Designation: E2854/E2854M – 21

Standard Test Method for Evaluating Response Robot Radio Communications Line-of-Sight Range[1]

This standard is issued under the fixed designation E2854/E2854M; 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 communications suite of test methods.

1. Scope

1.1 This test method is intended for remotely operated ground robots using radio communications to transmit real-time data between a robot and its remote operator interface. This test method measures the maximum line-of-sight radio communications distance at which a robot can maintain omni-directional steering, speed control, precise stopping, visual acuity, and other functionality. This test method is one of several related radio communication tests that can be used to evaluate overall system capabilities.

1.2 A remote operator is 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 this test method to address 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 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 the 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.

1.6 *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] 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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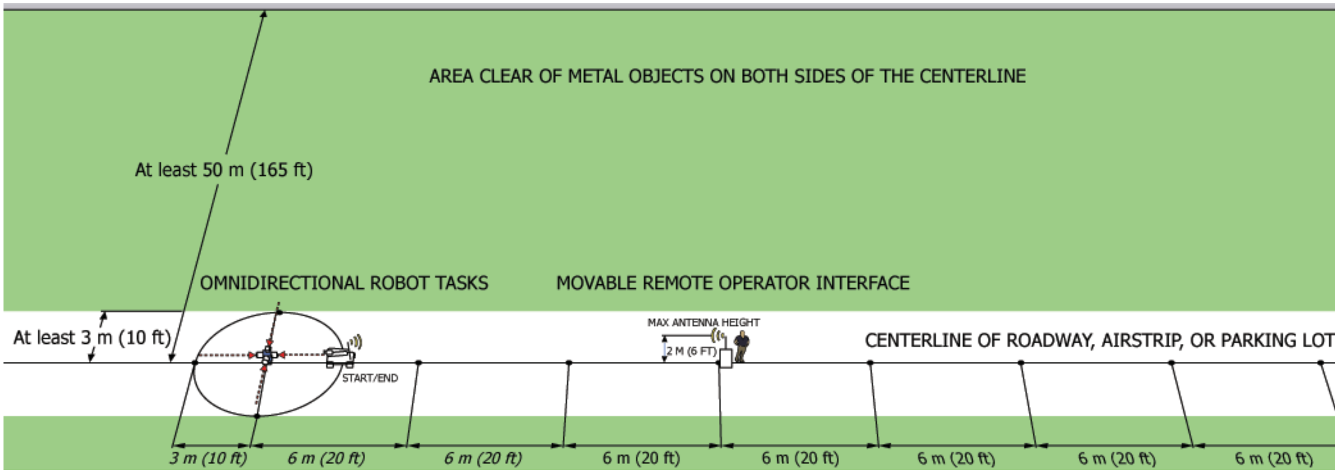


Overview of the test site showing a roadway, airstrip, or parking lot with a centerline and measured incremental distances between the omnidirectional robot tasks and a movable remote operator interface.

FIG. 1 Overview of the Test Site

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 Test Method for Evaluating Response Robot Sensing: Visual Acuity

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

E2855 Test Method for Evaluating Emergency Response Robot Capabilities: Radio Communication: Non-Line-of-Sight Range

2.2 *Other Documents:*

NIST Special Publication 1011-II-1.0 Autonomy Levels for Unmanned Systems (ALFUS) Framework Volume I:3[3]

NIST Special Publication 1011-I-2.0 Autonomy Levels for Unmanned Systems (ALFUS) Framework Volume I: Terminology, Version 2.04[3]

3. Terminology

3.1 The following terms are used in this test method and are defined in Terminology E2521: *emergency response robot* or *response robot*, *fault condition*, *Landolt C*, *line-of-sight communications*, *non-line-of-sight communications*, *optotype*, and *radio interference*.

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*, and *remote teleoperation*.

