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.

Designation: E2830 − 11 (Reapproved 2020)

Standard Test Method for Evaluating the Mobility Capabilities of Emergency Response Robots Using Towing Tasks: Grasped Sleds[1]

This standard is issued under the fixed designation E2830; 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 towing capability with the task of grasping loads and traversing a specified route on a flat and paved surface.

1.1.2 Robots shall possess a certain set of mobility capabilities, including towing, to suit critical operations such as emergency responses. This capability would be required to perform such emergency response-related tasks as delivering critical supplies, moving victims to safe locations, or transporting suspected packages away from humans.

1.1.3 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.

1.1.4 ASTM Task Group E54.08.01 specifies a mobility test suite, which consists of a set of test methods for evaluating these mobility capability requirements. This towing-by-grasping test method is a part of the mobility test suite. 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.

1.1.5 The test methods quantify elemental mobility capabilities necessary for ground robot emergency response applications. As such, the test suite should be used collectively to represent a ground robot's overall mobility performance.

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 *Units*—The values stated in SI units are to be regarded as the standard. The values given in parentheses are mathematical conversions to inch-pound units that 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *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 Standards:*

National Response Framework U.S. Department of Homeland Security[3]

3. Terminology

3.1 Terminology E2521 lists additional definitions relevant to 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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[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.

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3.2 *Definitions:*

3.2.1 *abstain, v*—the operator's action of notifying the administrator to withdraw from the test, causing the result not to be reported and the test form to be marked as abstained.

3.2.1.1 *Discussion*—The operator is the only person who can convey the decision to abstain the test. The abstention may be made when the robot configuration is not designed nor equipped to perform the test. The testing sponsor should make a consistent policy about the time period during which the abstention is allowed. The abstention is granted only before the test, as reflected in the procedure.

3.2.1.2 *Discussion*—Being marked as abstained indicates that all the parties involved in the test acknowledge the omission of the performance data while the test method was available at the test time.

3.2.2 *administrator, n*—person who conducts the test.

3.2.2.1 *Discussion*—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.

3.2.3 *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 and such a condition is called a fault condition.

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

3.2.4 *human-scale, adj*—used to indicate that the object, a response robot or an associated target, is in a volumetric and weight scale for a human or a small team of humans to handle properly, such as carrying it using nothing more than hand tools.

3.2.4.1 *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.

3.2.5 *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 from the test.

3.2.6 *operator control unit (OCU), n*—a device used by an operator to teleoperate the robot.

3.2.7 *operator station, n*—apparatus for hosting the operator and her/his operator control unit (OCU) to teleoperate (see Terminology E2521) the robot; sight and sound insulation from the robot may be required as specified by the testing sponsor.

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

3.2.8.1 *Discussion*—In a traversing task, the entire mobility mechanism shall be behind the START point before the traverse and shall pass the END point to complete a repetition. A test method can specify returning to the START point to complete the task. Multiple repetitions, performed in the same test condition, may be used to establish the test performance to a certain degree of statistical significance as specified by the testing sponsor.

3.2.9 *test event or event, n*—a set of testing activities that are planned and organized by the test sponsor and to be held at the designated test site(s).

3.2.9.1 *Discussion*—Testing may be done with or without being associated with a test event. A testing event may be organized for particular program purposes, such as procurement or applicability study. In such a case, the program and the organization names should be considered a part of the event name. Meanwhile, a robot may also be tested for its performance record purposes independent of any particular event. A test event can also serve such additional purposes as promoting the robotic tool in a new user community and facilitating user training.

3.2.10 *test form, n*—form corresponding to a test method and contains fields for recording the testing results and the associated information, including: *(1)* Metrics and corresponding measuring scales and ranges; *(2)* Any additional testing features such as those reflecting performance proficiency; *(3)* Important notes to be recorded during the test, including particular fault conditions that occurred, the reason for abstaining, any observations by the administrator that could augment the recorded results in either positive or negative ways, or any comments that the operator requests to be put on the form; *(4)* Administrative information including: names of the involved personnel, organizations, and robot; testing date(s) and time; version number of the form; testing conditions on the environment and the apparatus; and robotic configuration (tether versus radio communication for example). If audio/video recording is done during the testing, the file names should be recorded on the form.

3.2.11 *test sponsor, n*—organization or individual that commissions a particular test event and receives the corresponding test results.

