Designation: F3470 – 20

Standard Guide for A-UGV Capabilities[1]

This standard is issued under the fixed designation F3470; 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 This guide categorizes the autonomous capabilities of an automatic through autonomous-unmanned ground vehicle (A-UGV) based on the following list of capability categories:

(a) Goal Navigation: Pre-Programmed;

(b) Goal Navigation: In situ;

(c) Localization;

(d) Docking—Infrastructure Dependence;

(e) Obstacle Avoidance—Types of objects that can be avoided and are within the A-UGV envelope, and types of objects that can be avoided and are outside of the A-UGV envelope;

(f) Changing Contour Area or Envelope;

(g) Changing Payload;

(h) Impaired Communication Behavior;

(i) Lost Communication Behavior;

(j) Environmental Conditions;

(k) Fleet Makeup—Fleet Task Assignment, Information Sharing/Updating, Fleet Navigation Coordination, and Fleet Task Coordination.

1.2 This guide provides a basis for A-UGV manufacturers and users to compare the intended task to the A-UGV capability. This guide does not purport to cover all relevant capabilities or categories that an A-UGV can perform. Instead, this guide provides a method for defining A-UGV capabilities and limits of A-UGV capabilities within specified categories listed in 1.1.

1.3 One or more capabilities may be used to define the A-UGV capability and not all categories are required to be used for defining the capability of an A-UGV.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are not precise mathematical conversions to imperial 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 are provided for information only and are not considered standard.

1.5 *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.*

1.6 *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]

F3200 Terminology for Driverless Automatic Guided Industrial Vehicles

F3218 Practice for Documenting Environmental Conditions for Utilization with A-UGV Test Methods

F3244 Test Method for Navigation: Defined Area

F3265 Test Method for Grid-Video Obstacle Measurement

F3327 Practice for Recording the A-UGV Test Configuration

F3381 Practice for Describing Stationary Obstacles Utilized within A-UGV Test Methods

2.2 *Other Standards:*

ANSI/ITSDF B56.5-2019 Safety Standard for Driverless, Automatic Guided Industrial Vehicles and Automated Functions of Manned Industrial Vehicles [3]

ANSI/RIA 15.08 Safety Standard for Industrial Mobile Robots and Mobile Manipulators [3]

EN 60529 Degrees of Protection Provided by Enclosures (IP Code)[4]

BS EN 60529:1992 Degrees of Protection Provided by Enclosures (IP Code)[4]

[1] This guide is under the jurisdiction of ASTM Committee F45 on Driverless Automatic Guided Industrial Vehicles and is the direct responsibility of Subcommittee F45.91 on Terminology.

Current edition approved Aug. 1, 2020. Published September 2020. DOI: 10.1520/F3470-20.

[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 American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from European Committee for Standardization (CEN), Avenue Marnix 17, B-1000, Brussels, Belgium, http://www.cen.eu.

IEC 60509:1989 Degrees of Protection Provided by Enclosures (IP Code)[5]

2.3 *ASTM Adjuncts:*
Capabilities Report[6]

3. Terminology

3.1 Many terms used within this document are defined as in Terminology F3200. The following terms and definitions are used within this document and are not defined within Terminology F3200.

3.2 *Definitions:*

3.2.1 *capability, adj*—ability of an A-UGV (operating independently or within a fleet of A-UGVs) to perform a specified task.

3.2.2 *category, n*—a division of capabilities for an A-UGV (operating independently or within a fleet of A-UGVs) regarded as having particular shared characteristics.

3.2.3 *docking, v*—arrival and act of stopping at a position relative to another object.

3.2.4 *forcibly unlocalized, n*—an A-UGV that has been picked up and moved to another location (kidnapped) or is intentionally programmed that it is in the wrong location (for example, both a wildly-off position and an aliased position such as one aisle off).

3.2.5 *positioning, v*—arrival and act of stopping at a position relative to an absolute position in an environment.

4. Summary of Guide

4.1 The guide provides a list and description (see 5.4) of automatic through autonomous capabilities for industrial A-UGVs as compared to categories. Each category contains a set of capabilities, shown along the vertical axis of the example test report (see Section 9, Fig. 1), in which the guide-user can state, positively or negatively, the existence of a capability for an A-UGV.