4. Summary of Test Method

4.1 This test method is intended for remotely operated ground robots using radio communications to transmit real-time data between a robot and its remote operator interface. This test method specifies robot maneuvering and camera pointing tasks performed from designated standoff distances between the robot and remote operator interface (see Fig. 1). This test method measures the maximum line-of-sight radio communications range at which a robot can complete omnidirectional tasks including continuous steering, speed control, precise stopping, visual acuity, and other functionality. This test method is conducted in an environment with no radio frequency interference and minimal radio propagation effects. The same test can be conducted at any operationally significant environment (with representative radio interference) as a practical measure of line-of-sight radio communications range.

4.2 This test method is conducted on a straight and flat surface at least 6 m [20 ft] wide and longer than the maximum radio communications range of the robotic system being evaluated, or longer than the operationally significant range of the intended application. There must be no obstructions on the paved surface or radio reflective metal objects within 50 m [165 ft] of the centerline to minimize effects from multi-path radio transmissions. A roadway, airstrip, or parking lot can be used depending on the overall length required (see Fig. 2).

4.3 The maneuvering tasks require the robot to straddle and follow a circular path marked on the ground with 3 m [10 ft] radius to demonstrate continuous steering and speed control. The robot also aligns with four perpendicular buckets in the center using a designated forward-facing camera on or over the robot chassis. These tasks require the robot to face four different directions relative to the operator interface to ensure that there are no directionality issues with transmitting or

[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/el/isd/ks/autonomy_levels.cfm.

Left) The robot maneuvering tasks include a circular robot path with 3 m [10 ft] radius for the robot to straddle and follow.
Middle) The center buckets are perpendicular and limit the viewing angles of the interior targets.
Right) Each bucket target has an inscribed ring (shown as green) to evaluate successful alignment along with five increasingly small concentric ring gap orientations to evaluate visual acuity.

FIG. 2 Robot Maneuvering Tasks

receiving communication signals. Each recessed bucket target has an inscribed ring with a limited viewing angle to evaluate successful alignment. A 5-point score records successful completion of the robot maneuvering tasks (see Fig. 3 and Fig. 4).

4.4 The visual acuity tasks require identifying up to five increasingly small concentric ring gap orientations in each bucket. A separate 5-point acuity score per target across four different targets totals 20 points for overall acuity.

4.5 There are four performance metrics to consider when calculating the results of a test trial. They should be considered in the following order of importance: *line-of-sight radio communications range*, *reliability*, *average visual acuity*, and *efficiency*.

4.6 This test method is performed with appropriate safety precautions to mitigate any potentially dangerous robot behaviors due to lost communications. The operator performs the maneuvering and visual acuity tasks from a standoff distance near where loss of either control or video is evident. The test is then repeated closer to the robot along the centerline at incremental distances of 6 m [20 ft] until all omnidirectional maneuvering and visual acuity tasks are performed successfully. The maximum distance from the remote operator interface and its co-located antenna to the center of the circle is considered the maximum line-of-sight radio communications range.

4.7 *Potential Faults Include:*

4.7.1 Any contact by the robot with the apparatus that requires adjustment or repair to return the apparatus to the initial condition.

4.7.2 Any visual, audible, or physical interaction that assists either the robot or the remote operator.

4.7.3 Leaving the apparatus during the trial.

4.8 Test trials shall produce enough successful repetitions to demonstrate the reliability of the system capability or the remote operator proficiency. A complete trial of 10 to 30 repetitions should take 30 to 60 min to complete. When measuring system capabilities, it is important to allow enough time to capture a complete trial with an expert operator. When measuring operator proficiency, it is important to limit the time of the trial so that novice and expert operators are similarly fatigued.

4.9 Various other operationally significant targets can be incorporated into this test method to evaluate color acuity, thermal acuity, audio acuity, latency, signal/packet loss, etc.