3.2.12 *test suite, n*—designed collection of test methods that are used, collectively, to evaluate the performance of a robot's particular subsystem or functionality, including mobility, manipulation, sensors, energy/power, communications, human-robot interaction (HRI), logistics, safety, and aerial or aquatic maneuvering.

4. Summary of Test Method

4.1 The task for this test method, towing by grasping, is defined as when the robot grasps either the specified sled that carries the operator-selected weight and traverses from the START post for a specified route to the END post and back fully. The default route shall be a figure eight, also known as a continuous "S" that is anchored by the two posts, as described in Section 6. See Fig. 1 for an illustration.

4.2 The robot's towing capability is defined as when the robot is able to complete the task with the associated effective speed. Further, the test sponsor can specify the statistical reliability and confidence levels of such a capability and thus dictate the number of successful task performance repetitions that are required. In such a case, the average effective speed will be used, instead, as the robot's capability.

4.3 Teleoperation shall be used from the operator station specified by the administrator to test the robots using an OCU provided by the operator. The operator station shall be positioned and implemented in such a manner so as to insulate the operator from the sights and sounds generated at the test apparatuses.

4.4 The operator is allowed to practice before the test. She/he is also allowed to abstain from the test before it is started. Once the test begins, there shall be no verbal communication between the operator and the administrator regarding the performance of a test repetition other than instructions on when to start and notifications of faults and any safety related conditions. The operator shall have the full responsibility to determine whether and when the robot has completed a repetition, and notify the administrator accordingly. However, it is the administrator's authority to judge the completeness of the repetition.

NOTE 2—Practice within the test apparatus could help establish the applicability of the robot for the given test method. It allows the operator to gain familiarity with the standard apparatus and environmental conditions. It also helps the test administrator to establish the initial apparatus setting for the test when applicable.

4.5 The test sponsor has the authority to select the test methods that constitute the test event, to select one or more test site(s) at which the test methods are implemented, to determine the corresponding statistical reliability and confidence levels of the results for each of the test methods, and to establish the participation rules including the testing schedules and the test environmental conditions.

