Designation: E2855 − 12 (Reapproved 2021)

Standard Test Method for Evaluating Emergency Response Robot Capabilities: Radio Communication: Non-Line-of-Sight Range[1]

This standard is issued under the fixed designation E2855; 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 radio communication test methods, is to quantitatively evaluate a teleoperated robot's (see Terminology E2521) capability to perform maneuvering and inspection tasks in a non-line-of-sight environment.

1.1.2 Robots shall possess a certain set of radio communication capabilities, including performing maneuvering and inspection tasks in a non-line-of-sight environment, to suit critical operations for emergency responses. The capability for a robot to perform these types of tasks in obstructed areas down range is critical for emergency response operations. This test method specifies a standard set of apparatuses, procedures, and metrics to evaluate the robot/operator capabilities for performing these tasks.

1.1.3 Emergency response robots shall be able to operate remotely using the equipped radios in line-of-sight environments, in non-line-of-sight environments, and for signal penetration through such impediments as buildings, rubbles, and tunnels. Additional capabilities include operating in the presence of electromagnetic interference and providing link security and data logging. Standard test methods are required to evaluate whether candidate robots meet these requirements.

1.1.4 ASTM E54.08.01 Task Group on Robotics specifies a radio communication test suite, which consists of a set of test methods for evaluating these communication capabilities. This non-line-of-sight range test method is a part of the radio communication 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 This test method establishes procedures, apparatuses, and metrics for specifying and testing the capability of radio (wireless) links used between the operator station and the testing robot in a non-line-of-sight environment. These links include the command and control channel(s) and video, audio, and other sensor data telemetry.

1.1.6 This test method is intended to apply to ground based robotic systems and small unmanned aerial systems (sUAS) capable of hovering to perform maneuvering and inspection tasks down range for emergency response applications.

1.1.7 This test method specifies an apparatus that is, first of all, an essentially clear radio frequency channel for testing. In addition, a standard line-of-sight barrier between the testing operator control unit (OCU) and the robot is specified. Fig. 1 provides an illustration.

NOTE 1—Frequency coordination and interoperability are not addressed in this standard. These issues should be resolved by the affected agencies (Fire, Police, and Urban Search and Rescue) and written into Standard Operating Procedures (SOPs) that guide the responses to emergency situations.

1.1.8 The radio communication test suite quantifies elemental radio communication capabilities necessary for robots intended for emergency response applications. As such, based on their particular capability requirements, users of this test suite can select only the applicable test methods and can individually weight particular test methods or particular metrics within a test method. The testing results should collectively represent an emergency response robot's overall radio communication capability. These test results can be used to guide procurement specifications and acceptance testing for robots intended for emergency response applications.

NOTE 2—As robotic systems are more widely applied, emergency responders might identify additional or advanced robotic radio communication capability requirements to help them respond to emergency situations. They might also desire to use robots with higher levels of autonomy, beyond teleoperate onto help reduce their workload—see NIST Special Publication 1011-II-1.0. Further, emergency responders in expanded emergency response domains might also desire to apply robotic technologies to their situations, a source for new sets of requirements. As a result, additional standards within the suite would be developed. This standard is, nevertheless, standalone and complete.

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] 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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Left: The non-line-of-sight range test method uses an airstrip or flat, paved road with robot test stations placed in front of and behind a wall constructed of stacked 12 m (40 ft) International Standards Organization (ISO) shipping containers. Right: Robot test stations are prototyped behind the wall with targets on the barrels for visual inspection tasks and circular paths for maneuvering tasks.

FIG. 1 Test Fabrication at An Air Strip

1.3 *Units*—The values stated in SI units shall be 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 facilitate testing but 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 *Additional Documents:*

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

NIST Special Publication 1011-I-2.0 Autonomy Levels for Unmanned Systems (ALFUS) Framework Volume I: Terminology, Version 2.0[4]

NIST Special Publication 1011-II-1.0 Autonomy Levels for Unmanned Systems (ALFUS) Framework Volume II: Framework Models, Version 1.0[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *abstain, v*—the action of the manufacturer or designated operator of the testing robot choosing not to enter the test. Any decision to take such an action shall be conveyed to the administrator 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.

