DARPA Urban Challenge

E-Stop Guidelines

April 23, 2007
## Document Change Summary

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<td>Initial release</td>
<td>April 3, 2007</td>
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1. Introduction

DARPA Urban Challenge teams that participate in the National Qualification Event (NQE) and the DARPA Urban Challenge Final Event (UFE) are required to use a DARPA-supplied emergency stop (E-stop) system. The E-stop serves two essential purposes: basic remote stop/start command of the autonomous ground vehicle and communication to DARPA of position-tracking data as the vehicle runs the NQE and UFE routes.

Because the E-stop is loaned to the team by DARPA for use in the Urban Challenge, the system remains the property of the U.S. Government and must be returned as directed by DARPA. Team leaders must sign an agreement acknowledging responsibility for the E-stop and its use before the equipment will be issued.

On or about August 11, 2007, the leaders of the teams invited to the NQE will receive this agreement by email with other related information. Team leaders must sign and mail the document to the address provided. Following receipt of the agreement, DARPA will ship the E-stop to the address on the agreement form. Team leaders must inventory the system received against the packing list and acknowledge receipt via email within 10 business days.

2. Technical Guidelines

The E-stop unit is manufactured by Omnitech Robotics International (www.omnitech.com) and is the same model used in DARPA Grand Challenge 2005 with some software upgrades.

The overall system consists of a two way safety radio subsystem (Omnitech DGCSR(RX)). The tracking subsystem (Omnitech DGCTS) will not be used for the Urban Challenge. The radio subsystem consists of a safety transmitter (TX) and a safety receiver (RX). The RX is installed on the autonomous vehicle, and the TX is used by the team for testing in advance of arrival at the NQE, but is relinquished to DARPA upon arrival.

Teams are responsible for correct installation and powering of the unit and providing effective responses to the E-stop commands. Mechanical interface specifications for the units are available at www.omnitech.com/safetyradio.htm. The RX unit requires 12V DC power (10V min and 15V max) and draws approximately 1A average current, which must be provided by the vehicle. The unit should be installed at a location that affords protection from water, including all forms of precipitation, to ensure safe and reliable operation. The installation configuration should also ensure that the front panel display of the RX is readily accessible and viewable to facilitate unit testing at the NQE.

When installed, the RX has a 34-inch spring-mounted RF antenna with mounting bracket that should be mounted on the vehicle to afford a clear view of the horizon. In addition,
the RX has an external GPS patch antenna which requires proper view of satellites overhead. All cables should be routed so water will not flow down the cables and reach the enclosure. Power must not be applied to the units until all antennas are properly installed and connected.

Teams are responsible for devising an effective means of using the E-stop controls to produce an appropriate sequence of actions on the vehicle to ensure safe control in autonomous mode. The E-stop system is actuated through two switches on the TX, the RUN/PAUSE switch and the ENABLE/DISABLE switch by means of an RF link. The RUN/PAUSE control changes the electrical state of two separate electrical outputs on the RX. A relay-based contact closure interface is provided that is rated to carry 3A of current. A second output suitable for interfacing to digital electronics is also provided, capable of sourcing 100mA. The ENABLE/DISABLE on the TX controls a second pair of outputs on the RX with similar specifications.

When in ENABLE mode the vehicle should respond to the RUN and PAUSE commands. The DISABLE command response should invoke the DISABLE response irrespective of the RUN/PAUSE switch setting. The vehicle must respond to these E-stop states with a safe and effective series of actions. Verification of the E-stop integrated on the vehicle is an essential prerequisite before the team can run the NQE course.

When in ENABLE mode, the PAUSE response must cause the vehicle to be brought quickly and safely to a rolling stop. The wheels should then be locked to eliminate the possibility of rolling, even on a slope. When a RUN command is issued in this state, the vehicle should resume operation after a 5-second delay (see section 3.4.3 of the rules). Vehicles must be capable of responding to repeated PAUSE/RUN command sequences and should resume motion in response to a RUN command, even after sitting in PAUSE mode for multiple hours or starting on a slope or in rough terrain.

