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Standard Test Method for Evaluating Ground Robot Capabilities and Remote Operator Proficiency: Maneuvering: Align Ground Contacts with Parallel Rails[1]

This standard is issued under the fixed designation E3310/E3310M; 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 Maneuvering 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 align its ground contacts while maneuvering across parallel rails. This test method is one of several related maneuvering tests that can be used to evaluate overall system capabilities.

1.2 The robotic system includes a remote operator in control of most functionality, so an onboard camera and remote operator display are typically required. This test method can be used to evaluate assistive or autonomous behaviors intended to improve the effectiveness or efficiency of remotely operated systems.

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. 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.

[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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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

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

2.2 *Other Standard:*

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; or

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 the Section 6 (Apparatus) for the overall measurements and dimensions of the apparatus at each scale.

3.3.2 *pallet, n*—a stackable unit with an Oriented Strand Board (OSB) top surface or similar material sized to fit inside a subfloor.

3.3.3 *parallel rails, n*—two solid pieces of dimensional lumber positioned parallel to each other with variable distance between them.

3.3.4 *subfloor, n*—an underlayment of 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 traverses through a defined area to maneuver across the parallel rails with or without walls for confinement (see Fig. 1). The separation distance between the two parallel rails is set based on the width of the robot's ground contacts to produce a narrow traversal area. This test method requires the robot to overcome challenges such as controlled movements, effective camera positioning, control of variable chassis shape and articulators, and remote situational awareness by the operator.

4.2 The robot traverses a *path* as shown in Fig. 1. The robot starts on the A-side of the apparatus, crosses to the B-side into the nearest approach area, maneuvers across the parallel rails without making contact with the ground surface to the exit area on the opposite end of the apparatus, and then crosses to the A-side to complete each repetition. All repetitions alternate directions through the apparatus.

4.3 The robot traverses the path in one of two operationally-relevant driving orientations: *unrestricted* or *forward/reverse*. *Unrestricted* allows the robot to traverse the path in any driving orientation throughout the test. *Forward/reverse* requires the robot to alternate, for each repetition, driving in forward and reverse. As repetitions also alternate directions through the apparatus, this means that the robot shall not rotate between ending one repetition and starting the next. Resulting data from the two driving orientations are not comparable to one another.

4.4 There are three apparatus configurations: *open*, *rectangular confinement*, and *square confinement*. In the *open* configuration, no walls are used around the approach/exit areas. The open configuration is representative of operating in unobstructed areas. The *rectangular confinement* and *square confinement* configurations use walls around the approach/exit areas. The walls are used to define the robot's path and are representative of operating in a confined environment. The square configuration has half of the available area as the rectangular configuration.

4.5 *Potential Faults Include:*

[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.