Designation: E2829 – 11 (Reapproved 2020)

Standard Test Method for Evaluating Emergency Response Robot Capabilities: Mobility: Maneuvering Tasks: Sustained Speed[1]

This standard is issued under the fixed designation E2829; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 *Purpose:*

1.1.1 The purpose of this test method, as a part of a suite of mobility test methods, is to quantitatively evaluate a teleoperated ground robot's (see Terminology E2521) sustained maneuvering speed on paved surfaces.

1.1.2 Robots shall possess a certain set of mobility capabilities, including maneuvering, to suit critical operations such as emergency responses. The environments often pose constraints to robotic mobility to various degrees. Being able to maneuver effectively for extended distances is essential for deployment down-range during emergency responses. This test method specifies apparatuses to standardize this maneuvering task for testing.

1.1.3 Emergency response ground robots shall be able to handle many types of obstacles and terrain complexities. The required mobility capabilities include traversing gaps, hurdles, stairs, slopes, various types of floor surfaces or terrains, and confined passageways. Yet additional mobility requirements include sustained speeds and towing capabilities. Standard test methods are required to evaluate whether candidate robots meet these requirements.

1.1.4 ASTM Task Group E54.08.01 on Robotics specifies a mobility test suite, which consists of a set of test methods for evaluating these mobility capability requirements. This sustained speed test method is a part of the mobility test suite. The apparatuses associated with the test methods challenge specific robot capabilities in repeatable ways to facilitate comparison of different robot models as well as particular configurations of similar robot models.

1.1.5 The test methods quantify elemental mobility capabilities necessary for ground robot intended for emergency response applications. As such, users of this standard can use either the entire suite or a subset based on their particular performance requirements. Users are also allowed to weight particular test methods or particular metrics within a test method differently based on their specific performance requirements. The testing results should collectively represent an emergency response ground robot's overall mobility performance as required. These performance data can be used to guide procurement specifications and acceptance testing for robots intended for emergency response applications.

NOTE 1—Additional test methods within the suite are anticipated to be developed to address additional or advanced robotic mobility capability requirements, including newly identified requirements and even for new application domains.

1.2 *Performing Location*—This test method shall be performed in a testing laboratory or the field where the specified apparatus and environmental conditions are implemented.

1.3 *Units*—The values stated in SI units are to be regarded as the standard. The values given in parentheses are not precise mathematical conversions to inch-pound units. They are close approximate equivalents for the purpose of specifying material dimensions or quantities that are readily available to avoid excessive fabrication costs of test apparatuses while maintaining repeatability and reproducibility of the test method results. These values given in parentheses are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E2521 Terminology for Evaluating Response Robot Capabilities

[1] This test method is under the jurisdiction of ASTM Committee E54 on Homeland Security Applications and is the direct responsibility of Subcommittee E54.09 on Response Robots.

Current edition approved Jan. 1, 2020. Published January 2020. Originally approved in 2011. Last previous edition approved in 2011 as E2829 – 11. DOI: 10.1520/E2829-11R20.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E2592 Practice for Evaluating Response Robot Capabilities: Logistics: Packaging for Urban Search and Rescue Task Force Equipment Caches

2.2 *Other Standards:*

National Response Framework U.S. Department of Homeland Security[3]

NIST Special Publication 1011-I-2.0 Autonomy Levels for Unmanned Systems (ALFUS) Framework Volume I: Terminology, Version 2.0[4]

3. Terminology

3.1 Terminology E2521 lists additional definitions relevant to this test method.

3.2 *Definitions:*

3.2.1 *abstain, v*—prior to starting a particular test method, the robot manufacturer or designated operator shall choose to enter the test or abstain. Any abstention shall be granted before the test begins. The test form shall be clearly marked as such, indicating that the manufacturer acknowledges the omission of the performance data while the test method was available at the test time.

3.2.1.1 *Discussion*—Abstentions may occur when the robot configuration is neither designed nor equipped to perform the tasks as specified in the test method. Practice within the test apparatus prior to testing should allow for establishing the applicability of the test method for the given robot.

3.2.2 *administrator, n*—person who conducts the test. The administrator shall ensure the readiness of the apparatus, the test form, and any required measuring devices such as stopwatch and light meter; the administrator shall ensure that the specified or required environmental conditions are met; the administrator shall notify the operator when the safety belay is available and ensure that the operator has either decided not to use it or assigned a person to handle it properly; and the administrator shall call the operator to start and end the test and record the performance data and any notable observations during the test.

3.2.3 *emergency response robot, or response robot, n*—a robot deployed to perform operational tasks in an emergency response situation.