The DISABLE command is used to stop the vehicle as in PAUSE mode and shut down the vehicle. A vehicle that is in DISABLE mode should not restart in response to a RUN command. The DISABLE command should apply brakes (such as a spring-loaded emergency brake) to stop the vehicle promptly and hold the vehicle in position even if it is on a steep slope. It should also quickly disable the main propulsion unit and as many vehicle systems as necessary (e.g. fuel pump and electrical bus) to shut the vehicle down.

The DISABLE command serves an important secondary purpose as a fail-safe backup means of controlling a vehicle that has failed to stop in response to a PAUSE command. A single point failure on the vehicle (such as a computer) should not cause both the PAUSE and DISABLE functions to fail to operate. Teams should use a conservative design approach to provide assured operation of safety-critical functions such as braking.

The E-stop radio is a time domain multiple access system in which each unit transmits in an assigned time slot. This system is synchronized using a clock signal derived from GPS signals. If GPS signal reception is blocked (when the vehicle is moved indoors, for example), synchronization will eventually be lost, and the unit may transmit outside of its assigned time slot. In this case the vehicle may fail to properly receive GPS commands and may even jam transmissions in neighboring time slots. For this reason, the E-stop will shut down if GPS is lost for more than 10 minutes, and may be reset by power
cycling. Therefore, the GPS antenna must be installed and positioned properly so as to ensure a clear view of the sky to prevent an inadvertent shutdown during testing.

3. Requirements and Responsibilities

The team may use its own safety system for operations before arrival at the NQE, but only the DARPA-provided E-stop will be used once the vehicle arrives for the NQE.

Teams should notify DARPA immediately of any problems with the E-stop. Teams must inventory the components of the shipped systems immediately upon arrival. Damage during shipping, faulty operation, missing parts, or other problems should be reported immediately. The team’s E-stop must be fully functional for the team to be eligible to participate in the Urban Challenge.

The E-stop contains sensitive electronic systems and should be handled with care. Teams should avoid excessive heat, shock, electrostatic discharge, or humidity that could damage or impair the units. Electrical limits should be observed. Teams should read and observe the technical guidelines supplied with the units. The E-stop should be protected from water, including precipitation, at all times, including during operation at the Urban Challenge. Systems should be protected from incidental mechanical damage during testing including physical contact during operation in heavy brush.

The E-stop enclosure must not be opened for any reason. DARPA will provide the teams a technical support desk telephone number and email address to answer questions. If the support desk cannot resolve a problem, the team will be instructed to return the unit for in-shop repair or replacement. Teams must not attempt to repair or modify the E-stop without explicit written authorization from the support desk.

Teams should integrate and thoroughly test the E-stop on their vehicle in advance of arrival at the NQE. Teams that are not ready upon arrival at the track will not be allowed to compete and thus may incur a competitive disadvantage as a result of lost track time. Limited technical support will be available at the NQE.

Teams must return the complete E-stop (including antennas, cables, and associated hardware) in their original shipping containers within 24 hours of termination of involvement in the DARPA Urban Challenge. Should termination take place before the NQE, teams will ship the systems to the address provided with the unit. Should termination occur at the NQE, at the end of the NQE, at the UFE, or at the termination of the UFE, teams will return the systems to DARPA-identified personnel. Team leaders that do not return a complete E-stop will be liable to the U.S. Government for the replacement cost of the missing parts.

Teams should monitor the DARPA Grand Challenge web site and manufacturer web site (www.omnitech.com) for the latest information.
4. Contact Information

Prior to August 10, 2007, questions should be addressed to the Grand Challenge mailbox (grandchallenge@darpa.mil). After that date, direct technical support will be available from the manufacturer as described in the E-stop package.