Designation: E2828/E2828M – 20

Standard Test Method for Evaluating Response Robot Mobility Using Symmetric Stepfields Terrains[1]

This standard is issued under the fixed designation E2828/E2828M; 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.

INTRODUCTION

The robotics community needs ways to measure whether a particular robot is capable of performing specific missions in complex, unstructured, and often hazardous environments. These missions require various combinations of elemental robot capabilities. Each capability can be represented as a test method with an associated apparatus to provide tangible challenges for various mission requirements and performance metrics to communicate results. These test methods can then be combined and sequenced to evaluate essential robot capabilities and remote operator proficiencies necessary to successfully perform intended missions.

The ASTM International Standards Committee on Homeland Security Applications (E54) specifies these standard test methods to facilitate comparisons across different testing locations and dates for diverse robot sizes and configurations. These standards support robot researchers, manufacturers, and user organizations in different ways. Researchers use the standards to understand mission requirements, encourage innovation, and demonstrate break-through capabilities. Manufacturers use the standards to evaluate design decisions, integrate emerging technologies, and harden systems. Emergency responders and soldiers use them to guide purchasing decisions, align deployment expectations, and focus training with standard measures of operator proficiency. Associated usage guides describe how these standards can be applied to support various objectives.

Several suites of standards address these elemental capabilities including maneuvering, mobility, dexterity, sensing, energy, communications, durability, proficiency, autonomy, and logistics. This standard is part of the Mobility Suite of test methods.

1. Scope

1.1 This test method is intended for remotely operated ground robots operating in complex, unstructured, and often hazardous environments. It specifies the apparatuses, procedures, and performance metrics necessary to measure the capability of a robot to traverse complex terrains in the form of symmetric stepfields. This test method is one of several related mobility tests that can be used to evaluate overall system capabilities.

1.2 The robotic system includes a remote operator in control of all functionality, so an onboard camera and remote operator display are typically required. Assistive features or autonomous behaviors that improve the effectiveness or efficiency of the overall system are encouraged.

1.3 Different user communities can set their own thresholds of acceptable performance within this test method for various mission requirements.

1.4 *Performing Location*—This test method may be performed anywhere the specified apparatuses and environmental conditions can be implemented.

1.5 *Units*—The International System of Units (SI Units) and U.S. Customary Units (Imperial Units) are used throughout this document. They are not mathematical conversions. Rather, they are approximate equivalents in each system of units to enable use of readily available materials in different countries. This avoids excessive purchasing and fabrication costs. The differences between the stated dimensions in each system of units are insignificant for the purposes of comparing test method results, so each system of units is separately considered standard within this test method.

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[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.

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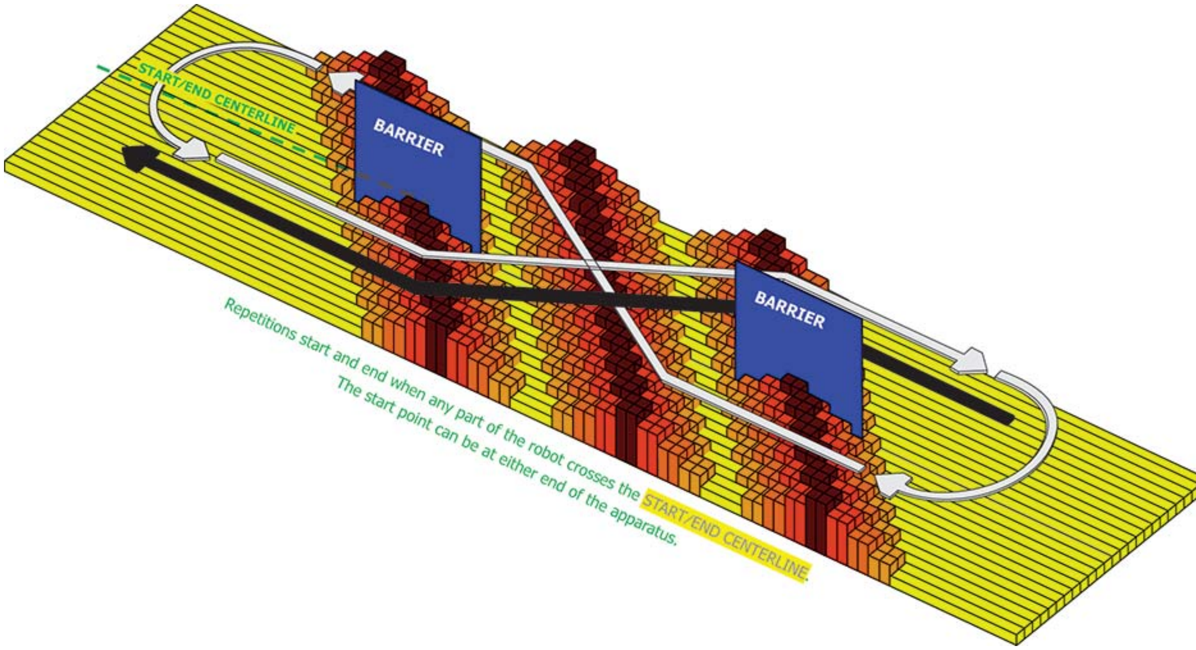


