INTERNATIONAL

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Standard Test Method for Evaluating Aerial Response Robot Capabilities: Fly Through Apertures[1]

This standard is issued under the fixed designation E3479/E3479M; 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 pilot 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 and align deployment expectations. Associated usage guides describe how these standards can be applied to support various objectives. These standard test methods may be used in concert with Specification F3330 to create scenario-based training programs.

Several suites of standards address these elemental capabilities including maneuvering, mobility, dexterity, sensing, endurance, communications, durability, proficiency, autonomy, and logistics.

1. Scope

1.1 This test method is intended for remotely operated aerial response robots (that is, unmanned aerial systems (UAS), drones, unmanned aircrafts) operating in complex, unstructured, and often hazardous environments. It specifies the apparatuses, procedures, and performance metrics necessary to measure the robot's capability to maneuver through apertures wherein the boundaries of the space pose transient constraints on horizontal and vertical movement and hazards for potential collision through a series of narrow opening profiles with variable environmental properties. This test method is one of several robot tests that can be used to evaluate overall system capabilities.

1.2 The robotic system includes a remote pilot in control of most functionality, so an onboard camera and remote pilot display are typically required. This test method can be used to evaluate assistive or autonomous behaviors intended to improve the effectiveness or efficiency of remotely operated systems.

1.3 Different user communities can set their own thresholds of acceptable performance within this test method for various mission requirements.

1.4 *Performing Location*—This test method may be performed anywhere the specified apparatuses and environmental conditions can be implemented. Flying unmanned aircraft without a comprehensive understanding of the laws and regulations enforced by the relevant jurisdiction poses significant safety and legal risks. Failure to comply with these regulations may result in accidents, injuries, property damage, and legal consequences. Users of this standard are strongly advised to review and adhere to all applicable ASTM Committee F38 standards and to ensure full compliance with the authorities holding jurisdiction.

1.5 *Units*—The International System of Units (SI Units) and U.S. Customary Units (Imperial Units) are used throughout this

[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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document. They are not mathematical conversions. Rather, they are approximate equivalents in each system of units to enable 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.*

1.7 *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

E3132/E3132M Practice for Evaluating Response Robot Logistics: System Configuration

F3330 Specification for Training and the Development of Training Manuals for the UAS Operator

F3341/F3341M Terminology for Unmanned Aircraft Systems

2.2 *Additional Documents:*

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

3. Terminology

3.1 *Definitions*—The following terms are used in this test method and are defined in Terminology E2521: *abstain, administrator or test administrator, emergency response robot or response robot, fault condition, operator, operator station, remote control, repetition, robot, teleoperation, test event or event, test form, test sponsor, test suite, testing target or target, testing task or task,* and *trial or test trial*.

3.2 The following terms are used in this test method and are defined in NIST Special Publication 1011-I-2.0 (ALFUS Framework): *autonomous, autonomy, level of autonomy, operator control unit (OCU),* and *semi-autonomous*.

3.3 The following terms are used in this test method and are defined in Terminology F3341/F3341M: *remote pilot* and *unmanned aircraft*.

3.4 *Definitions of Terms Specific to This Standard:*

3.4.1 *apparatus clearance width (W), n*—a specification for the apparatus dimensions chosen from one of four possible measurements, based on the intended robot deployment environment:

240 cm ± 2.5 cm tolerance [96 in. ± 1 in. tolerance], such as open and outdoor public spaces;

120 cm ± 2.5 cm tolerance [48 in. ± 1 in. tolerance], such as indoor spaces in accessibility-compliant buildings;

60 cm ± 1.3 cm tolerance [24 in. ± 0.5 in. tolerance], residences and aisles of public transportation; and

30 cm ± 1.3 cm tolerance [12 in. ± 0.5 in. tolerance], cluttered indoor spaces, ductwork, and voids in collapsed structures.

3.4.1.1 *Discussion*—The measures for these scales are nominal and do not represent the measurement of the narrowest point in the apparatus through which the robot should pass. Consult Section 6 for the overall measurements and dimensions of the apparatus at each scale.

3.4.2 *remote pilot, n*—the remote pilot in command (RPIC) or person other than the RPIC who is controlling the flight of an unmanned aircraft (UA) under the supervision of the RPIC. **F3341/F3341M**

3.4.3 *unmanned aircraft, n*—aircraft operated without the possibility of direct human intervention from within or on the aircraft. **F3341/F3341M**

NOTE 1—Due to similarities in characteristics and to maintain consistency across standards developed through ASTM E54.09, the "unmanned aircraft" (Terminology F3341/F3341M) is referred to as the "robot" (Terminology E2521) throughout this standard.

4. Summary of Test Method

4.1 This test method is performed by a remote pilot in control of an aerial response robot (that is, unmanned aerial system (UAS), drone, unmanned aircraft). The test administrator and all participants shall ensure compliance with the regulations of the authority holding jurisdiction before conducting any tests. The robot maneuvers through an aperture in a wall (for example, window, door) or in a ceiling/floor (for example, hatch, skylight) of varying dimensions. For the purposes of this test method, an aperture is considered an opening, portal, or ingress/egress point that separates two spaces (for example, descending through a roof hatch from outdoors to indoors, or through a doorway that separates two rooms), meaning the robot is only spatially confined for a short period of time (that is, the thickness of the wall or ceiling/floor that contains the aperture). A separate test method is under development and will specify maneuvering through confined spaces (for example, hallways, tunnels) meaning the robot is spatially confined for a longer period of time (that is, the length of the confined space).

4.2 Two tests are defined based on the orientation of the aperture and the corresponding robot flight paths: wall aperture (where the robot flies forward through the aperture) and ceiling/floor aperture (where the robot ascends and descends through the aperture); see Fig. 1.

4.3 There are two segments of robot performance per task repetition: *(1)* ingress and *(2)* egress. Both segments must be

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at www.astm.org/contact. 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.