Designation: E3426/E3426M – 24

Standard Test Method for Evaluating Aerial Response Robot Endurance[1]

This standard is issued under the fixed designation E3426/E3426M; 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 mission endurance of an aerial robot while either station keeping or following an approximate flight path defined by obstacles or boundaries, or both, intended to induce repeated cyclical movement. 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 document. They are not mathematical conversions. Rather, they are approximate equivalents in each system of units to

[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.

Current edition approved Feb. 1, 2024. Published February 2024. DOI: 10.1520/E3426_E3426M-24.

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

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

E3132 Practice for Evaluating Response Robot Logistics: System Configuration

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

F3341 Terminology for Unmanned Aircraft Systems

2.2 *Other Documents:*

NIST Special Publication 1011-I-2.0 Autonomy Levels for Unmanned Systems (ALFUS) Framework Volume I: Terminology[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 ALFUS Framework Volume I:3: *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: *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; or

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**

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

NOTE 1—Due to similarities in characteristics and to maintain consistency across standards developed through ASTM E54.09, the "unmanned aircraft" (Terminology F3341) 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 follows one of four defined operating profiles in the specified testing area, requiring the robot to overcome challenges such as continuous movement, obstacle avoidance, constant vector adjustment, station keeping, or dwelling in varied environmental conditions. Four tests are defined, one for each operating profile: *outdoor movement* endurance (where the robot continuously flies down range, ascends, descends, and returns up range), *indoor movement* endurance (where the robot continuously flies following a figure-8 flight path inside a confined space), *indoor hovering* endurance (where the robot hovers in place inside a confined space), and *indoor dwelling* endurance (where the robot lands on the ground and remains in place inside a confined space). The outdoor operating profile is performed in a testing area measuring at least 15 m [50 ft] wide by 90 m [300 ft] long by 90 m [300 ft] tall; see Fig. 1. The three indoor operating profiles are performed in a testing area measuring 2W wide by 7W long (or longer) by 2W tall, defined by physical boundaries and with barrier posts that aid in defining the flight path. See Fig. 2.

4.2 The *outdoor movement* test uses a straight, forward flight path followed by an ascending/descending flight path in

[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.