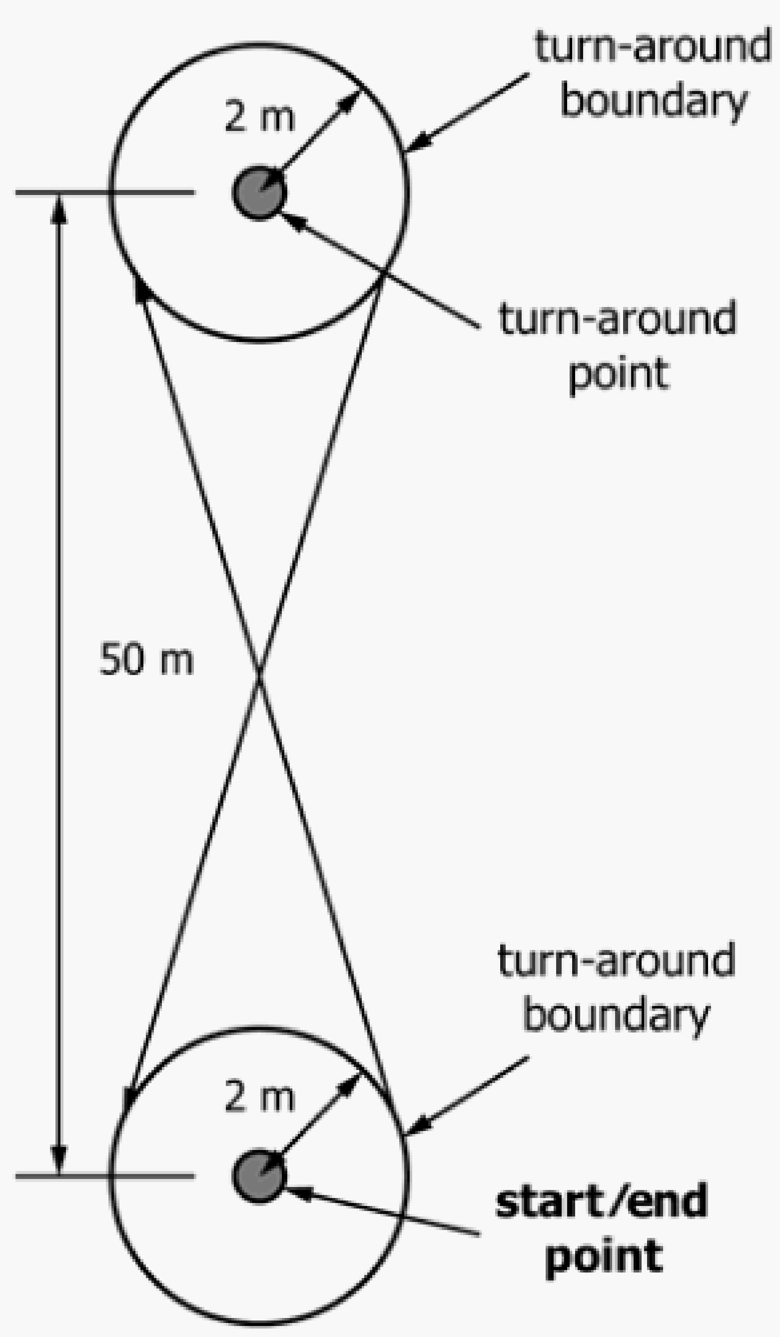


FIG. 1 Towing Apparatus

5. Significance and Use

5.1 This test method corresponds to the requirements as specified by U.S. emergency responders and additional constituents. A robot's performance in this test is indicative of its capabilities needed in such operations as emergency responses. To have the successfully tested robots available to the emergency operations is consistent with the National Response Framework.

5.2 Although these test methods were developed first for emergency response robots, they may be applicable to other operational domains, such as law enforcement and military. They can also be used to ascertain operator proficiencies during training or serve as practice tasks that exercise robot actuators, sensors, and OCUs.

5.3 The standard apparatus is specified to be easily assembled to facilitate robotic developers' self evaluation of the robots and facilitate the emergency responders' and other users' proficiency training in applying the robotic tools.

5.4 The objective of using robots in emergency response operations is to enhance the emergency responder's capability of operating in hazardous or hard-to-reach environments. The testing results of the candidate robot shall describe, in a statistically significant way, how reliably the robot is able to traverse the obstacle, thus enabling emergency responders to determine the applicability of the robot.

6. Apparatus

6.1 This test apparatus includes a flat, paved surface. Each of the START and END points is identified with a post and they are 50 m (164 ft) apart from each other. The path is a figure eight or a continuous "S" and is marked with white chalk, with the turning radius around the START and END points being a 2-m (6.5-ft) radius (Fig. 1). The effective distance for the traversing task is 100 m (328 ft) and the robot is allowed to turn around with as small a radius as it chooses.

6.1.1 The apparatus also includes a loading device for carrying the towing load and a set of weights of 2 and 11 kg (5 and 25 lb). Backpacks with weights lighter than the loading device can also be used as stand-alone towing weights when the weight of the sled itself is too heavy for some of the testing robots.

6.1.2 The loading device, such as a sled or a medical stretcher, is not standardized. Users of this test method may select a device that fit their needs with the following requirements:

6.1.2.1 Include the weight of the device as a part of the towing capability;

6.1.2.2 Use the same device for comparison purposes. Also, the test sponsor has the authority to determine whether a tow line is to be used and tied to the loading device to facilitate the grasping. Such a decision shall be applied consistently to all the robots that are to be compared against each other.

6.1.2.3 Describe the device, including the product name, model, material used, and manufacturer in the reports documenting the testing results.

6.1.2.4 This test method standardizes on the type of loading devices that cause high surface friction, including sleds and stretchers, and not wheels, which cause much lower surface friction.

NOTE 3—The towing capability for wheel-based devices can be a separate test method.

6.2 Various test conditions such as temperature extremes, darkness or other types of lighting, smoke, and rain shall be facilitated and the corresponding measuring devices, including stopwatches, shall be provided when the test sponsor requires. For example, for a test run in the dark environment, a light meter shall be used to read 0.1 lux or less. The darkness shall be re-measured when the lighting condition might have changed. The actual readings of these conditions should be recorded on the test form.

NOTE 4—The darkness is specified as 0.1 lux and not lower because of the implementation costs concerns and the fact that robotic cameras are less sensitive than human eyes to distinguish any darkness below 0.1 lux. It is recognized that the environments in real applications may be darker than the specified.

6.3 A stopwatch shall be provided to measure the timing performance.

7. Hazards

7.1 A test sponsor may specify for this test method to be conducted in adversarial environments including at high or low temperatures or in moist or wet conditions that could damage or accelerate the aging process of the robotic components, including permanently reducing the capacity of the batteries or breaking the sensors.