5. Significance and Use

5.1 This guide is intended to be used by manufacturers and users of A-UGVs: (*1*) to fully define capabilities of their A-UGV(s) or (*2*) to allow the standard requestor to describe the A-UGV capabilities required for the requested A-UGV to align with assigned task(s). A-UGVs that are covered within ASTM Committee F45 are industrial vehicles that, for example, can be automatic guided vehicles through mobile robots, can be pre-programmed-through-autonomously controlled, can operate indoors or outdoors in infinitely diverse environmental conditions and therefore, with infinitely diverse functionality. To fully describe and measure the usefulness of these vehicles, functionality can be divided into categories where associated capabilities can be independently measured. This guide therefore provides a decomposition of many, perhaps not all, categories and capabilities that are typical of current A-UGVs globally marketed.

5.2 *Capability Categories:*

5.2.1 *Goal Navigation: Pre-Programmed*—Capabilities are the various abilities of the A-UGV to navigate a series of externally-defined waypoints on the way to a final goal.

5.2.2 *Goal Navigation: In situ*—Capabilities are the various abilities of the A-UGV to navigate to a final goal by using the A-UGV system's internal logic to determine the route.

5.2.3 *Localization*—Capabilities are the various abilities of the A-UGV to determine its pose within an environment map.

5.2.4 *Docking*—Capabilities are the various abilities of the A-UGV to stop at a position relative to another object or an absolute position in an environment.

5.2.4.1 *Infrastructure Dependence*—Sub-category describing the need of the A-UGV to rely on features in the environment for Goal Navigation: Pre-Programmed, Goal Navigation: In-Situ, Localization, or Docking.

5.2.5 *Obstacle Avoidance: Single Vehicle*—Capabilities are the various abilities of the A-UGV not to collide with an obstacle(s).

5.2.5.1 *Types of objects that can be avoided and are within the A-UGV envelope*—Describe the types of objects that can be avoided, as in 5.2.6, and are within the A-UGV envelope.

5.2.5.2 *Types of objects that can be avoided and are outside of the A-UGV envelope*—Describe the types of objects that the A-UGV can avoid, as in 5.2.6, and that are outside of the A-UGV envelope.

5.2.6 *Changing Contour Area or Envelope*—the A-UGV can change contour area or envelope using stock settings or while operating and stopped or moving.

5.2.7 *Changing Payload*—The A-UGV can transport fixed or moving payload(s) at 100 % rated weight and speed.

5.2.8 *Impaired Communication Behavior*—A-UGV action(s) when communication is disrupted.

5.2.9 *Lost Communication Behavior*—A-UGV action(s) when communication stops.

5.2.10 *Environmental Conditions*—Capabilities are the various abilities of the A-UGV to overcome environmental conditions. Section 5.4 provides example standards referencing ingress protection (IP) rating and examples referenced within Practice F3218-18 that affect mobility where other environmental conditions may also affect A-UGV capabilities (for example, electrical interference, humidity, etc.).

5.3 *Fleet Categories:*

5.3.1 Fleets of A-UGVs are defined in Terminology F3200 as a coordinated collection of vehicles. The following sections related to fleets provide descriptions of the capability categories that a single A-UGV has as one of the vehicles within a fleet.

5.3.2 *Fleet Makeup*—The A-UGV type as compared to the fleet: homogeneous (the same type and configuration as vehicles within the fleet), or heterogeneous (different type or configuration as vehicles within the fleet).

5.3.2.1 *Fleet Task Assignment*—Tasks can be given individually to the A-UGV or collectively to the A-UGV and the other vehicles within the fleet.

[5] Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, 1st floor, P.O. Box 131, CH-1211, Geneva 20, Switzerland, https://www.iec.ch.

[6] Available from ASTM International Headquarters. Order Adjunct No. ADJF3470-EA. Original adjunct produced in 2020. Adjunct last revised in 2020.

5.3.2.2 *Information Sharing/Updating (for example, presence of obstacles, environment map changes)*—The A-UGV can provide/receive data or knowledge to/from other A-UGVs or sensors.

5.3.2.3 *Fleet Navigation Coordination*—The A-UGV can interact with a fleet through a fleet controller for A-UGV navigation permissions or other navigation requirements.

5.3.2.4 *Fleet Task Coordination*—The A-UGV can share features (for example, task fulfillment requirements, such as: roller table docking issues causes a shifted pickup position; unit loader is required instead of a forklift) that the fleet can use to accomplish operations. A-UGV categories and capabilities are listed and described in the following sections. A standard test method is also shown in parentheses within a capability for those that are currently available as, for example Test Method F3244, to allow the capability to be repeatably tested.

