the run. Assuming the Scribe has already noted that 5 minutes have passed since Step 3, the Task Official will verbally announce the end of the intervention, and the run may resume. The Scribe will record the end of the intervention.

## **Procedure for Starting a Run**

The procedure for starting a run may begin once the robot is behind the start line for the task.

The Team Field Lead will inform the Task Official that the team is ready to start a run.

The Task Official will ensure that all personnel and equipment are ready, and inform the Team Field Lead that they may begin the run.

The Team Field Lead will inform the Team Operator to begin the run.

When the robot crosses the start line, the Task Official will verbally announce that the run has begun. The Scribe will record the start of the run.

# Procedure for Communications with Team Operator

DARPA will provide each team a pair of two-way radios with a set channel for communications between the operator in the garage and the Team Field Lead in the field with the robot. The teams may use these, but may also use their own radios, phones, or other communication devices.

When not performing a run (for example, in transit, during setup for a task, or during an intervention while performing a task) the Team Field Lead and the Team Operator may communicate freely.

During a run, the Team Field Lead **may not** communicate information to the Team Operator. The sole exceptions to this rule are that the Team Field Lead may inform the Team Operator of the following:

- The run has begun
- The robot has crossed the start line
- A sub-task has been completed
- An E-stop has been triggered
- An intervention has been triggered or concluded
- A tether management pause has been triggered or concluded

From the time that a run has begun until the time that a run has terminated, the Team Field Lead and anyone else with direct view of the task is **specifically prohibited** from giving advice to the Team Operator, and from communicating information to increase the Team Operator's situation awareness.

During a run, the Team Operator may communicate with the Team Field Lead to request a STOP. The Team Field Lead must then relay such requests to the Task Official or the Safety Official.