8. Calibration and Standardization

8.1 The configuration of the testing robot shall be fully and specifically recorded in terms of the features and functionality of all the subsystems and components, including manipulators, energy/power, communications, sensors, lights, and payloads. The configuration shall be subjected to all the test suites as appropriate. Any variation in the configuration shall cause the resulting robot variant to be retested across all the test suites to provide a consistent and comprehensive representation of the performance. Practice E2592 shall be used to record the robotic configuration.

8.2 Once a robot begins a test, by starting executing the task as specified in 4.1, the robot shall be teleoperated to traverse the entire specified path for the specified number of repetitions through completion without leaving the apparatus. During the process, the robot shall not be allowed to have the energy/power source replenished nor shall the robot be allowed any human physical intervention, including maintenance, to be repaired, tools to be relocated, or in any other way adjusted. Any such actions shall cause the robot to be retested for all the repetitions.

8.3 The first metric for this test method is whether the robot is able to grasp the load that the operator selected and complete all the repetitions of the traverse continuously as the administrator specified.

8.4 The second metric is the effective speed (metres/minutes) of the completed task execution, or average effective speed in a multiple-repetition testing situation. This metric also reflects the robot's capability and efficiency, the OCU's ease of use, and the operator's skill level.

NOTE 5—The term "effective" is used because the speed is calculated based on the designed length of the path and not on the actual trajectories of the traverses, which can deviate from the designed path.

8.5 The metrics are based on teleoperation and do not explicitly reward or punish any autonomous capabilities that a testing robot might possess. The autonomous behaviors are allowed as long as the testing procedure is specifically followed. The testing scores reflect the overall robotic performance, including the possible improvement in the robot's or the operator's performance, efficiency, or survivability due to the autonomy.

8.6 The test sponsor has the authority to specify the lighting condition, which can affect the test results.

9. Procedure

9.1 *Pre-Test Information Collection*—For data traceability and organization purposes, the administrator shall obtain and record the following testing information before the test (these items are listed at the top and the bottom of the test form in Fig. 2):

9.1.1 *Date*—Testing date; some test methods, when explicitly specified, can allow the tasks or repetitions to be distributed into multiple days; the time-of-the-day information may also be included.

9.1.2 *Facility*—Name of laboratory or field where the test is to be conducted.

9.1.3 *Location*—Names of campus, city, and state in which the facility is located.

9.1.4 *Event*—See 3.2.9. This field shall be recorded as general when a robot is tested for its performance record purposes independent of any particular event.

9.1.5 *Robot*—Name and model number, including any extension or remark, to fully identify the particular configuration of the robot as tested.

9.1.6 *Developer or Organization*—Name of the developer of the robot and the contact information.