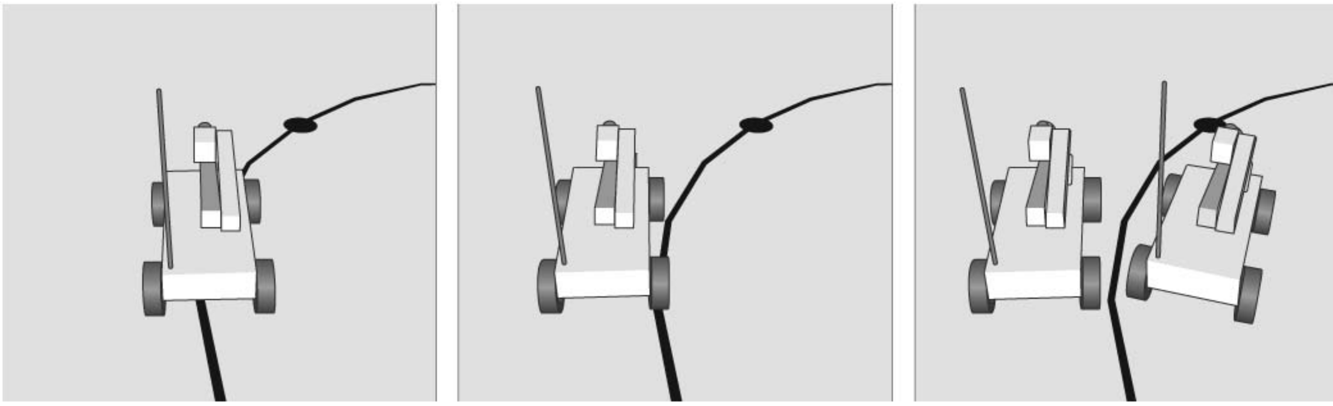
5. Significance and Use

5.1 This test method is part of an overall suite of related tests that provide reproducible measures of radio communications for remotely operated robots. It measures the maximum line-of-sight radio communications range between a robot and its remote operator interface using omnidirectional robot maneuvering and visual acuity tasks to evaluate the degradation of essential mission capabilities due to communications latency and loss.

5.2 This test method is inexpensive, easy to fabricate, and simple to conduct so it can be replicated widely. This enables comparisons across various testing locations and dates to determine best-in-class system capabilities and remote operator proficiency.

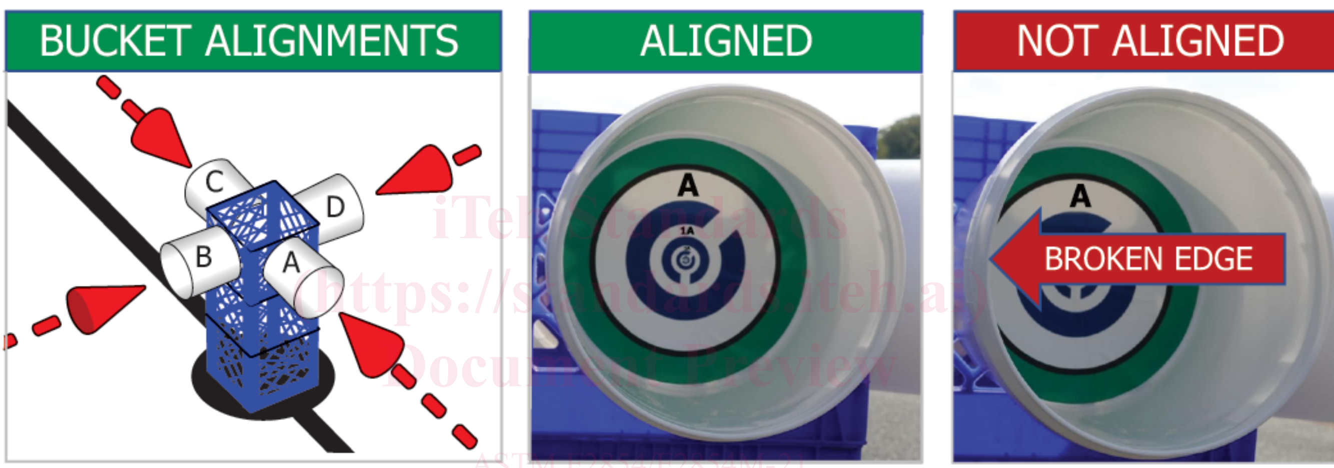
5.3 *Evaluations*—This test method can be conducted in a controlled environment with no radio frequency interference and minimal radio propagation effects to measure baseline capabilities that can be compared widely across robotic systems. It also can be embedded into any operational training scenario as a practical measure of line-of-sight radio communications range with additional degradation due to uncontrolled variables such as radio frequency interference, weather, etc. The results of these scenario tests can be compared across robotic systems only when conducted in the same environment in similar conditions. However, the results cannot be compared reliably to results from other venues or environmental conditions due to the uncontrolled variables.

