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# Standard Test Method for Evaluating Ground Robot Capabilities and Remote Operator Proficiency: Terrains: K-Rails[1]

This standard is issued under the fixed designation E3349/E3349M; 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 Terrain 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 k-rails. This test method is one of several related Terrain 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 (a.k.a. SI Units) and U.S. Customary Units (a.k.a. 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

[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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of comparing test method results, so each system of units is separately considered standard within this test method.

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:*

NIST Special Publication 1011–I–2.0 Autonomy Levels for Unmanned Systems (ALFUS) Framework, Volume 1: Terminology, Version 2.04[3]

## 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*.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *apparatus clearance width (W), n*—a specification for the apparatus dimensions chosen from one of four possible measurements, based on the intended robot deployment environment:

240 cm ± 2.5 cm tolerance [96 in. ± 1 in. tolerance], such as open and outdoor public spaces;

120 cm ± 2.5 cm tolerance [48 in. ± 1 in. tolerance], such as indoor spaces in accessibility-compliant buildings;

60 cm ± 1.3 cm tolerance [24 in. ± 0.5 in. tolerance], residences and aisles of public transportation;

30 cm ± 1.3 cm tolerance [12 in. ± 0.5 in. tolerance], cluttered indoor spaces, ductwork, and voids in collapsed structures.

3.3.1.1 *Discussion*—The measures for these scales are nominal and do not represent the measurement of the narrowest point in the apparatus through which the robot should pass. Consult Section 6 for the overall measurements and dimensions of the apparatus at each scale.

3.3.2 *cross-over slope, n*—an optional test configuration that augments the center of the terrain apparatus which positions two portions of terrain on adjacent slopes of 15° in opposite directions.

3.3.3 *diagonal rail, n*—a solid piece of dimensional lumber that is sized to fit horizontally inside a subfloor at a 45° angle to the direction of travel.

3.3.4 *subfloor, n*—an underlayment of Oriented Strand Board (OSB) or similar material with dimensional lumber borders used to affix multiple subfloors to one another and can contain apparatus elements such as terrains or obstacles.

## 4. Summary of Test Method

4.1 This test method is performed by a remote operator, out of sight and sound of the robot, while controlling the 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 control of variable chassis shape and articulators 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 Figs. 1 and 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 k-rail terrain at a chosen scale. The robot follows either the figure-8 path (forward) or the zig-zag 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; and

4.5.3 Leaving the apparatus during the trial.

4.6 By default, the terrain apparatus is fabricated such that it is not inclined and sits flat on the ground. An optional configuration of this test method is available wherein a

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