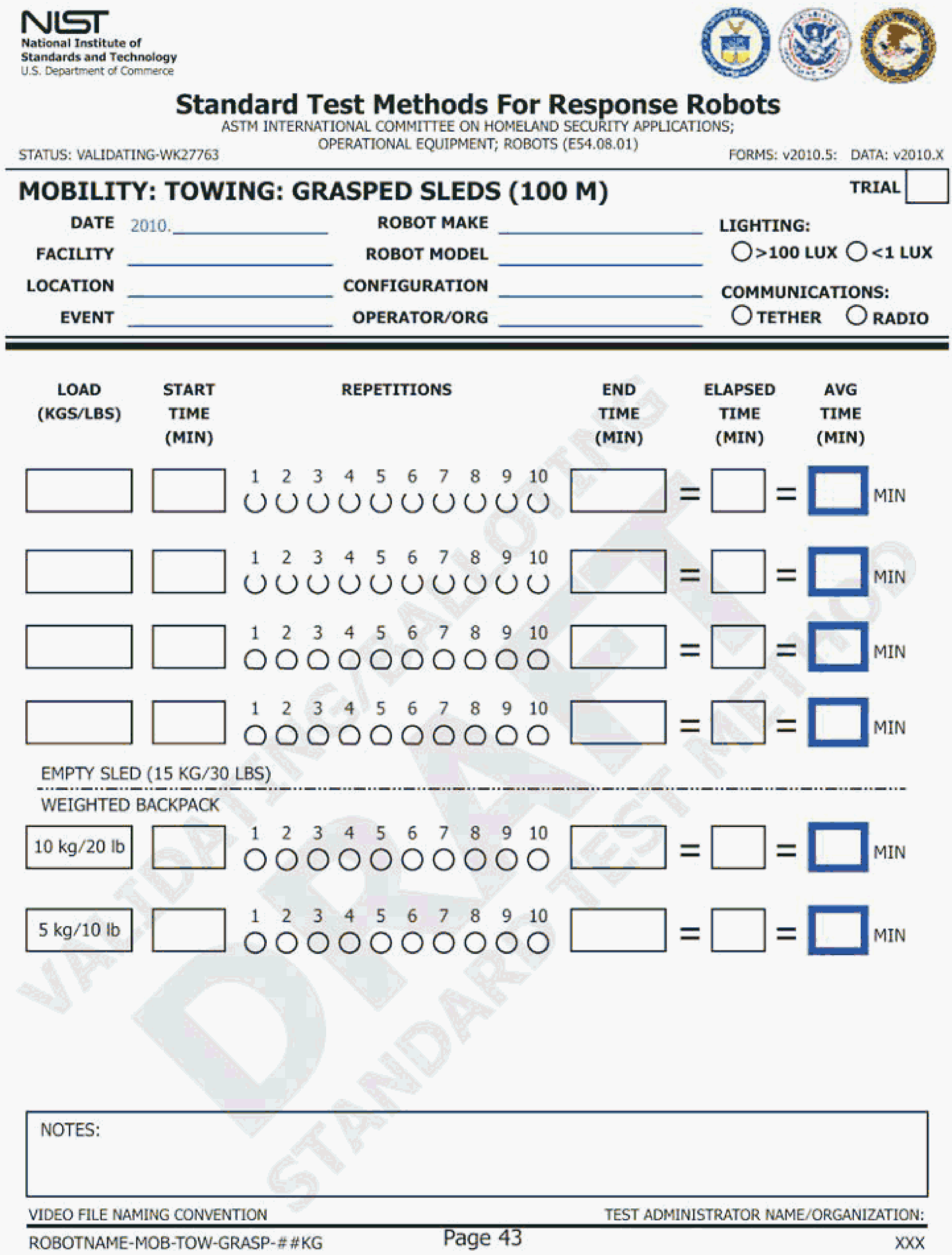
9.1.7 *Operator*—Name of the person who will teleoperate the robot for the testing.

9.1.8 *Organization*—Name of the organization with which the operator is associated; it could be the developer or the custodian of the robot. Also provide the contact information.

9.1.9 *Lighting*—Conditions under which the test will be conducted; the test sponsor can specify the lighting condition.

9.1.10 *Communication*—State whether the robot is using radio, tether, or combined to run the test.

9.1.11 *Trial Number*—In a numerical sequence, record the particular time for which the robot is to be tested with the test method.



NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Standard Test Methods For Response Robots
ASTM INTERNATIONAL COMMITTEE ON HOMELAND SECURITY APPLICATIONS;
OPERATIONAL EQUIPMENT; ROBOTS (E54.08.01)

STATUS: VALIDATING-WK27763 FORMS: v2010.5: DATA: v2010.X

MOBILITY: TOWING: GRASPED SLEDS (100 M) TRIAL

DATE 2010.____ ROBOT MAKE ____ LIGHTING:
FACILITY ____ ROBOT MODEL ____ ○>100 LUX ○<1 LUX
LOCATION ____ CONFIGURATION ____ COMMUNICATIONS:
EVENT ____ OPERATOR/ORG ____ ○TETHER ○RADIO

LOAD (KGS/LBS)	START TIME (MIN)	REPETITIONS	END TIME (MIN)	ELAPSED TIME (MIN)	AVG TIME (MIN)
		1 2 3 4 5 6 7 8 9 10		=	= MIN
		1 2 3 4 5 6 7 8 9 10		=	= MIN
		1 2 3 4 5 6 7 8 9 10		=	= MIN
		1 2 3 4 5 6 7 8 9 10		=	= MIN
EMPTY SLED (15 KG/30 LBS)					
WEIGHTED BACKPACK					
10 kg/20 lb		1 2 3 4 5 6 7 8 9 10		=	= MIN
5 kg/10 lb		1 2 3 4 5 6 7 8 9 10		=	= MIN

NOTES:

VIDEO FILE NAMING CONVENTION: ROBOTNAME-MOB-TOW-GRASP-##KG
Page 43
TEST ADMINISTRATOR NAME/ORGANIZATION: XXX

FIG. 2 Test Form Implementation

NOTE 6—If a robot is tested for the first time, the trial number is 1 when the results are recorded. Some time later, in either the same or a different test event, if the robot is tested again, the trial number is 2 when the results are recorded, on a separated test form.