3.2.3.1 *Discussion*—A response robot is a deployable device intended to perform operational tasks at operational tempos during emergency responses. It is designed to serve as an extension of the operator for gaining improved remote situational awareness and for projecting her/his intent through the equipped capabilities. It is designed to reduce risk to the operator while improving effectiveness and efficiency of the mission. The desired features of a response robot include: rapid deployment; remote operation from an appropriate standoff distance; mobility in complex environments; sufficiently hardened against harsh environments; reliable and field serviceable; durable or cost effectively disposable, or both; and equipped with operational safeguards.

3.2.4 *fault condition, n*—during the performance of the task(s) as specified by the test method, a certain condition may occur that renders the task execution to be failed and such a condition is called a fault condition. Fault conditions result in a loss of credit for the partially completed repetition. The test time continues until the operator determines that she/he can not continue and notifies the administrator. The administrator shall, then, pause the test time and add a time-stamped note on the test form indicating the reason for the fault condition.

3.2.4.1 *Discussion*—Fault conditions include robotic system malfunction, such as detracking, and task execution problems, such as excessive deviation from a specified path or failure to recognize a target.

3.2.5 *human-scale, adj*—used to indicate that the objects, terrains, or tasks specified in this test method are in a scale consistent with the environments and structures typically negotiated by humans, although possibly compromised or collapsed enough to limit human access. Also, that the response robots considered in this context are in a volumetric and weight scale appropriate for operation within these environments.

3.2.5.1 *Discussion*—No precise size and weight ranges are specified for this term. The test apparatus constrains the environment in which the tasks are performed. Such constraints, in turn, limit the types of robots to be considered applicable to emergency response operations.

3.2.6 *operator, n*—person who controls the robot to perform the tasks as specified in the test method; she/he shall ensure the readiness of all the applicable subsystems of the robot; she/he through a designated second shall be responsible for the use of a safety belay; and she/he shall also determine whether to abstain the test.

3.2.7 *operator station, n*—apparatus for hosting the operator and her/his operator control unit (OCU, see NIST Special Publication 1011-I-2.0) to teleoperate (see Terminology E2521) the robot; the operator station shall be positioned in such a manner so as to insulate the operator from the sights and sounds generated at the test apparatuses.

3.2.8 *repetition, n*—robot's completion of the task as specified in the test method and readiness for repeating the same task when required.

3.2.8.1 *Discussion*—In a traversing task, the entire mobility mechanism shall be behind the START point before the traverse and shall pass the END point to complete a repetition. A test method can specify returning to the START point to complete the task. Multiple repetitions, performed in the same test condition, may be used to establish the robot performance of a particular test method to a certain degree of statistical significance as specified by the testing sponsor.

3.2.9 *test event or event, n*—a set of testing activities that are planned and organized by the test sponsor and to be held at the one or multiple designated test site(s).

3.2.10 *test form, n*—form corresponding to a test method that contains fields for recording the testing results and the associated information.

3.2.11 *test sponsor, n*—organization or individual that commissions a particular test event and receives the corresponding test results.

[3] Available from Federal Emergency Management Agency (FEMA), P.O. Box 10055, Hyattsville, MD 20782-8055, http://www.fema.gov.

[4] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

3.2.12 *test suite, n*—designed collection of test methods that are used, collectively, to evaluate the performance of a robot's particular subsystem or functionality, including mobility, manipulation, sensors, energy/power, communications, human-robot interaction (HRI), logistics, safety, and aerial or aquatic maneuvering.

3.2.13 *testing task, or task, n*—a set of activities well defined in a test method for testing robots and the operators to performs in order for the robots' performance to be evaluated. A test method may specify multiple tasks. A task corresponds to the associated metric or metrics.

4. Summary of Test Method

4.1 The task for this test method, traversing a specified path while straddling a line, is defined as the robot traversing from the START point along the specified path, which ends back at the START point, thus enabling continuous repetitions. The specified path shall be a figure-eight, also known as a continuous "S," around two pylons installed in the test course as described in Section 6. See Fig. 1 for an illustration. The robot must straddle the line continuously throughout the path, maintaining some part of the mobility chassis over the line at all times. This task is one of the maneuvering tasks that candidate response robots shall be able to perform.

4.2 The robot's traversing capability is defined as the robot's ability to complete the task and the associated effective speed. Further, the test sponsor can specify the statistical reliability and confidence levels of such a capability and, thus, dictate the number of successful task performance repetitions that is required. In such a case, the average effective speed shall be used, instead, as the robot's capability. In either case, the resulting effective speed is specified as the robot's sustained speed.

