



Standard Test Method for Evaluating Emergency Response Robot Capabilities: Mobility: Confined Area Terrains: Continuous Pitch/Roll Ramps¹

This standard is issued under the fixed designation E2826; 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](#)) capability of traversing complex terrain composed of continuous pitch/roll ramps in confined areas.

1.1.2 Robots shall possess a certain set of mobility capabilities, including negotiating complex terrains, to suit critical operations such as emergency responses. A part of the complexity is that the environments often pose constraints to robotic mobility to various degrees. This test method specifies apparatuses to standardize a confined areas terrain that is composed of continuous pitch/roll ramps and that notionally represents types of terrains containing undulating slopes, existent in emergency response and other environments. This test method also specifies procedures and metrics to standardize testing using the apparatus.

1.1.3 The test apparatuses are scalable to provide a range of lateral dimensions to constrain the robotic mobility during task performance. [Fig. 1](#) shows three apparatus sizes to test robots intended for different emergency response scenarios.

1.1.4 Emergency response ground robots shall be able to handle many types of obstacles and terrains. 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.

1.1.5 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 continuous pitch/roll ramps terrain traversing test method is a part of the mobility test suite. [Fig. 2](#) shows examples of other

confined area terrains, along with the traversing paths. 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.

1.1.6 The mobility 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 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 and health practices and determine the applicability of regulatory limitations prior to use.*

¹ This test method is under the jurisdiction of ASTM Committee [E54](#) on Homeland Security Applications and is the direct responsibility of Subcommittee [E54.08](#) on Operational Equipment.

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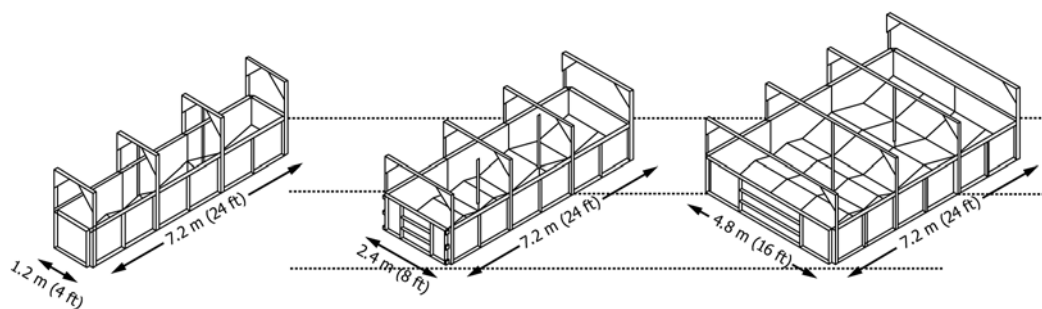