3.1.1.1 *Discussion*—Abstentions may occur when the robot configuration is neither designed nor equipped to perform the tasks as specified in the test method. Practices within the test apparatus prior to testing should allow for establishing the applicability of the test method for the given robot.

3.1.2 *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 the test and record the performance data and any notable observations during the test.

3.1.3 *emergency response robot, or response robot, n*—a remotely deployed device intended to perform operational tasks at operational tempos to assist the operators to handle a disaster.

3.1.3.1 *Discussion*—A response robot is designed to serve as an extension of the operator for gaining improved remote

[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/nrf/.

[4] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov/el/isd/ks/autonomy_levels.cfm.

situational awareness and for accomplishing the tasks remotely through the equipped capabilities. The use of a robot is designed to reduce risk to 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 standoff distance; mobile in complex environments; sufficiently hardened against harsh environments; reliable and field serviceable; durable and/or cost effectively disposable; and equipped with operational safeguards.

3.1.4 *fault condition, n*—a certain situation or occurrence during testing whereby the robot either cannot continue without human intervention or has performed some defined rules infraction.

3.1.4.1 *Discussion*—Fault conditions include robotic system malfunctions such as de-tracking, task execution problems such as excessive deviation from a specified path, or uncontrolled behaviors and other safety violations which require administrative intervention.

3.1.5 *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.

3.1.5.1 *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.

3.1.6 *line-of-sight communications, n*—propagating electromagnetic energy with a direct path between a transmitting radio antenna and a receiving radio antenna which are in visual contact with each other with no obstructions between them. In the ideal case, the only paths that the radio waves can take in the line-of-sight case are either the direct path between the transmitter and receiver or a path that corresponds to a single reflection of the radio wave off of the ground before it encounters the receiving antenna.

3.1.7 *non-line-of-sight communications, n*—propagating electromagnetic energy with no direct path between a transmitting radio antenna and a receiving radio antenna which are not in visual contact with each other due to obstructions between them. Radio waves propagate between the transmitting and the receiving antennas via reflections off structures, diffraction around structures, and/or passage through structures with attenuation.

3.1.8 *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.

3.1.8.1 *Discussion*—An emergency responder would be a typical operator in emergency response situations.

3.1.9 *operator station, n*—apparatus for hosting the operator and her/his operator control unit (OCU, see NIST Special Publication 1011-I-2.0) to teleoperate (see Terminology E2521) the robot. The operator station shall be positioned in such a manner as to insulate the operator from the sights and sounds generated at the test apparatuses.

3.1.10 *radio interference, n*—adverse effect on the transfer of data when unrelated external signals are received by a robot receiver or an operator station receiver.

3.1.10.1 *Discussion*—In licensed frequency bands such as those used by the public safety community, each radio transmitter and receiver is assigned a unique frequency channel typically with limits on power emissions. Some radio systems are designed to work effectively when multiple systems operate in the same frequency band at the same time. Many of these systems can be found in the unlicensed Industrial, Scientific, and Medical (ISM) frequency bands.

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.

3.1.11.1 *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 tested capability to a certain degree of statistical significance as specified by the test sponsor.

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

3.1.13 *test form, n*—a collection of data fields or graphics used to record the testing results along with the associated information. A single test form shall not be used to record the results of multiple trials.

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

3.1.15 *test suite, n*—a 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-system interaction (HSI), logistics, safety and operating environment, and aerial or aquatic maneuvering.

3.1.16 *testing target, or target, n*—a designed physical feature to be used by the testing robotic subsystem for evaluating the subsystem capabilities. The feature may be an operationally relevant object, a notional object, or one designed specifically for exercising the subsystem features to its full extent.

