Designation: ~~E2521 – 16~~ E2521 – 23

Standard Terminology for Evaluating Response Robot Capabilities[1]

This standard is issued under the fixed designation E2521; 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 quantitatively measure whether a particular robot is capable of performing and reliable enough to perform specific missions. These missions decompose into sets of elemental robot tasks that can be represented individually as standard test methods. The ASTM International Committee on Homeland Security Applications, ~~Operational Equipment Subcommittee, Robots Task Group (E54.08.01)~~ Subcommittee E54.09 on Response Robots, specifies standard test methods, practices, and guides for evaluating response robots. These standard test methods measure specific robot capabilities in repeatable ways to facilitate comparisons among different robot models or different configurations of a particular robot model. Users assemble different sets of standard test methods into combinations that address their envisioned missions tasks.

Resulting robot capabilities data support robot researchers, manufacturers, and user organizations in different ways. Researchers use them to understand mission requirements, refine innovating approaches, and demonstrate break-through capabilities. Manufacturers use them to evaluate design decisions, integrate payloads and emerging technologies, and harden systems. Responder organizations use them to guide purchasing, align with deployment objectives, and focus training with measures of operator proficiency.

The overall set of the standards addresses the robotic terminology, safety, maneuvering, terrains, obstacles, dexterity, sensing, communications, energy/power, durability, proficiency, autonomy, and logistics. Each standard test method enables repeatable testing to establish statistically significant levels of reliability and confidence that the robot can perform the task. Standard test methods essentially define the test apparatuses, procedures, and performance metrics so they can be fabricated and practiced by robot manufacturers and user groups alike. They provide a tangible language to communicate responder requirements and demonstrate robot capabilities.

1. Scope

1.1 This terminology identifies and precisely defines terms as used in the standard test methods, practices, and guides for evaluating response robots intended for hazardous environments. Further discussions of the terms can be found within the standards in which the terms appear.

1.2 The term definitions address response robots, including ground, aquatic, and aerial systems. Some key features of such systems are remotely operated from safe standoff distances, deployable at operational tempos, capable of operating in complex environments, sufficiently hardened against harsh environments, reliable and field serviceable, durable or cost effectively disposable, and equipped with operational safeguards.

[1] This terminology is under the jurisdiction of ASTM Committee E54 on Homeland Security Applications and is the direct responsibility of Subcommittee E54.09 on Response Robots.

Current edition approved ~~Jan. 1, 2016~~Sept. 1, 2023. Published ~~January 2016~~September 2023. Originally approved in 2007. Last previous edition approved in ~~2007~~2016 as ~~E2521 – 07a.~~E2521 – 16. DOI: ~~10.1520/E2521-16.~~10.1520/E2521-23.

1.3 *Units*—Values stated in either the International System of Units (metric) or U.S. Customary units (inch-pound) are to be regarded separately as standard. The values stated in each system may not be exact equivalents. Both units are referenced to facilitate acquisition of materials internationally and minimize fabrication costs. Tests conducted using either system maintain repeatability and reproducibility of the test method and results are comparable.

1.4 *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. Terminology

2.1 *Definitions:*

abstain, *v*—robot manufacturer or designated operator declaring not to perform a particular test or not to have the test result disseminated.

alcove, *n*—a square area with walls on three of four sides whose sides are equal to the chosen apparatus clearance width (W).

aspect ratio, *n*—ratio of width to height of an image produced by a camera system.

cache, *n*—stock of tools, equipment, and supplies stored in a designated location.[2]

collapse hazard zone, *n*—area established by the responsible official for the purpose of controlling all access to an area that could be impacted or affected by building collapse, falling debris, or other associated types of hazards including electrical, chemical, water, and aftershocks.[2]

dynamic range (of a camera), *n*—a measure of the ability of a camera system to observe detail in a dark part of an otherwise bright environment, or vice versa, "simultaneously" in a single image or "sequentially" across multiple images, under "automatic" or "manual" control of the camera system's settings.

emergency response robot or **response robot,** *n*—deployable sensing and control device intended to perform tasks at operational tempos to assist the operator with handling the involved task.

emergency response team (ERT), *n*—team assembled by involved organization in response to the occurrence of a disaster.[2]

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

~~**falt-floor**~~**flat-floor terrain element,** *n*—~~flat surface with nominal overall dimensions of 1.2 by 1.2 m [4 by 4 ft] and elevation of 10 by 10 cm [4 by 4 in.].~~square flat surface whose sides measure one apparatus clearance width (W).

DISCUSSION—
The material used to build these elements shall be strong enough to allow the participating robots to execute the testing tasks.

focal length, *n*—equivalent distance in free air between the point at which rays of light entering the optical system are first collimated and the focal point of the camera.

foveated vision or **foveated vision system,** *n*—camera system that has higher resolution (provides more information) at the center of the image than at the edges.

full-ramp terrain element, *n*—inclined surface with nominal overall dimensions of ~~1.2 by 1.2 m [4 by 4 ft]~~ 1.2 m by 1.2 m [4 ft by 4 ft] and slope of 15°.

[2] FEMA US&R-2-FG "Urban Search and Rescue Response System Field Operations Guide," Latest Version (September 2003 or later).