9.1.12 *Administrator*—Name, organization, and contact information.

9.1.13 Additional information such as the naming convention for the performance-capturing video files is provided at the bottom of the form.

9.2 *Testing Procedure:*

9.2.1 The operator either abstains or proceeds with the test. The abstention shall not be granted after this point.

9.2.2 The administrator announces the number of repetitions to be performed.

9.2.3 The administrator sets and verifies the test environmental condition (for example, lighting, temperature, etc).

9.2.4 The operator places the robot at the START position, which is at the right-hand side of the START post (Fig. 1), and facing the END post.

9.2.5 The operator chooses the load to be grasped, either the loading device and the optional, additional weights or a specified backpack. Administrator notes the entire load on the test form.

9.2.6 The administrator instructs the operator to begin the task, starts the timer when the operator begins, and records the total elapsed time.

9.2.7 The operator controls the robot to perform the task and complete one repetition. The administrator records the results on the test form. If the robot fails to complete the task, the test ends and the administrator records the result accordingly.

9.2.8 In the multiple-repetition testing situation, without stopping, the operator controls the robot and repeats 9.2.7 until all repetitions are completed or until any of the fault conditions, given in 9.3, occurs.

9.2.9 Upon success, the operator has the option of selecting a heavier load and repeating 9.2.5 – 9.2.8.

9.2.10 Note on the test form the task completion with the heaviest load as the robot's towing capability.

9.3 *Fault Conditions*—The following are the conditions that cause the test to end:

9.3.1 Failure to traverse the route as specified or to complete the specified number of repetitions continuously and without operator intervention, including when caused by component failure;

9.3.2 Determination by the operator that the task can not be completed successfully; and

9.3.3 Failure to follow the teleoperation requirements as specified in 8.1.

10. Report

10.1 A test form, as defined in 3.2.10, is required for this test method. The form shall reflect the purpose, metrics, apparatus, and procedure of this test method and allow recording both the testing information, as described in 9.1, and the test results. The test form shall be filled out completely. In the situation where a field is not applicable, it shall be noted as such.

10.2 The entire test form shall be filled out using the following designations to indicate the testing results:

10.2.1 *Not Tested*—The scoring section of the test form shall be left blank. The notes section shall record the reason(s) for not testing, such as:

10.2.1.1 The test method was not available during testing time, including the apparatus cannot be properly set up, uncontrollable environmental conditions, or scheduling difficulties.

10.2.1.2 The robot is not equipped for the test while the test method is applicable for the robot's operating domain, for example, when a ground robot does not have an arm to perform a manipulation test. The operator can also elect to abstain in this situation.

10.2.1.3 The test method is not applicable to the robot, for example, a ground robot test method is not applicable to an aerial robot.

10.2.1.4 The robot has failed at certain repetition of the test, which caused the test to end and the remaining slots on the test form to be left blank.

10.2.2 *Abstained*—A red stamp to the effect is printed on the lower corner on the right-hand side.

10.2.3 *Success*—The corresponding reporting spot, typically a checking circle, is painted in solid blue.

10.2.4 *Tested but Failed*—The corresponding reporting spot, typically a checking circle, is painted in solid red. An additional black cross can be drawn in the circle to facilitate black-and-white printed reports.

10.2.5 *Test Results Accepted but Retest Is Desired*—The corresponding reporting spot, typically a checking circle, is painted in orange. An additional horizontal black bar can be drawn inside the circle to facilitate black-and-white printed reports. This designation is used when the test apparatus is becoming unavailable soon (the facility is closing, a thunderstorm is approaching, etc.) during the task performance such that the repetitions during which minor errors occurred are marked in the orange color in the interest of time, enabling the test to continue through completion. This can also be used when the errors occur at certain steps or certain measures of the test method that are being evolved for a future version.

10.3 Fig. 2 is an implementation of the test form. Multiple copies can be used as needed when the specified number of repetitions is higher than ten. Note that users may implement their own test forms that meet the requirements.

11. Precision and Bias

11.1 *Precision:*

11.1.1 Table 1 provides a set of testing results for a representative collection of the participating human-scale robots.