5.4 *Procurement*—This test method can be used to identify inherent capability trade-offs in systems, make informed purchasing decisions, and verify performance during acceptance testing. This aligns requirement specifications and user expectations with existing capability limits.



Left) The robot is shown successfully straddling the circular line by having at least one ground contact on both sides.
Middle) When ground contacts are touching the circular line the robot is still considered successfully straddling.
Right) All the ground contacts are on one side of the circular line, so the task is considered unsuccessful. Alternatively, the robot could have left the circular line toward the inside which would also be considered unsuccessful.

FIG. 3 Successful Straddling and Unsuccessful Attempt



Successful alignment with each bucket requires visibility of a continuously inscribed ring on the interior bottom of the bucket. The inscribed ring is shown as green with a black inner edge to increase contrast. When the inner black edge is clearly broken the robot is considered NOT ALIGNED.

FIG. 4 Successful Alignment and Unsuccessful Alignment

5.5 *Training*—This test method can be used to focus operator training as a repeatable practice task or as an embedded task within training scenarios. Operators can learn system behaviors during radio communication degradation and refine techniques to mitigate issues while performing tasks. The resulting measures of remote operator proficiency enable tracking of perishable skills over time, along with comparisons of performance across organizations, regions, or national averages.

5.6 *Innovation*—This test method can be used to inspire technical innovation, demonstrate break-through capabilities, and measure the reliability of systems performing specific tasks within an overall mission sequence. Combining or sequencing multiple tests can guide manufacturers toward implementing the combinations of capabilities necessary to perform essential mission tasks.

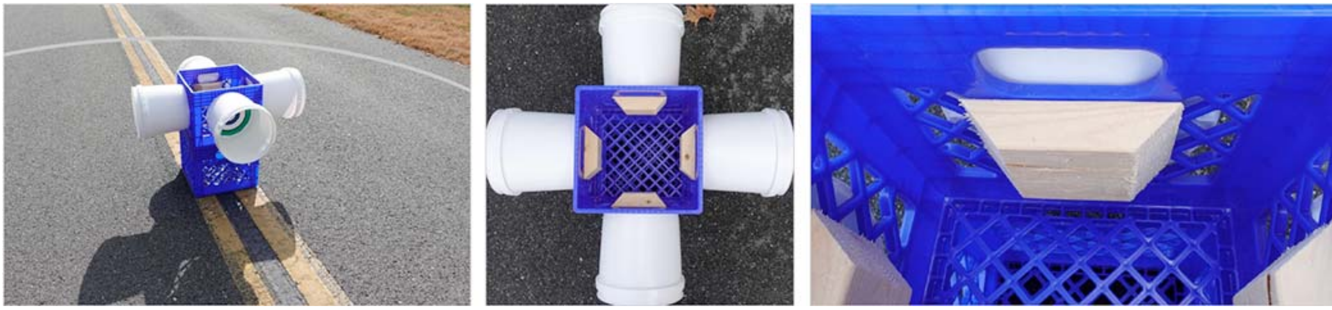
6. Apparatus

6.1 *Test Environment:*

6.1.1 This test method is conducted in an environment with no radio frequency interference near the frequency bands used by the robot being evaluated. This requires radio frequency monitoring equipment to ensure there is no interference from other sources. Variants of this test method should also be performed in environments with other known or unknown radio frequency emissions in the vicinity. Robots should be evaluated using this test method in operational scenarios with powerful radio transmitters nearby such as emergency response vehicles, cell phone towers, and even hand-held radios as a source of potentially significant radio interference. These test variants are less repeatable but can still provide performance comparisons for various systems tested in the same environment at roughly the same time.

