



Designation: E2566 – 08

# Standard Test Method for Determining Visual Acuity and Field of View of On-Board Video Systems for Teleoperation of Robots for Urban Search and Rescue Applications<sup>1</sup>

This standard is issued under the fixed designation E2566; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the measurement of several key parameters of video systems for remote operations. It is initially intended for applications of robots for Urban Search and Rescue but is sufficiently general to be used for marine or other remote platforms. Those parameters are (1) field of view of the camera system, (2) visual acuity at far distances with both ambient lighting and lighting on-board the robot, (3) visual acuity at near distances, again in both light and dark environments, and (4), if available, visual acuity in both light and dark environments with zoom lens capability.

1.2 These tests measure only end-to-end capability, that is, they determine the resolution of the images on the display screen at the operator control unit since that is the important issue for the user.

1.3 This test method is intended to be used for writing procurement specifications and for acceptance testing for robots for urban search and rescue applications.

1.4 This test method will use the Snellen fraction to report visual acuity; readers may wish to convert to decimal notation to improve intuitive understanding if they are more familiar with that notation. Distances will be given in metres with English units in parentheses following.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Terminology

### 2.1 Definitions:

2.1.1 *field of view, n*—angle subtended by the largest object that can be imaged with the video system.

2.1.2 *optotype, n*—character used on a chart for testing visual acuity.

2.1.2.1 *Discussion*—Optotypes are generally built on a 5 by 5 grid, with the size for “standard” vision subtending a square 5 min of arc on a side. This makes one grid element 1 min of arc square.

2.1.3 *tumbling E, n*—specific optotype that can be drawn in various orientations (facing left, right, up, or down) and in various sizes to create an eye chart (see Fig. 1).

2.1.3.1 *Discussion*—This optotype is reported in the literature as being maximally distinguishable. Eye charts with Tumbling Es are available commercially for use at different distances.

2.1.4 *standard vision, n*—ability to resolve target features subtending 1 min of arc.

2.1.5 *visual acuity, n*—ability to resolve features subtending some angle, as compared with “standard” vision measured at the same distance.

2.1.5.1 *Discussion*—An angle  $\Theta$  subtends a feature of size  $h$  at a distance  $d$ , of size  $2h$  at a distance of  $2d$ , of size  $3h$  at a distance  $3d$ , and so on. If  $2d$  is the “standard” measurement distance of 6 m (20 ft), an eye chart for use at 3 m (10 ft) would have characters of  $h$  high rather than  $2h$  high and the measurement of visual acuity would be the same. See Fig. 2 for an illustration of the angle/distance relationship.

2.1.6 *Snellen fraction, n*—a measure of visual acuity.

2.1.6.1 *Discussion*—The subject is placed a standard distance from an eye chart, typically 6 m (20 ft). The subject is asked to identify the line with the smallest characters that he can resolve. The Snellen fraction is the ratio of the distance at which that line would be resolved by a subject with standard vision to the standard test distance. Thus, a subject with standard vision would have 6/6 (20/20) vision.

2.1.7 *remote operation, n*—act of controlling a distant robot on a continuous or intermittent basis via tethered or radio-linked devices while being provided with sensory information (for example, visual information through cameras onboard the robot).

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee E54 on Homeland Security Applications and is the direct responsibility of Subcommittee E54.08 on Operational Equipment.

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FIG. 1 Tumbling E Optotype in Various Orientations

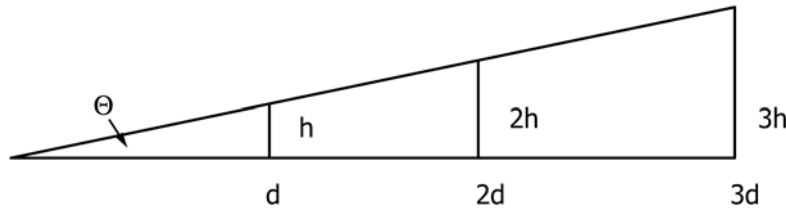


FIG. 2 Angle Subtended by Various Size Objects at Various Distances

2.1.7.1 *Discussion*—Remote operation includes teleoperation as well as forms of intermittent autonomy or assisted autonomy.