FIG. 1 Overview of the Symmetric Stepfield Terrain Apparatus

1.6 *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.*

1.7 *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

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 2.04[4]

3. Terminology

3.1 *Definitions*—The following terms are used in this test method and are defined in Terminology E2521: *abstain*, *administrator* or *test administrator*, *emergency response robot* or *response robot*, *fault condition*, *operator*, *operator station*, *remote control*, *repetition*, *robot*, *teleoperation*, *test event* or *event*, *test form*, *test sponsor*, *test suite*, *testing target* or *target*, *testing task* or *task*, and *trial* or *test trial*.

3.2 The following terms are used in this test method and are defined in ALFUS Framework Volume I:3: *autonomous*, *autonomy*, *level of autonomy*, *operator control unit (OCU)*, and *semi-autonomous*.

4. Summary of Test Method

4.1 This test method is performed by a remote operator controlling the robot out of sight and sound of robot within the test apparatus. The robot follows one of two defined paths in the specified terrain requiring the robot to overcome challenges including pitch, roll, traction, and turning on uneven surfaces within open or confined spaces.

4.2 *The Figure-8 Path (forward)* is a continuous forward path through the terrain with alternating left and right turns to avoid barriers. It can be used to demonstrate terrain traversal over long distances within a relatively small apparatus. The continuous traverse is shown as the white path (see Fig. 1 and Fig. 2).

4.3 *The Zig-Zag Path (forward/reverse)* is an end-to-end path that requires forward and reverse traversal through the terrain with alternating left and right turns to avoid barriers. This can be used to demonstrate traversal of the terrain within confined spaces. The down-range traverse, shown as the white path, is performed in a forward orientation and the up-range traverse, shown as the black path, is performed in reverse (see Fig. 1 and Fig. 3).

4.4 The robot starts on one side or the other of a lane full of fabricated symmetric stepfield terrain at a chosen scale. The robot follows either the figure-8 path (forward) or the zig-zag

[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.

[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.