6.2 *Test Site (see Fig. 1):*

6.2.1 The test site must be a flat paved surface at least 6 m [20 ft] wide with an overall centerline length longer than the maximum radio communications range of the robotic system being evaluated, or longer than the operationally significant range of the intended application. It must be flat and straight enough to maintain an unobstructed view between the robot and the remote operator interface antenna throughout the test.



Left) The elevation of the buckets needs to align with various size robots, so some vertical adjustment is necessary.
Middle) Stackable crates provide excellent perpendicular mounting surfaces and easy adjustment of elevation.
Right) Wood blocks inside the crates enable the buckets to be affixed to the outside surfaces with screws. Bolts, washers, and wingnuts through the bucket and crate can also be used to enable quick set up and stowing.

FIG. 5 Perpendicular Buckets

A slight incline or decline can be tolerated as long as there is no depression along the centerline that obscures the direct line-of-sight path from the robot to the operator interface antenna. The top of the antenna is limited to a maximum height of 2 m [6 ft] from the ground. There must also be no obstructions or reflecting metal objects within 50 m [165 ft] of the centerline to minimize effects from multi-path radio transmissions to only reflections off the ground. A roadway, airstrip, or parking lot can be used depending on the system capabilities being evaluated as long as there are no metal buildings, vehicles, guardrails, signs, etc. Operationally significant variants of this test method performed on absorptive ground surfaces such as grass and with reflective metal objects in the vicinity, or with antennas mounted on vehicles or structures such that they exceed 2 m [6 ft] in height, or combinations thereof, are less repeatable but can still provide points of comparison for various systems tested in the same environment in similar conditions.

6.3 *Incremental Standoff Distances (see Fig. 1):*

6.3.1 The incremental standoff distances along the centerline locate the remote operator interface relative to the center of the circular robot tasks. Each incremental distance is 6 m [20 ft]. The overall length must extend beyond the maximum line-of-sight radio communications range of the robotic system being evaluated. The centerline can be a roadway lane marker line, pavement seam, or measuring tape pulled taught and secured to the ground. Each measured increment should be marked with spray chalk or other means to clearly identify the location and distance from the center of the circular robot path.

