Designation: E3408/E3408M – 25a

Standard Test Methods for Evaluating Ground Response Robot Capabilities: Dexterity: Inspect[1]

This standard is issued under the fixed designation E3408/E3408M; 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 *dexterity* suite of test methods.

1. Scope

1.1 These test methods are intended for remotely operated ground robots operating in complex, unstructured, and often hazardous environments. They specify the apparatuses, procedures, and performance metrics necessary to measure the capability of a robot to dexterously inspect objects of interest in the environment at various heights, depths, orientations, and confinement. This standard is one of several related dexterity tests that can be used to evaluate overall system capabilities. Three test methods are included in this standard: linear dexterity, omni-directional dexterity, and combination dexterity. All test methods use the same apparatus components (Section 6), pose the same hazards (Section 7), use the same procedure (Section 8), the same precision and bias (Section 9), and the same keywords (Section 16). The combination dexterity test method uses additional apparatus components (Section 10), has its own metrics (Section 11), and report (Section 12). The linear dexterity and omni-directional dexterity test methods use additional apparatus components (Section 13), their own metrics (Section 14), and report (Section 15). Appendix X2 contains example filled out report forms for all test methods.

1.2 The robotic system typically 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 may improve the effectiveness or efficiency of the overall system.

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

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

[1] These test methods are under the jurisdiction of ASTM Committee E54 on Homeland Security Applications and are the direct responsibility of Subcommittee E54.09 on Response Robots.

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1.5 *Units*—The International System of Units (SI Units) and U.S. Customary Units (Imperial Units) are used throughout this test method. 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. 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 these test methods.

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

E2566/E2566M Test Method for Evaluating Response Robot Sensing: Visual Acuity

E3132/E3132M Practice for Evaluating Response Robot Logistics: System Configuration

E3349/E3349M Test Method for Evaluating Ground Robot Capabilities and Remote Operator Proficiency: Terrains: K-Rails

2.2 *ISO Standards:*[3]

ISO 8596 Ophthalmic optics – Visual acuity testing – Standard and clinical optotypes and their presentation

3. Terminology

3.1 *Definitions*—The following terms are used in these test methods and are defined in Terminology E2521: *abstain, administrator or test administrator, emergency response robot or response robot, fault condition, operator, operator station, remote control, robot, stepfield terrain element, 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 *Definitions of Terms Specific to This Standard:*

3.2.1 *alcove, n*—a square area with walls on three of four sides whose sides are equal to the chosen apparatus clearance width (*W*).

3.2.1.1 *Discussion*—See Fig. 1.

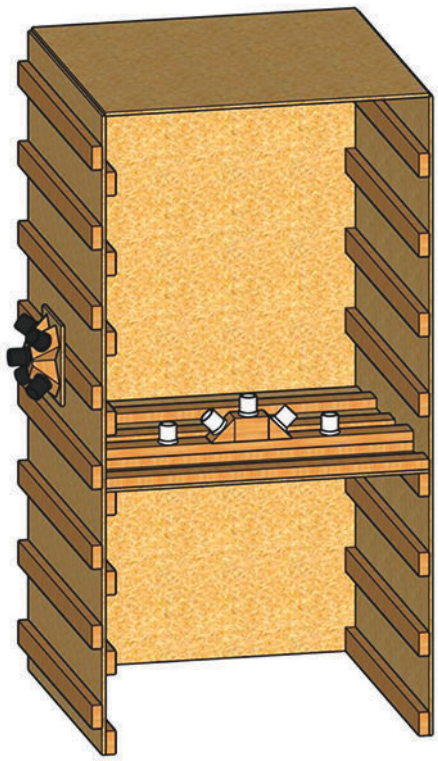

FIG. 1 Alcove Apparatus with an Omni-directional Star Mounted on the Outside Wall and a Linear Rail Mounted on Top of a Platform Inside of the Alcove

3.2.2 *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:

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

(2) 120 cm ± 2.5 cm tolerance [48 in. ± 1 in. tolerance], such as indoor spaces in accessibility-compliant buildings;

(3) 60 cm ± 1.3 cm tolerance [24 in. ± 0.5 in. tolerance], residences and aisles of public transportation; or

(4) 30 cm ± 1.3 cm tolerance [12 in. ± 0.5 in. tolerance], cluttered indoor spaces, ductwork, and voids in collapsed structures.

3.2.2.1 *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.

3.2.3 *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.

3.2.4 *Landolt C, n*—an optotype or symbol consisting of a black circle with a white gap or vice versa of specified sizes, as described in ISO 8596 and shown in Fig. 2.

3.2.4.1 *Discussion*—The outer diameter of the circle is five times the thickness (*t*) of the ring and displayed on a white or black background (opposite the color of the ring) to maximize

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

[3] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.