3.1.17 *testing task, or task, n*—a set of activities well defined in a test method for testing robots and the operators to perform in order for the system's capabilities to be evaluated according to the corresponding metric(s). A test method may specify multiple tasks. A task corresponds to the associated metric(s).

3.1.18 *trial, n*—the number of repetitions to be performed for a test to reach required statistical significance. The repetitions may be recorded on a single test form.

3.2 Terminology E2521 lists additional definitions relevant to this test method.

4. Summary of Test Method

4.1 This test method uses remote maneuvering and inspection tasks to measure the non-line-of-sight range of a robot using its equipped radio communication system. This test method represents an obstructed propagation environment with ground effects that will be encountered by radio linked robotic systems.

4.2 The test course shall be a flat paved surface at least 1000 m (3300 ft) long by 20 m (65 ft) wide with a centerline robot path. A minimum of 50 m (165 ft) on each side of the centerline robot path shall be clear of any obstructions or reflecting objects to minimize multi-path effects.

4.3 A stacked set of six International Standards Organization (ISO) shipping containers measuring 24 m (80 ft) wide by 7 m (24 ft) tall provides a line-of-sight obstruction abutting the centerline robot path allowing the robot to turn 90° from the centerline path to perform non-line-of-sight tasks in the radio shadow of the obstruction.

4.4 Robot test stations shall be placed 100 m (330 ft) in front of the stacked ISO container obstruction along the centerline path and within line-of-sight of the operator station to establish reference radio communication functionality. Additional test station shall be placed in specified locations behind the stacked ISO container obstruction. Each test station consists of eight visual and audio targets for inspection tasks along with circular robot paths marked on the ground for maneuvering tasks.

4.5 At each test station, the robot shall perform a maneuvering task to follow the circular path to locate each of the visual and audio targets.

4.6 The visual and audio targets shall be identified using the robot's forward facing cameras, requiring the robot to face all four compass directions relative to the direction of travel to ensure there are no directionality issues with transmitting or receiving communication signals.

4.7 The robot's non-line-of-sight range capability is measured as the number of robot test stations successfully completed behind the stacked ISO container obstruction to verify the functionality of non-line-of-sight control, video and audio transmissions.

4.8 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 as to insulate the operator from the sights and sounds generated at the test apparatus.

NOTE 3—Separate, autonomous radio communications test methods will be separately specified in the future as per community requirements. This standard is, nevertheless, stand-alone and complete.

4.9 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 describing the targets as seen by the operator, 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 4—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 test method and environmental conditions. It also helps the test administrator to establish the initial apparatus setting for the test when applicable.

4.10 The test sponsor has the authority to establish the testing policy, including the robot participation, testing schedules, test site at which this test method is implemented, associated environmental conditions, the apparatus settings, and statistical reliability and confidence levels of the testing results.

5. Significance and Use

5.1 A main purpose of using robots in emergency response operations is to enhance the safety and effectiveness of emergency responders operating in hazardous or inaccessible environments. The testing results of the candidate robot shall describe, in a statistically significant way, how reliably the robot is able to perform the specified types of tasks and thus provide emergency responders sufficiently high levels of confidence to determine the applicability of the robot.

5.2 This test method addresses robot performance requirements expressed by emergency responders and representatives from other interested organizations. The performance data captured within this test method are indicative of the testing robot's capabilities. Having available a roster of successfully tested robots with associated capabilities data to guide procurement and deployment decisions for emergency responders is consistent with the guideline of "Governments at all levels have a responsibility to develop detailed, robust, all-hazards response plans" as stated in National Response Framework.

5.3 This test method is part of a test suite and is intended to provide a capability baseline for the robotic communications systems based on the identified needs of the emergency response community. Adequate testing performance will not ensure successful operation in all emergency response environments due to possible extreme communications difficulties. Rather, this standard is intended to provide a common comparison that can aid in choosing appropriate systems. This standard is also intended to encourage development of improved and innovative communications systems for use on emergency response robots.