FIG. 1 Mobility: Confined Area Terrains: Continuous Pitch/Roll Ramps Apparatuses

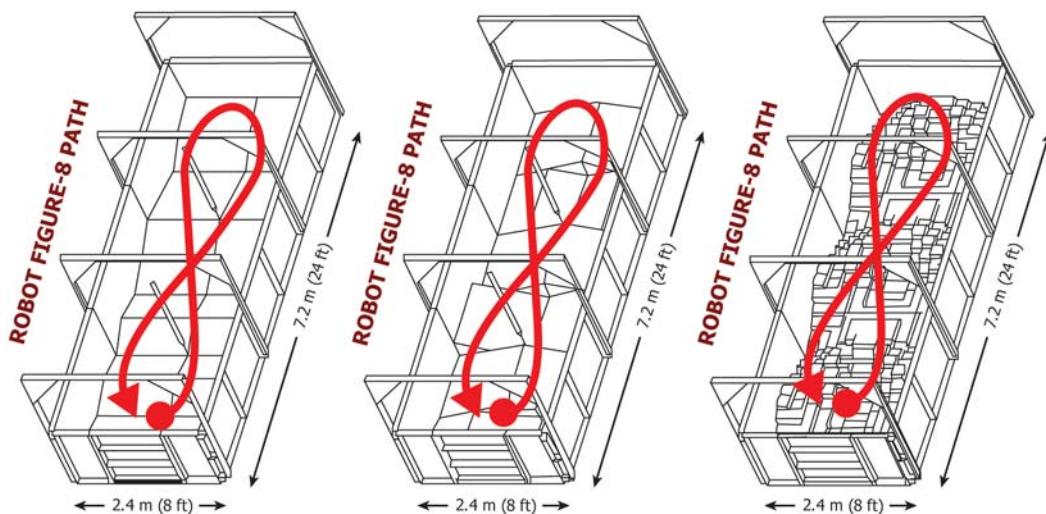
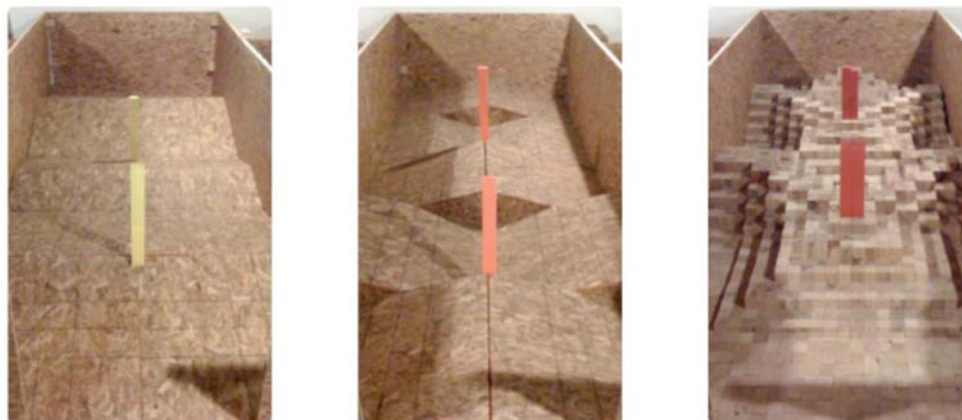


FIG. 2 Three Confined Area Terrain Apparatuses in the Mobility Test Suite with Increasing Complexity; The Continuous Pitch/Roll Ramps Terrain is Shown on the Left. The Crossing Pitch/Roll Ramps is Shown at the Center. The Symmetric Stepfields Terrain is Shown on the Right.

2. Referenced Documents

2.1 ASTM Standards:²

E2521 Terminology for Urban Search and Rescue Robotic Operations

E2592 Practice for Evaluating Cache Packaged Weight and Volume of Robots for Urban Search and Rescue

2.2 Additional Documents:

National Response Framework, U.S. Department of Homeland Security³

NIST Special Publication 1011–I–2.0 Autonomy Levels for

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/emergency>.

3. Terminology

3.1 Definitions:

3.1.1 Terminology **E2521** lists additional definitions relevant to this test method.

3.1.2 *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.

3.1.2.1 *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.

3.1.3 *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.

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

3.1.4.1 *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 stand-off distance; mobility in complex environments; sufficient hardening against harsh environments; reliable and field serviceable; durable or cost effectively disposable, or both; and equipped with operational safeguards.

3.1.5 *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. 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.

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

3.1.6 *full-ramp terrain element*, *n*—1.2 by 1.2 m (4 by 4 ft) surface ramp with 15° slope using solid wood support posts with angle cuts. The material used to build these elements shall be strong enough to allow the participating robots to execute the testing tasks.

3.1.6.1 *Discussion*—The material that is typically used to build these elements, oriented strand board (OSB) is a commonly available construction material. The frictional characteristics of OSB resemble that of dust covered concrete and other human improved flooring surfaces, often encountered in emergency responses. Solid wood posts with 10- by 10-cm (4- by 4-in) cross-section dimensions typically support the ramped surface.

3.1.6.2 *Discussion*—Similar elements like this type are used, sometimes mixed and assembled in different configurations, to create various levels of complexities for robotic functions such as orientation and traction.

3.1.7 *half-ramp terrain element*, *n*—0.6-by 1.2-m (2-by 4-ft) surface with the shorter dimension ramped at 15° using solid wood posts with angle cuts. The material used to build these elements shall be strong enough to allow the participating robots to execute the allow tasks.

3.1.7.1 *Discussion*—See the discussions under **full-ramp terrain element**.

3.1.8 *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.

3.1.8.1 *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.

3.1.9 *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.

3.1.10 *operator station*, *n*—apparatus for hosting the operator and her/his operator control unit (OCU, see ALFUS Framework Volume I: Terminology) 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.

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

⁴ Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov/customcf/get_pdf.cfm?pub_id=824705.