5.4 *Goal Navigation: Pre-Programmed:*

5.4.1 Can navigate a preprogrammed path to the goal (Test Method F3244).

5.4.2 If encounters obstacle, can leave the preprogrammed path and return to the preprogrammed path to the goal (Test Method F3244, Practice F3381).

5.4.3 If blocked, can navigate an alternate preprogrammed path to the goal, for example, navigate a different hallway/aisle.

5.4.4 If blocked, can navigate multiple alternate preprogrammed paths to the goal, for example, navigate a third hallway/aisle if the second is blocked.

5.5 *Goal Navigation: In situ:*

5.5.1 Can determine and navigate an initial path to the goal (Test Method F3244).

5.5.2 If blocked, can determine and navigate an alternate path to the goal, for example, navigate a different hallway/aisle.

5.5.3 If blocked, can determine and navigate multiple alternate paths to the goal, for example, navigate a third hallway/aisle if the second is blocked.

5.6 *Localization:*

5.6.1 A-UGV can find its initial pose automatically.

5.6.2 Given an initial pose, A-UGV does not get lost in a static environment, for example, office building (Test Method F3244, Practice F3381).

5.6.3 Given an initial pose, A-UGV does not get lost in a dynamic environment, for example, warehouse with pallets being moved (Test Method F3244).

5.6.4 Given that the A-UGV is correctly localized, it becomes forcibly unlocalized, then it stops and requires human intervention to restart. The A-UGV becomes forcibly unlocalized when, for example, it gets picked up and moved to another location (kidnapped) or is intentionally told it is in the wrong location through software (both a greatly off position and an aliased position such as one aisle off).

5.6.5 A-UGV can automatically determine its pose after being forcibly unlocalized.

5.6.6 A-UGV can update its environment map based on detected changes in the environment, for example, continuous SLAM.

5.7 *Docking:*

5.7.1 Can position at preprogrammed waypoints, for example, absolute coordinates.

5.7.2 Can dock with a static object, for example, conveyer.

5.7.3 Can dock with a moveable, but stationary, object, for example, another vehicle, pallet, or cart.

5.7.4 Can dock with coordinated movement between the A-UGV and the dock, for example, mid-air fueling.

5.8 *Infrastructure Dependence*—Ability to rely on features in the environment. This category is a subset of Goal Navigation: Pre-Programmed, Goal Navigation: In situ, Localization, and Docking.

5.8.1 Can rely on features in the environment that were specifically installed to assist A-UGV operation, for example, magnetic tape, QR codes.

5.8.2 Can rely on natural features, for example, walls, racking.

5.9 *Obstacle Avoidance:*

5.9.1 Can stop when path is obstructed, for example, pallet in the path (Test Method F3244, Practice F3381, Test Method F3265).

5.9.2 Can navigate around static obstacles without collision, for example, navigating around a box partially blocking a hallway (Test Method F3244, Practice F3381, Test Method F3265).

5.9.3 Can navigate around moving obstacles without collision, for example, navigating around a moving vehicle that crosses the A-UGV path (Test Method F3244, Test Method F3265).

5.10 *Types of Objects that can be Avoided and are Within the A-UGV Envelope* (Practice F3381):

5.10.1 On ground, <10 cm obstacle height.

5.10.2 On ground, 10 cm to 20 cm obstacle height. Note that 20 cm is based on a test piece size described in ITSDF B56.5.

5.10.3 On ground, >20 cm obstacle height.

5.10.4 Elevated/suspended ≥20 cm and within the A-UGV envelope, <10 cm obstacle height. Elevated is measured from the bottom of obstacle to the ground.

5.10.5 Elevated/suspended ≥20 cm and within the A-UGV envelope, ≥10 cm obstacle height.

5.11 *Types of Objects that can be Avoided and are Outside of the A-UGV Envelope*:

5.11.1 Negative obstacles, ≤1 cm obstacle height, for example, missing tile.

5.11.2 Negative obstacles, >1 to ≤10 cm obstacle height, for example, removable panel on a raised floor.

5.11.3 Negative obstacles, >10 cm obstacle height, for example, loading dock, cliff, manhole.

5.11.4 Elevated/suspended above the A-UGV envelope and within the vertical projection of the A-UGV envelope.

5.11.5 Beside the A-UGV envelope.

5.12 *Changing Contour Area or Envelope:*

5.12.1 Can change contour area from stock settings;

5.12.2 Can change contour area while operating and stopped;

5.12.3 Can change contour area while operating and moving;

5.12.4 Can change envelope from stock settings;

5.12.5 Can change envelope while operating and stopped, and;

5.12.6 Can change envelope while operating and moving.

5.13 *Changing Payload:*

5.13.1 Can transport fixed payload at 100 % rated weight, speed, and;

5.13.2 Can transport moving payload (for example, robot arms, liquid tanks, shifting loads, unsecured (in bins), trailer loads) at 100 % rated weight, speed.