5.4 The standard apparatus is specified to be easily fabricated to facilitate self-evaluation by robot developers and provide practice tasks for emergency responders to exercise robot actuators, sensors, and operator interfaces. The standard

A) The non-line-of-sight range test apparatus includes a reference line-of-sight robot test station 100 m (330 ft) in front of the stacked ISO container obstruction. B) Two additional such test stations are located behind the obstruction to provide non-line-of-sight tasks to perform (one target barrel placed away from the obstruction is not shown).

FIG. 2 Test Station Implementation

apparatus can also be used to support operator training to establish operator proficiency.

5.5 Although the test method was developed first for emergency response robots, it may be applicable to other operational domains, such as law enforcement and armed services.

6. Apparatus

6.1 The test apparatus is a straight, flat section of airstrip, roadway or other paved asphalt or concrete surface at least 1000 m (3300 ft) long and 20 m (65 ft) wide. It shall have no obstructions or reflective objects within at least 50 m (165 ft) on either side of the centerline.

6.2 A stacked set of six ISO containers shall form a reproducible line-of-sight obstruction measuring 24 m (80 ft) wide by 7 m (24 ft) tall abutting the centerline robot path allowing the robot to turn 90° from the centerline path to perform non-line-of-sight tasks in the radio shadow of the obstruction (see Fig. 2). Gaps between adjacent containers shall be fully covered with metal.

6.3 A robot test station, specified below, shall be placed 100 m (330 ft) in front of the stacked ISO container obstruction along the centerline within line-of-sight of the operator station as a reference to establish the radio communication functionality prior to turning behind the obstruction. Two additional test stations shall be placed in specified locations behind the stacked ISO container obstruction (see Fig. 3).

6.4 Each test station shall have two circular robot paths marked on the ground each with a 2 m (6.5 ft) radius. The circular robot paths shall be tangent to each other, with the connection point marking the measured distance downrange from the operator station. Markings on the circular paths shall show the location at which the robot must turn and face the targets to identify them.

6.5 Each test station shall have eight unique visual targets to be identified through the equipped communications channel. The visual targets shall be placed at the center of the circular robot paths facing all four compass directions (north, south, east, and west) relative to the direction of travel on the centerline path.

6.6 Each test station shall also have two audio sources to be identified through the equipped communications channel. The center of each circular robot path shall have an audio source and speaker playing a continuous series of single digit numbers for the identification task. The numbers shall be articulated using a computer-generated voice with a volume of at least 60 to 80 dB.

6.7 The operator station shall be placed at a distance away from the stacked ISO container obstruction equal to half the maximum range performed in the associated ASTM standard line-of-sight test method. A start position for the robot shall be located nearby the operator station with the same distance from the wall.

6.8 Antennas at the operator station shall be limited to a maximum of 2 m (6.5 ft) elevation above the ground.

6.9 Since this test apparatus must be fabricated outside, control over environmental variables is not strictly possible. Various test conditions such as apparatus surface types and conditions including wetness along with environmental temperature and humidity may be specified by the test sponsor and shall be noted on the test form.