4.3 Teleoperation shall be used from the operator station specified by the administrator to test the robots using an OCU provided by the operator. The operator station shall be positioned and implemented in such a manner so as to insulate the operator from the sights and sounds generated at the test apparatus.

4.4 The operator is allowed to practice before the test. She/he is also allowed to abstain from the test before it is started. Once the test begins, there shall be no verbal communication between the operator and the administrator regarding the performance of a test repetition other than instructions on when to start and notifications of faults and any safety related conditions. The operator shall have the full responsibility to determine whether and when the robot has completed a repetition and notify the administrator accordingly. However, it is the administrator's authority to judge the completeness of the repetition.

NOTE 2—Practice within the test apparatus could help establish the applicability of the robot for the given test method. It allows the operator to gain familiarity with the standard apparatus and environmental conditions. It also helps the test administrator to establish the initial apparatus setting for the test when applicable.

4.5 The test sponsor has the authority to select the turning radii for the traversing task. The test sponsor also has the authority to select test methods that constitute the test event, to select one or more test site(s) at which the test methods are implemented, to determine the corresponding statistical reliability and confidence levels of the results for each of the test methods, and to establish the participation rules including the testing schedules and the test environmental conditions.

5. Significance and Use

5.1 A main purpose of using robots in emergency response operations is to enhance the safety and effectiveness of emergency responders operating in hazardous or inaccessible environments. The testing results of the candidate robot shall describe, in a statistically significant way, how reliably the robot is able to traverse the specified types of terrains and thus provide emergency responders sufficiently high levels of confidence to determine the applicability of the robot.

5.2 This test method addresses robot performance requirements expressed by emergency responders and representatives from other interested organizations. The performance data captured within this test method are indicative of the testing robot's capabilities. Having available a roster of successfully tested robots with associated performance data to guide procurement and deployment decisions for emergency responders is consistent with the guideline of "Governments at all levels have a responsibility to develop detailed, robust, all-hazards response plans" as stated in National Response Framework.

5.3 The standard apparatus is specified to be easily fabricated to facilitate self-evaluation by robot developers and

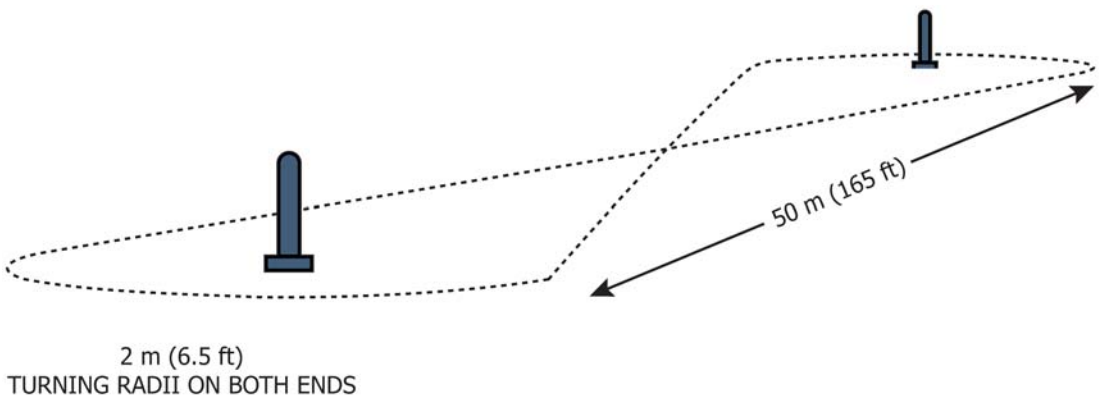

FIG. 1 Mobility: Maneuvering Tasks: Sustained Speed Apparatus

provide practice tasks for emergency responders to exercise robot actuators, sensors, and operator interfaces. The standard apparatus can also be used to support operator training and establish operator proficiency.

5.4 Although the test method was developed first for emergency response robots, it may be applicable to other operational domains.

6. Apparatus

6.1 This test apparatus is a flat, paved surface with two pylons or barrels placed 50 m (165 ft) apart. A specified path line is marked on the pavement forming a figure-eight or a continuous "S." The turning radius of 2 m (6.5 ft) is specified around each of the pylons or barrels (Fig. 2 and Fig. 3). The path line shall be marked so as to be visible by the remote testing operator through her/his OCU, with, for example, white or brightly colored paint. The robot must straddle the line continuously throughout the path, maintaining some part of the mobility chassis over the line at all times. The effective distance of the specified path guiding the traversing task is 100 m (325 ft).