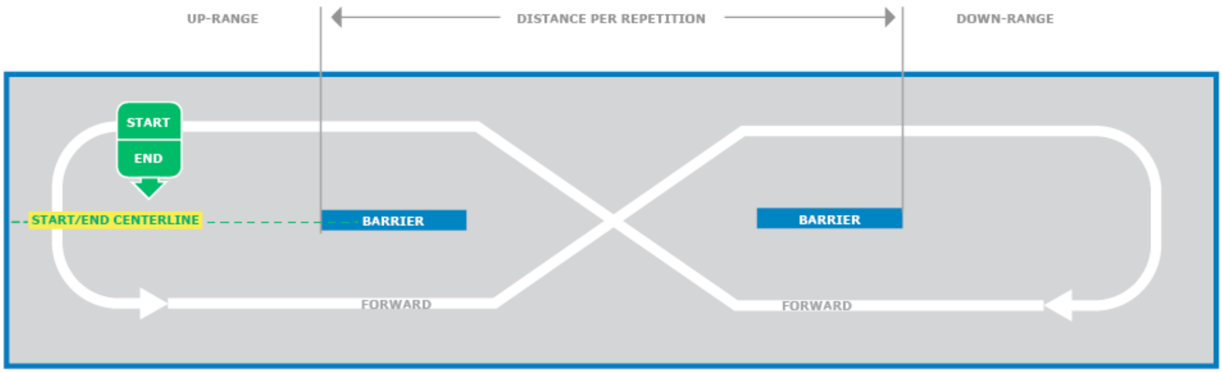
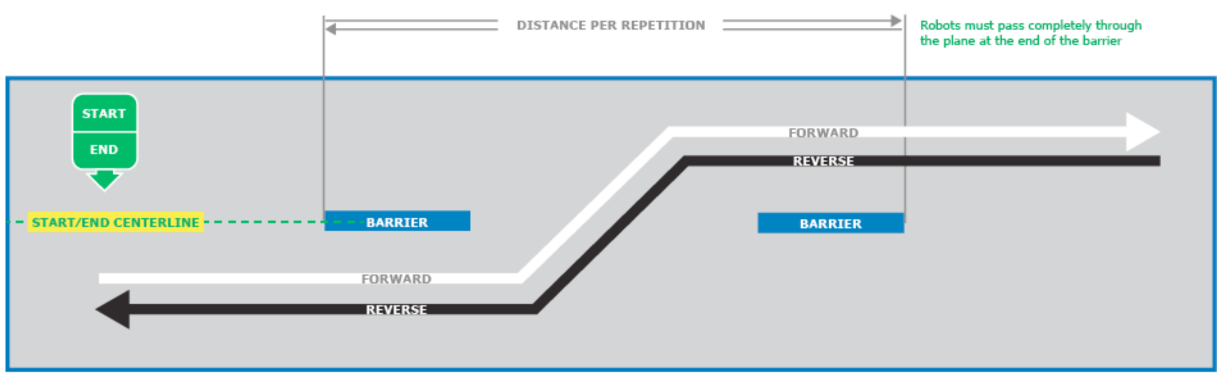


Figure-8 repetitions start and end when any part of the robot crosses the START/END CENTERLINE and approximately follows the white path. Returning to the start position completes one repetition. The distance traversed is measured from the outer edges of both barriers. (Note: The start point can be at either end of the apparatus.)

FIG. 2 Top View Showing the Figure-8 Path (Forward) Defined by the Barriers



Zig-Zag repetitions start and end when any part of the robot crosses the START/END CENTERLINE and approximately follows the white and black paths. Each repetition completes alternating forward and reverse turns past the ends of the barriers. The distance traversed is measured from one end of the apparatus to the other. The traversal length of the robot beyond the barriers is disregarded because of various size robots. (Note: The start point can be at either end of the apparatus.)

FIG. 3 Top View Showing the Zig-Zag Path (Forward/Reverse) Defined by the Barriers

path (forward/reverse) between the two barriers. The figure-8 path (forward) repetition is completed when the robot crosses the start/end centerline of the lane without a fault after approximately following the white path. The zig-zag path (forward/reverse) repetition is completed when the robot crosses the start/end centerline without a fault after approximately following the white and black paths.

4.5 *Potential Faults Include:*

4.5.1 Any contact by the robot with the apparatus that requires adjustment or repair to return the apparatus to the initial condition;

4.5.2 Any visual, audible, or physical interaction that assists either the robot or the remote operator;

4.5.3 Leaving the apparatus during the trial.

4.6 Test trials shall produce enough successful repetitions to demonstrate the reliability of the system capability or the remote operator proficiency. A complete trial of 10 to 30 repetitions in either one of the defined paths should take 10 to 30 min to complete. When measuring system capabilities, it is important to allow enough time to capture a complete trial with an expert operator. When measuring operator proficiency, it is important to limit the time of the trial so that novice and expert operators are similarly fatigued.

4.7 There are three metrics to consider when calculating the results of a test trial. They should be considered in the following order of importance: completeness score, reliability, and efficiency. The results from the figure-8 path (forward) and the zig-zag path (forward/reverse) are not comparable because they measure different capabilities. The results from different scales of test apparatus are also not comparable because they represent different clearances and distances.

5. Significance and Use

5.1 This test method is part of an overall suite of related test methods that provide repeatable measures of robotic system mobility and remote operator proficiency. This symmetric stepfield terrain specifically challenges robotic system locomotion, suspension systems to maintain traction, rollover tendencies, self-righting in complex terrain (if necessary), chassis shape variability (if available), and remote situational