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

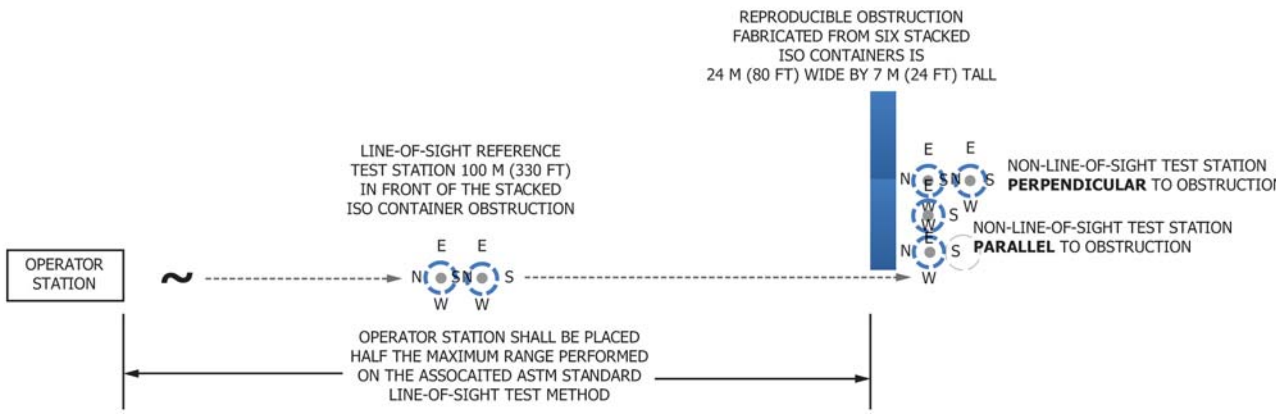
7. Hazards

7.1 Besides section 1.4 that addresses the human safety and health concerns, users of the standard shall also address the equipment preservation concerns and human-robot coexistence concerns.

NOTE 5—Adverse environmental conditions such as high or low temperatures, excessive moisture, and rough terrains can be stressful to the humans, can damage the robotic components, or can cause unexpected robotic motions.

8. Calibration and Standardization

8.1 The robot configuration as tested shall be recorded in detail on the test form, including all subsystems and components and their respective features and functionalities. The configuration shall be subjected to all the applicable test methods as determined by the test sponsor. Any variation in the



The non-line-of-sight range test apparatus includes a reference line-of-sight robot test station 100 m (330 ft) in front of the stacked ISO container obstruction and two additional robot test stations located behind the obstruction to provide non-line-of-sight tasks to perform. The operator station shall be placed half the maximum range performed in the associated ASTM standard line-of-sight test method from the stacked ISO container obstruction.

FIG. 3 Test Station

configuration shall cause the resulting robot variant to be retested across all the determined test methods to provide a consistent and comprehensive representation of the capabilities. Practice E2592 shall be used to record the robotic configuration.

8.2 Once a robot begins to be teleoperated to execute a specified task, the task shall be performed for the specified number of repetitions through completion without leaving the apparatus. During the process, any human physical intervention, including adjustment, maintenance, or repair constitutes a fault condition.

8.3 The metric for this test method is the number of non-line-of-sight test stations at which the robot completes tasks to verify the functionality of control, video, and audio transmissions.

8.4 Although the metric is based on teleoperation, autonomous behaviors are allowed as long as the testing procedure is followed, with the associated effects reflected in the testing scores. See NIST Special Publication 1011-I-2.0 for the definition of autonomy.

8.5 The test sponsor has the authority to specify the lighting condition and other environmental variables under which to test with. All environmental settings shall be noted on the test form.

8.6 A robot's reliability (R) of performing the specified task at a particular apparatus setting 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 during the test. With a given set of the R and C values, more successes will be needed when more failures are allowed. A test sponsor has the authority to specify the R and C values for her/his testing purposes. The factors to be considered in determining the values are mission requirements, consistency with the operating environments, ease of performing the required number of repetitions, and testing costs such as time and personnel. To meet the statistical significance established by the standards committee, which is 80 % reliability (probability of success) with 80 % confidence at any given setting of a test apparatus, the number of failures (incomplete repetitions or the occurrences of the fault conditions) in the specified set of repetitions shall be no more than the following:

zero failures in 8 repetitions
one failure in 16 repetitions
three failures in 32 repetitions

NOTE 6—These repetition requirements correspond to the numbers of tasks to be performed at each test station. The eight repetitive tasks configuration as specified in Sections 4 and 6 differ from many other standards that ASTM E54.08.01 specified which use 10 repetitions. As a result, the default C and R values used in this standard are different.

8.6.1 Additional repetition requirements can be calculated, if a test sponsor requires, by referring to general statistical analysis methods. In such situations, the test stations shall be redesigned so that the corresponding, different numbers of the tasks can be implemented.