NOTE 7—The towing device itself is not standardized. This successful testing demonstrates that the selected sled is suitable for this test method. However, the application does not imply that the sled is necessarily the best available for the testing purposes. A search, such as on the internet, could yield multiple sleds or other similar types of towing devices that might be used for this test method, including stretchers that emergency responders might carry.

11.1.2 The effective distance for each repetition is 100 m (328 ft). The lighting condition was daylight. The robots, particular their mobility traction components, were verified to be in good condition for the testing. A robot was abstained because it was not equipped to perform this test. Otherwise:

11.1.2.1 The respective mobility subsystem designs and the capabilities of the required subsystems, collectively contribute to the robots' towing capabilities.

11.1.2.2 The test method properly differentiates the towing capabilities among the robots.

11.1.2.3 Overall, the results demonstrate that the specified testing apparatus and the metrics are suitable for the evaluation of the human-scale robots being considered for emergency response operations and many other types of critical operations.

NOTE 8—A higher towing capability probably indicates that the robot has a more effective mobility subsystem and more sustainable power/energy subsystem.

11.1.3 A robot's reliability (R) of performing the traversing task and the associated confidence (C) shall be established. The required R and C values dictate the required number of successful repetitions and the allowed number of failures.

TABLE 1 Testing Results[A]

RID	WT (kg)	Average Effective Speed (m/min) over 10 Continuous Repetitions of Successful Traverses
I	<15	ABS
II	16–35	23
III	46–65	18

[A] Key: RID = robot ID; WT = weight category; ABS = abstained.

More successes will be needed when more failures are allowed. This test method specifies the default required values for R and C as 80 % for both. The following four are among the satisfying combinations for the numbers of successes and failures:

11.1.3.1 Eight successful traverses of the specified route and no failure,

11.1.3.2 Fifteen successful traverses of the specified route and one failure,

11.1.3.3 Twenty-one successful traverses of the specified route and two failures, and

11.1.3.4 Twenty-eight successful traverses of the specified route and three failures.

11.1.4 In other words, any of the four combinations can be selected to result in the sufficient number of successful repetitions and the allowable number of failures. Additional combinations can be developed for use from the applicable statistical principles.

11.1.5 The test results of ten successes and zero failures exceeds the eight success criteria as specified in 11.1.3.1, thus exceeds the default requirements on the statistical reliability and confidence levels.

11.1.6 This test method strives to cope quantitatively with human-scale entities involved in possibly multiple-day long operations, kilometre-range long distances, and disparate frictional surfaces. While statistical methods might be able to be developed to interpolate the traversing capability to smaller increments, those are considered too fine for the operational conditions and are, thus, out of the scope of this testing approach. For the same reason, this test method does not require the R and C values to the fraction level.

11.1.7 The test sponsor has the authority to specify other R and C values. A good balance should be struck between testing costs and reliability.

11.1.8 As specified in Section 1, it is recommended that users of this test method consider the scope of the test as it applies to their own projects. Performance in this test method alone shall not be considered as the collective indication of the performance of the robot's mobility subsystem nor of the entire robotic system.

11.2 *Bias:*

11.2.1 One variable that was found typically to introduce a bias was the operator's familiarity with the test method. The operator's performance was typically lowest when she/he did not have prior practice. The performance typically improved to a stable level once the operator practiced sufficiently.

11.2.1.1 There are additional human factors that can introduce biases, including the skill level, fatigue level, and level of concentration of the operator. An operator who obtained proper training and possessed abundant field experiences could perform at a higher level, particularly when all the robotic capability was fully exercised. Therefore, it is recommended for the vendor or developer of a robot to designate an expert operator to obtain the performance for the robot.

11.2.2 Onboard sensing capability can affect the task performance. The range(s) and the field of view of the camera(s) can affect how the operator is able to see the test apparatus and control the robot accordingly. Lighting conditions can also affect the performance.

12. Measurement Uncertainty

12.1 Proper use of this test method to measure the traversing time will result in an uncertainty of less than the specified unit, or 1 m (3.3 ft) as well as one half of the towing weight increment, or 1 kg (2.2 lb). Subsection 11.1.6 specifies that finer resolutions are insignificant for this test method.

13. Keywords

13.1 abstain; emergency responder; emergency response; grasp; human-scale; mobility; OCU; operator control unit; operator station; repetition; robot; test suite; tow; urban search and rescue; US&R

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