6.4 *Circular Robot Path (see Fig. 2):*

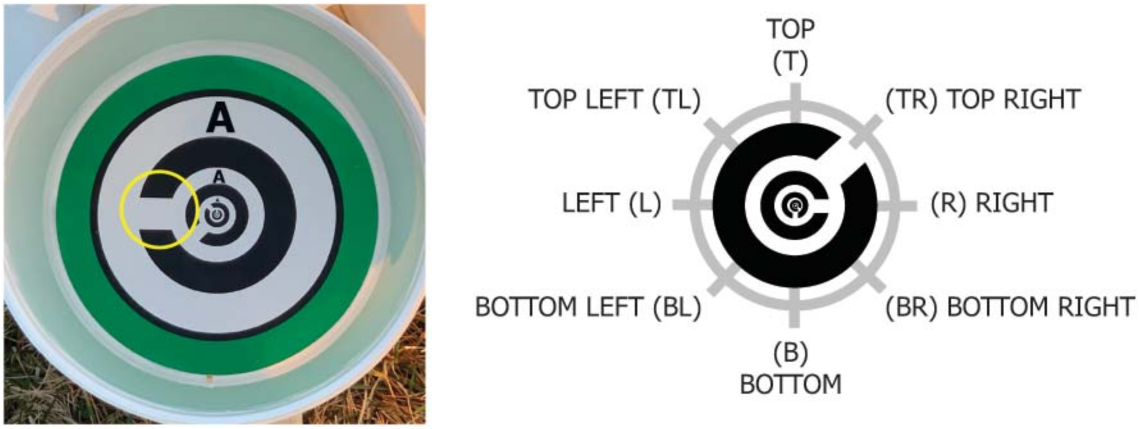
6.4.1 The circular robot path marked on the ground provides a 3 m [10 ft] radius line for the robot to straddle and follow. The circle can be marked using a fixed length rope tied between a spray chalk roller wand and center stake or weight. Pull the rope taught to ensure the radius is correct, then pull continuously outward away from the center while marking. Four additional markings at 90-degree increments around the circle designate the locations where the robot rotates inward to align with the perpendicular buckets. The locations for bucket A and bucket C are the intersection of the circle and the centerline with Bucket A closer to the remote operator interface and C further from the remote operator interface. The locations for bucket B and bucket D are 90-degrees from the centerline with bucket B to the left when viewed from the operator interface and bucket D to the right. Use the correct alignment position of bucket B and bucket D to mark the locations.

6.5 *Perpendicular Buckets (see Fig. 5):*

6.5.1 Four perpendicular buckets are located at the center of the circular robot path to restrict the viewing angles of targets affixed to their inside bottom surfaces. They are aligned with positions every 90-degrees around the circular robot path starting where the circle intersects the centerline. The buckets are incrementally elevated using the crates shown or other non-metallic apparatus to ensure different sized robots can see the entire inscribed ring when in the correct location around the circle. The buckets shown are 7.5 L [2 gal] with 20 cm [8 in.] inner diameter so they fit letter/A4-size target stickers. White buckets are used to reflect light and illuminate the recessed targets. Other bucket sizes and colors can work as long as the recessed targets are clearly visible to the robot being evaluated. Each bucket is uniquely named with letters (A, B, C, D) to identify the different robot orientations for scoring purposes. The bucket labeled "A" is viewable from the intersection of the circular robot path and the centerline closest to the remote operator station. The other letters continue leftward or clockwise from there.

6.6 *Bucket Targets (see Fig. 4, Fig. 5, and Fig. 6):*

6.6.1 Each bucket contains a recessed target affixed to the interior bottom surface. Targets include an inscribed ring to verify robot alignment. The inscribed ring shown is 2.5 cm [1 in.] thick and green, but any contrasting color can be used. The visual acuity target contains five increasingly small concentric rings with various gap orientations to correctly identify. These are concentric Landolt-C optotypes (see Test Method E2566 – 17a or later). Each ring gap can be in eight different orientations making the overall visual acuity target randomizable with a unique answer key. The naming convention for the different gap orientations are: top (T), top right (TR), right (R), bottom right (BR), bottom (B), bottom left (BL), left (L), top left (TL). The ring gaps are the following sizes from largest (outer) to smallest (inner):



Left) Visual acuity targets affixed to the interior bottom of the buckets have increasingly small concentric ring gap orientations.
Right) The associated naming convention for each ring gap orientation.

FIG. 6 Bucket Targets

Largest	Ring 1 Gap Size = 20 mm [0.8 in.]	5 % Human Vision from 3 m [10 ft]
	Ring 2 Gap Size = 8.0 mm [0.3 in.]	11 % Human Vision from 3 m [10 ft]
	Ring 3 Gap Size = 3.2 mm [0.125 in.]	27 % Human Vision from 3 m [10 ft]
	Ring 4 Gap Size = 1.3 mm [0.05 in.]	67 % Human Vision from 3 m [10 ft]
Smallest	Ring 5 Gap Size = 0.5 mm [0.02 in.]	175 % Human Vision from 3 m [10 ft]

6.7 *Timer:*

6.7.1 A timer is used to measure the elapsed time for the robot to perform each set of maneuvering and visual acuity tasks.