9. Procedure

9.1 For data traceability and organization purposes, the administrator shall obtain and record the testing conditions and administrative information first. A set of specified fault conditions shall be followed during the test.

NOTE 7—For example, different robot models could help partially explain the differences in the test results. Different trial numbers could partially tell how much effort an operator has taken to accomplish the results.

9.2 *Testing Conditions and Administrative Information:*

9.2.1 *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.

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

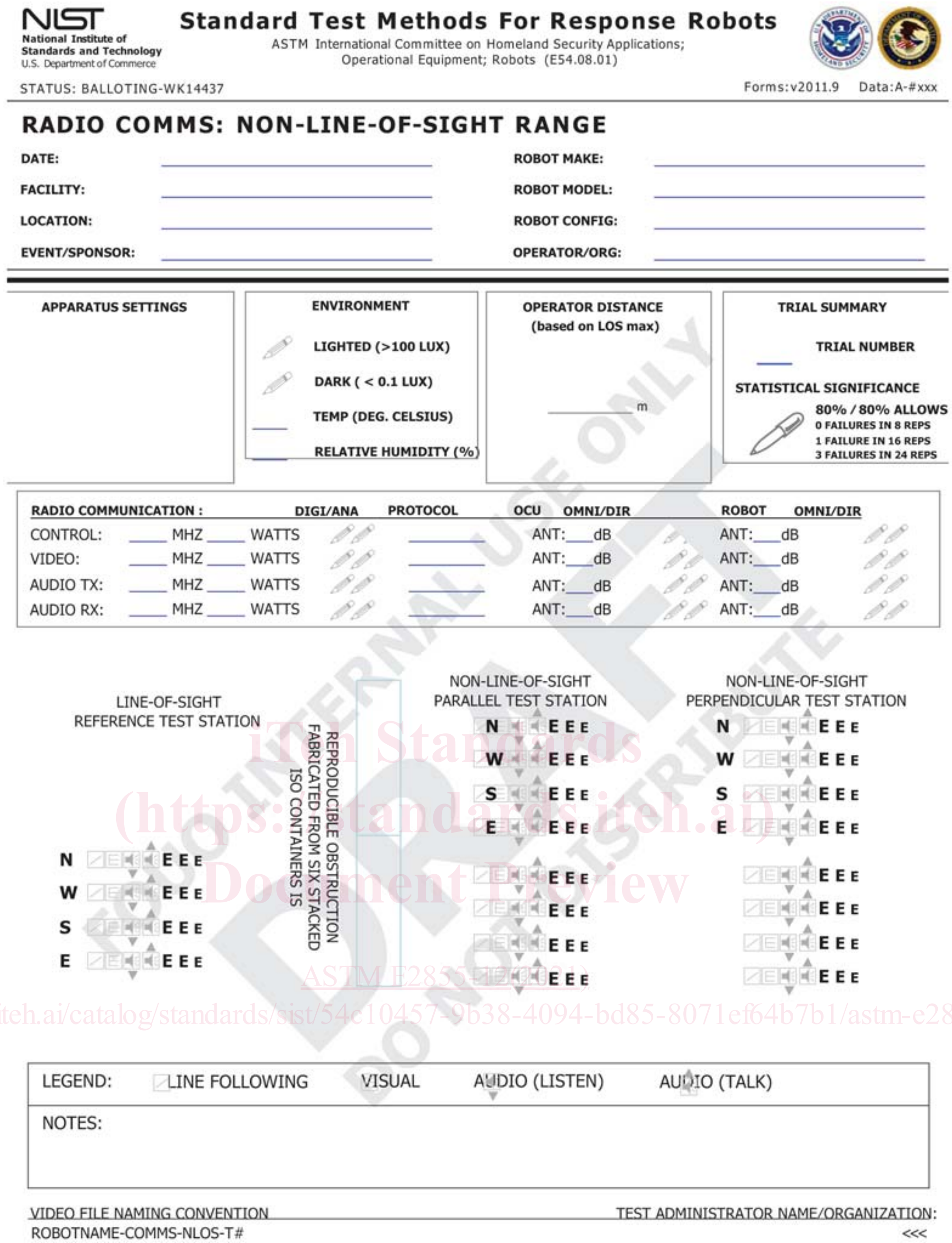
9.2.3 *Location*—Names of campus, city, and state in which the facility is located.