5.14 *Impaired Communication Behavior* (all sub-sections of 5.20 and 5.21 can refer to Test Method F3244)*:*

5.14.1 When communication is impaired, A-UGV stops and when communication resumes, requires human intervention in order to restart normal operation.

5.14.2 When communication is impaired, A-UGV stops and when communication resumes, does not require human intervention in order to restart normal operation.

5.14.3 While communication is impaired, A-UGV has modified operation, for example, drive slower.

5.14.4 While communication is impaired, continues normal operation.

5.15 *Lost Communication Behavior:*

5.15.1 When communication is lost, A-UGV stops and when communication resumes, requires human intervention in order to restart normal operation.

5.15.2 When communication is lost, A-UGV stops and when communication resumes, does not require human intervention in order to restart normal operation.

5.15.3 While communication is lost, A-UGV has modified operation, for example, drive slower.

5.15.4 While communication is lost, continues normal operation.

5.16 *Environmental Conditions:*

5.16.1 IP Rating: refer to IP Rating scale, for example, EN 60529 (British BS EN 60529:1992, European IEC 60509:1989).

5.16.2 For each capability, list the environmental condition (Practice F3218) under which the A-UGV can operate (for example, mobility: ground surface with elevation change up/down; gap; grade; deformability; undulation; floor particulates; coefficient of friction; boundaries (for example, cold storage curtains)).

5.17 *Fleet Makeup:*

5.17.1 *Homogenous A-UGVs.*

5.17.2 *Heterogenous A-UGVs:*

5.17.2.1 Same manufacturer,

5.17.2.2 Same manufacturer with different configurations, and,

5.17.2.3 Different manufacturer.

5.18 *Fleet Task Assignment:*

5.18.1 *Manual Task Assignment*—Give each A-UGV its own task;

5.18.2 *Automatic Task Assignment*—Give fleet controller tasks to be performed by the A-UGVs.

5.19 *Information Sharing/Updating, for example, presence of obstacles, environment map changes:*

5.19.1 One A-UGV's information is shared with one or more A-UGVs in its fleet from the same manufacturer;

5.19.2 One A-UGV's information is shared with one or more A-UGVs in its fleet from different manufacturers;

5.19.3 Information from a sensor connected to the A-UGV system informs one or more A-UGVs in its fleet from the same manufacturer;

5.19.4 Information from a sensor connected to the A-UGV system informs one or more A-UGVs in its fleet from different manufacturers;

5.19.5 External systems can inform the fleet.

5.20 *Fleet Navigation Coordination:*

5.20.1 Stop and wait for permission to use a traffic zone (one A-UGV per traffic zone);

5.20.2 Gets permission to use a traffic zone without requiring stopping (one A-UGV per traffic zone);

5.20.3 Stop and wait for permission to use a traffic zone (more than one A-UGV per traffic zone);

5.20.4 Gets permission to use a traffic zone without requiring stopping (more than one A-UGV per traffic zone);

5.20.5 Does not require traffic zones, requires communication with fleet controller or other vehicles, or combinations thereof;

5.20.6 Does not require traffic zones and does not require communication with fleet controller or other vehicles, or combinations thereof.

5.21 *Fleet Task Coordination:*

5.21.1 Tasks can only be given when they are able to be executed;

5.21.2 Can give future time that task needs to occur;

5.21.3 Tasks are performed by one A-UGV but can only be performed by a subset of the fleet;

5.21.4 Tasks can require collaboration of multiple A-UGVs;

5.21.5 Can reorder execution of tasks when given new tasks;

5.21.6 Tasks can have priority;

5.21.7 Can change A-UGV performance based on predicted future tasks;

5.21.8 Tasks can have dependencies of other tasks.

6. Hazards

6.1 Follow the hazards guidance as described in each of the listed safety standards in Section 2 (for example, ANSI/ITSDF B56.5; ANSI/RIA 15.08).

6.2 A description of hazards and mitigation procedures are described within each associated test method relative to a capability to be tested.

7. Procedure

7.1 This procedure describes how to complete the A-UGV Capabilities Report shown in Section 9, Fig. 1.

7.2 *Pre-Test Information Collection*—For data traceability and organization purposes, the test supervisor shall obtain and record the pre-test information first using the report form