6.8 *Optional Time-synced Clocks:*

6.8.1 Two time-synced digital clocks can be used to detect and measure latency and loss issues due to degraded radio communications. These latency and loss issues can last several seconds and increase the difficulty of the tasks. One time-synced clock should be placed with the remote operator interface display and the other time-synced clock placed so it is viewable by the robot's camera when the robot is aligned with the buckets. The time-synced clock with the buckets needs to be large enough to be viewable through the remote operator interface and easily comparable to the time-synced clock with the remote operator interface display.

6.9 *Optional Still-image Camera:*

6.9.1 A still-image camera can be used to capture images of the remote operator interface display at each bucket alignment to pictorially document both the alignment and visual acuity score with static examples of video degradation. The camera must have sufficient quality to record the pixels of the remote operator interface display to ensure the camera does not add uncertainty to the image degradation. Similarly, a "screenshot" of the remote operator interface display can be used for scoring. However, any images captured by the robot but not transmitted via the radio communications link cannot be used for scoring. If a system recording of a video feed from the remote operator interface is available to be captured, it shall be marked "streamed" to make it clear to the viewer that the effect of the remote operator interface screen (for example, a small or low-resolution screen reducing the acuity of the system) will not be represented in the resulting recording. Any video captured by the robot but not transmitted via the radio communications link cannot be used for scoring.

6.10 *Optional Video Cameras:*

6.10.1 Two video cameras can be used to simultaneously record the remote operator interface and robot behaviors to capture more detailed performance of the communications link. Watching the two videos side by side is ideal to see subtle issues of latency and loss caused by radio communications degradation. Start both recordings with the cameras pointing at time-synced clocks so the videos can be synchronized after the trial. The two cameras should record the following points of view:

6.10.1.1 A view of the remote operator interface display, operator hands to capture all inputs to the system, the time-synced digital clock, and a whiteboard or page display described below. A tripod mounted camera over the shoulder of the operator is typically sufficient.

6.10.1.2 A view of the robot performing the maneuvering tasks with enough detail to clearly determine if the robot maintains straddle over the circular path. If a mobile camera is used, ensure that the person stays out of the line-of-sight radio propagation path to the remote operator interface.

6.11 *Optional Whiteboard or Page Display:*

6.11.1 A whiteboard or page display helps capture key trial information in documentary images and video. This includes at least the date, location, robot configuration, operator code, and standoff distance from the center of the circular robot path.

6.12 *Optional Attenuation:*

6.12.1 Operational use cases often include some unavoidable attenuation of the radio communications transmissions. An armored vehicle is an example of an operationally significant enclosure for the remote operator that can attenuate the line-of-sight radio communications range. Variants of this test method can be conducted with the operator control unit inside the armored personnel carrier to determine the maximum line-of-sight range with the hatches open or closed, facing down range through the front window or otherwise, and with the engine on or off. The specific configurations used shall be noted on the trial form.

7. Hazards

7.1 Functional emergency-stop systems are essential for safe remote or autonomous robot operation. The emergency-stop switch on the operator control unit shall be clearly marked and accessible. The emergency-stop switch on the robot chassis, if available, should also be marked. All personnel involved in testing shall familiarize themselves with the locations of all emergency-stop switches prior to conducting trials.

7.2 Emergency stop systems shall be engaged prior to approaching a remotely operated robot. Constant communication is essential between a remote robot operator and any people in the vicinity until the robot is safely within the test apparatus and people are either outside the apparatus or at a safe distance. The remote operator may not be aware that someone is interacting with the robot when they start to drive or actuate a manipulator. People should avoid standing directly in front of the robot, directly behind the robot, or within reach of the manipulator arm unless the robot is completely deactivated.