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

9.2.5 *Robot Make*—Name of the manufacturer of the robot.

9.2.6 *Robot Model*—Specific name and model number.

9.2.7 *Robot Configuration*—Identifier of the particular configuration of the robot as tested.


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: BALLOTING-WK14437 Forms:v2011.9 Data:A-#xxx

RADIO COMMS: NON-LINE-OF-SIGHT RANGE

DATE:		ROBOT MAKE:	
FACILITY:		ROBOT MODEL:	
LOCATION:		ROBOT CONFIG:	
EVENT/SPONSOR:		OPERATOR/ORG:	

APPARATUS SETTINGS

ENVIRONMENT
LIGHTED (>100 LUX)
DARK (< 0.1 LUX)
TEMP (DEG. CELSIUS)
RELATIVE HUMIDITY (%)

OPERATOR DISTANCE (based on LOS max)
____ m

TRIAL SUMMARY
TRIAL NUMBER
STATISTICAL SIGNIFICANCE
80% / 80% ALLOWS
0 FAILURES IN 8 REPS
1 FAILURE IN 16 REPS
3 FAILURES IN 24 REPS

RADIO COMMUNICATION :			DIGI/ANA	PROTOCOL	OCU OMNI/DIR		ROBOT OMNI/DIR	
CONTROL:	____ MHZ	____ WATTS		____	ANT:___dB		ANT:___dB	
VIDEO:	____ MHZ	____ WATTS		____	ANT:___dB		ANT:___dB	
AUDIO TX:	____ MHZ	____ WATTS		____	ANT:___dB		ANT:___dB	
AUDIO RX:	____ MHZ	____ WATTS		____	ANT:___dB		ANT:___dB	

LINE-OF-SIGHT REFERENCE TEST STATION
N E E E
W E E E
S E E E
E E E E

REPRODUCIBLE OBSTRUCTION FABRICATED FROM SIX STACKED ISO CONTAINERS IS

NON-LINE-OF-SIGHT PARALLEL TEST STATION
N E E E
W E E E
S E E E
E E E E
E E E
E E E
E E E
E E E

NON-LINE-OF-SIGHT PERPENDICULAR TEST STATION
N E E E
W E E E
S E E E
E E E E
E E E
E E E
E E E
E E E

LEGEND: LINE FOLLOWING VISUAL AUDIO (LISTEN) AUDIO (TALK)

NOTES:

VIDEO FILE NAMING CONVENTION
ROBOTNAME-COMMS-NLOS-T#

TEST ADMINISTRATOR NAME/ORGANIZATION:
<<<

FIG. 4 Example of a Test Form (Blank)

9.2.8 *Operator/Org*—Name of the person who will teleoperate the robot for testing and the name of the organization with which the operator is associated.

9.2.9 *Apparatus Settings*—Incremental metric or features included in test if applicable.

9.2.10 *Environment*—Conditions under which the test will be conducted, including the light level, temperature, and humidity. The test sponsor has the authority to specify these conditions.

9.2.11 *Robot Communications*—State whether the operator is using radio, tether, or a combination to run the test.

9.2.12 *Trial Number*—Provide the numerical sequence of the test being recorded.

9.2.13 Provide the naming convention for the video file associated with the test when applicable.

9.2.14 *Administrator*—Name, organization, and the contact information.

9.2.15 See the top and the bottom of the test form in Fig. 4 for an illustration.

9.3 *Testing Procedure:*