6.2 Various test conditions such as apparatus surface types and conditions, including wetness and friction levels, temperature, types of lighting, smoke, humidity, and rain shall be facilitated when the test sponsor requires. For example, for a test run in the dark environment, a light meter shall be used to read 0.1 lux or less. The darkness shall be re-measured when the lighting condition might have changed. The actual readings of these conditions should be recorded on the test form.

NOTE 3—The darkness is specified as 0.1 lux due to the implementation cost concerns for the apparatuses and due to the fact that robotic cameras are less sensitive than human eyes, such that any darkness below 0.1 lux would not make a difference in the cameras' functioning. It is recognized that the environments in real applications may be darker than the specified test condition.

6.3 A stopwatch shall be provided to measure the timing performance.

7. Hazards

7.1 Besides 1.4, which addresses the human safety and health concerns, users of the standard shall also address the equipment preservation concerns and human robot coexistence concerns.

NOTE 4—A test sponsor has the authority to decide the environmental conditions under which this test is to be conducted. Such conditions can be stressful not only to the humans but also to the robots, such as high or low temperatures, excessive moisture, and rough terrains that can damage the robotic components or cause unexpected robotic motions.

8. Calibration and Standardization

8.1 The robot configuration as tested shall be described in detail on the test form, including all subsystems and components and their respective features and functionalities. The configuration shall be subjected to all the test suites, as defined in 3.2.12, as appropriate. Any variation in the configuration shall cause the resulting robot variant to be retested across all the test suites to provide a consistent and comprehensive representation of the performance. Practice E2592 shall be used to record the robotic configuration.

8.2 Once a robot begins a test, by starting executing the task as specified in 4.1, the robot shall be teleoperated to perform the task for the specified number of repetitions through completion without leaving the apparatus. During the process, the robot shall not be allowed to have the energy/power source replenished nor shall the robot be allowed any human physical

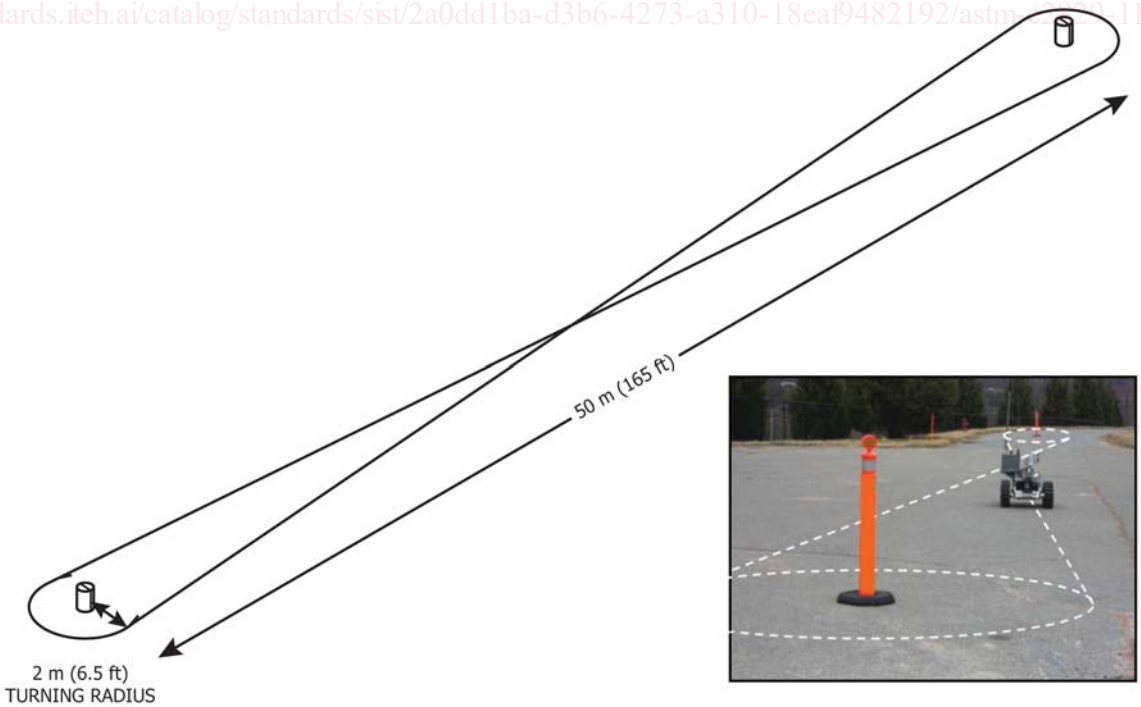

FIG. 2 Mobility: Maneuvering Tasks: Sustained Speed Apparatus (Perspective View)