7.3 Tests that are intended to challenge the radio communications of the robot increase the probability of malfunction, including unpredictable movements of the robot and its manipulator. Proper footwear and other personal protective equipment shall be worn to mitigate risk. Caution is required when attending to a robot or carrying it within the apparatus. Additional infrastructure, such as containment walls, fences, or other enclosures, may be necessary to ensure the safety of bystanders.

8. Procedure

8.1 *Identify the Robot Configuration*—The robotic system configuration being tested shall be identified and uniquely named (for example, make, model, configuration), including all subsystems and components with their respective features and functionalities. The configuration of the robotic system should be representative of a configuration that will be used in its intended application. A given robotic make and model may have several different configurations. Any number of configurations can be subjected to testing. The system configuration shall remain the same for all relevant tests to enable direct comparison of performance and to identify trade-offs between different configurations. In general, robotic system configurations shall maintain their overall cubic volume, weight, and center of gravity, as well as major sub-systems such as tracks, wheels, legs, manipulator, radio communications, tether, operator control unit, etc. Documentation should include detailed photographs of all of the above as well as videos of routine maintenance tasks such as a track change, battery change, etc. If the robot's physical configuration is changed during a trial, it should be noted and potentially considered a different configuration that should be re-tested from the start. More information can be found in Practice E2592. Some specific configuration options that may be relevant include:

8.1.1 Weights and measurements of all containers as shipped or ready for deployment.

8.1.2 List of sustainment items such as batteries, chargers, and consumables.

8.1.3 List of maintenance items such as tools and spare parts.

8.1.4 Optional payloads.

8.1.5 *Directional Antennas*—There is no prohibition against directional antennas as long as they are part of the initial configuration and used throughout any associated testing to evaluate trade-offs in performance. The antenna located at the remote operator interface is stationary, so it could benefit from a directional antenna. However, the robot performs omnidirectional tasks so a directional antenna may not be as helpful.

8.1.6 *Software Settings*—This test method is particularly sensitive to software configuration changes. Settings that may affect communications include enabling/disabling multiple video streams, streaming resolution, assistive features, low power modes, different transmission frequencies, modulation schemes, antenna types, antenna gains, and other options. Each of these settings should be noted on the test form and associated with the results for comparison purposes. An exception is where the system is of a type where the operator is expected to tune the settings remotely from the remote operator interface without touching the robot; or where the system automatically adapts and tunes the system without operator intervention.

8.1.7 *Mesh Networking Nodes*—If mesh networking nodes are included as part of the robot configuration, this test method represents the maximum line-of-sight range of the final link in the mesh network between the last repeater node and the robot. If the robot configuration includes droppable repeater nodes, the repeater nodes shall be turned on and placed at or behind the operator station in an operationally reasonable configuration prior to the commencement of this test method. None of the repeater nodes shall be closer to the robot than the remote operator interface. Where the repeater nodes are a significant part of the overall weight or volume of the robot (more than 10 % is considered significant), associated mobility tests should be performed in separate configurations with a full set of repeater nodes and with no repeater nodes onboard. All test forms should indicate how many repeater nodes were onboard the robot at the time of the test.

8.2 *Prepare the Apparatus:*

8.2.1 Use an existing line in the test site or a measuring tape as the centerline extending from the intended location of the circular robot path to beyond the line-of-sight radio communications range of the robotic system being evaluated (see Fig. 1 and Fig. 2).

8.2.2 Measure and mark the circular robot path with a 3 m [10 ft] radius at one end of the centerline (see Fig. 1 and Fig. 2).

8.2.3 Place the four perpendicular buckets with visual acuity targets at the center of the circular robot path (see Fig. 2 and Fig. 4). Align bucket A with the centerline pointing toward the operator interface. Ensure the buckets are at an elevation that allows the robot to view the entire inscribed circle when properly aligned. Ensure the visual acuity targets are upright and the answer keys are correctly represented on the trial form.

8.2.4 Add markings on the circular robot path designating the four robot alignment locations. The two intersections of the