~~**half-ramp terrain element,**~~ **hallway,** *n*—~~inclined surface with nominal overall dimensions of 0.6 by 1.2 m [2 by 4 ft] and slope of 15°.~~an area with a width equal to the chosen apparatus clearance width (W) and a variable length that is a multiple of W.

human robot interaction/interface (HRI), *n*—(*1*) physical activities that users engage with robots to perform assigned tasks; (*2*) physical devices that facilitate the aforementioned activities; (*3*) logical design and description of planned and anticipated interactions between the robot and the user.[3]

DISCUSSION—
Also referred to as or human system interaction/interface (HSI).

human-scale, *adj*—used to indicate that (*1*) the concerned objects, terrains, or other environmental features are, individually, in volumetric and weight scales typically handled by humans, although possibly compromised or collapsed enough to limit human access; (*2*) the concerned robots are suitable for operating within these contexts; and (*3*) the robot tasks are identifiable, perceivable, and controllable with human interaction.

image, *n*—two-dimensional matrix of values with each of the two dimensions representing angular deviation (possibly nonlinear) in orthogonal directions from the sensor's optical axis.

image acuity or **acuity,** *n*—measure of the resolving capability of the robot's camera system.

image field of view or **field of view,** *n*—measure of the extent of a scene that may be observed in a single visual image, measured in terms of degrees in the horizontal and vertical directions.

image resolution, *n*—measure of the level of detail of a scene that the robot's camera system is capable of capturing, measured as the number of horizontal scan lines per image height in the horizontal, vertical, and diagonal directions.

imager, *n*—sensory, or system of sensors, that produces an image.

Landolt C, *n*—optotype consisting of a black circular ring with a gap on white background; all the dimensions are specified.

linear rail, *n*—a length of wood, plastic, or metal which scales with the apparatus clearance width (W), with mounting points at specified angles, used to hold additional hardware to perform dexterity tasks.

DISCUSSION—
The standard in which this term is used will specify the hardware for a particular set of dexterity tasks.

line-of-sight communication, *n*—propagating signal-carrying electromagnetic energy between a transmitting and a receiving radio antennas using paths that are in direct visual contact without obstructions between them.

maze, *n*—network of mobility passages interconnected without any repetitive order of opening and closing directions.

mission planning, *n*—process used to generate tactical goals, routes, tasks, commanding structures, coordination, and timing.[3]

mixed initiative control, *n*—type of control for robotic systems with which both the operator and the robot can take the initiative to perform the assigned missions or tasks.

non-line-of-sight communication, *n*—propagating signal-carrying electromagnetic energy between a transmitting and receiving radio antennas through paths that are not in direct visual contact because of obstructions between them.

[3] *Autonomy Levels for Unmanned Systems Framework, Volume I: Terminology, Version 1.1, NIST Special Publication 1011*, Huang, H., Ed., National Institute of Standards and Technology, Gaithersburg, MD, September 2004.

operator, *n*—person that controls the robot to perform specified tasks.

operator station, *n*—apparatus for hosting the operator and her/his operator control unit (OCU) to teleoperate the robot.[4]

optotype, *n*—standardized symbol used to test visual capabilities.

radio interference—adverse effect on electromagnetic transfer of data when unrelated signals are received by either a transmitting or receiving radio antenna or both.

remote control, *n*—continuously controlling a robot from an off-robot separate location and under direct observation.

resolution wedge, *n*—series of co-planar lines that, in a consistent pattern, show decreases in the spacing between the lines and in individual line thicknesses.

resolve, *v*—act of visually discerning the presence of a marking or an object.

response robot, *n*—a robot controlled by a remote operator to perform tasks in unstructured and complex environments at an operational tempo.

Discussion—

Response robot capabilities may include, but are not limited to: rapid deployment, mobility, dexterity, autonomous functionality, providing operator situational awareness, and hardening against harsh environments.

robot, *n*—mechanical system designed to be able to control its sensing and acting for the purpose of achieving goals in the physical world.

robot system, *n*—response robot and all necessary associated components required for field operation and maintenance of the robot.

Discussion—

Necessary associated components include, but are not limited to: the operator control unit (OCU), power sources, spare parts, sensors, consumables (such as lubricating oil, gasoline, etc.), accessories, and maintenance tools.

room, *n*—a square area whose sides are equal to twice the chosen apparatus clearance width (W).

sensor fusion, *n*—process that combines, integrates, or correlates, or a combination thereof, data generated by multiple sensory sources to create information that fits the needs, including decision-making and display for user.

stepfield ~~**terrain element,**~~ **terrain,** *n*—discontinuous terrain type ~~completely~~ formed using an array of wood posts standing on end with nominal dimensions ~~of 10- by 10-cm [4- by 4-in.] for the cross section and elevations of 10, 20, 30, 40, and 50 cm [4, 8, 12, 16, and 20 in.]; the posts may be~~ and specified elevations based on the chosen apparatus clearance width (W), arranged to form specified topologies.

Discussion—

For example, if W = 120 cm [96 in.], then the nominal dimensions of the wood posts are 10 cm by 10 cm [4 in. by 4 in.] positioned at elevations of 10 cm, 20 cm, 30 cm, 40 cm, and 50 cm [4 in., 8 in., 12 in., 16 in., and 20 in.].

teleoperation, *v*—controlling a distant robot on a continuous basis and being provided with sensory or control information, or both, through means other than direct observation.[4]

test administrator, ~~**or, administrator,**~~ ~~*n*—person that conducts a test or a role that was played to conduct such~~ a person who oversees and records the results of a test.

[4] U.S. DOD OUSD (AT&L) FY2005 Joint Robotics Program Master Plan.