### 3. Units for Reporting Visual Acuity

3.1 The commonly used distance for measuring visual acuity is 20 ft in the United States. This leads to the “Snellen fraction” as the common measure of visual acuity: 20/20, 20/40, and so on. The Snellen fraction is also used in England, referred to 6 m as the standard measurement distance (6/6, 6/12, etc.), while the rest of Europe generally used the decimal fraction equivalent:  $20/20 = 6/6 = 1.0$ ;  $20/40 = 6/12 = 0.5$ , etc. Measurements may be taken at any distance and the result scaled to the common distance.

3.2 The meaning of 6/12 (20/40 or 0.5) is that features that can be resolved at 6 m (20 ft) by the test subject are of a size such that a person with “standard” visual acuity could resolve them at 12 m (40 ft). The characters on the 6/12 (20/40, 0.5) line of an eye chart are twice the size of the characters on the 6/6 (20/20, 1.0) line. The best human vision is not 6/6 (20/20, 1.0), resolving 1 min of arc ( $1/60^\circ = .016^\circ$ ) but more like 6/3.6 (20/12, 1.7), resolving about  $0.01^\circ$ .

### 4. Significance and Use

4.1 Responder-defined requirements for these test methods are documented in a preliminary document entitled “Statement of Requirements for Urban Search and Rescue Robot Performance Standards.”<sup>2</sup>

4.2 Field of View is important in terms of the ability of the operator to drive the robot. Looking at the world through a zoom lens is like “looking through a soda straw.” Looking with a 30 or 40° field of view lens is like “driving with blinders on.” On the other hand, using a very wide field of view lens (with a field of view of 120 or 150°), the operator’s use of optic flow to cue depth perception is severely degraded and navigating in a tight environment is very difficult. Multiple cameras are

recommended, with one providing a very wide field of view or all together providing a very wide field of view.

4.3 Far Vision Visual Acuity is important for both unmanned air vehicles (UAVs) and ground vehicles for wide area survey. Zoom is required for ground vehicles for wide area survey.

4.4 Near Vision Visual Acuity is important for ground vehicles for wide area survey in examining objects at close range and also for small robots which operate in constrained spaces.

4.5 Testing in the dark is important for small robots since they must sometimes operate in spaces with no ambient lighting.

### 5. Hazards

5.1 There are no hazards and no environmental issues associated with this test method.

### 6. Procedure

#### 6.1 Field of View:

6.1.1 The test environment for 6.2 below is established, with eye charts on a wall and the robot located at a set test distance 6 m (20 ft) away from the wall (see Fig. 3). Vertical lines are drawn on the wall subtending fields of view from the test distance of 20 to 60° (or more if space allows) in increments of 10° and labeled.

6.1.2 Taking the line from the robot camera to the center of the eye chart as the center line, field of view lines need only be drawn to one side because of symmetry.

6.1.3 Determine field of view and record the result.

6.1.4 If the camera lens has a field of view beyond 60°, and test site space does not allow further reference marks, the field of view can be calculated using trigonometry (see Fig. 4).

$$\text{Field of View} = 2 \phi = 2 \tan^{-1}(h/d)$$

6.1.4.1 Beyond 100° h becomes very large and using trigonometry may be impractical. The vendor will generally know the field of view of the lens provided with the camera, or an estimate may be made. High precision is not important in determining the field of view since this only provides an

<sup>2</sup> Messina, E., et al., “Statement of Requirements for Urban Search and Rescue Robot Performance Standards,” [http://www.isd.mel.nist.gov/US&R\\_Robot\\_Standards/Requirements\\_Report\\_\(prelim\).pdf](http://www.isd.mel.nist.gov/US&R_Robot_Standards/Requirements_Report_(prelim).pdf)



FIG. 3 Test of Visual Acuity and Field of View

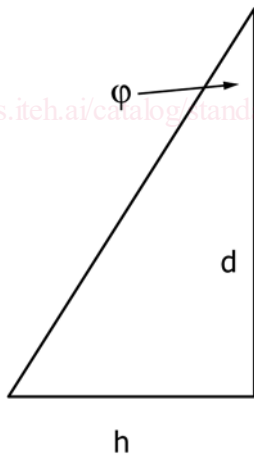


FIG. 4 Geometry of Field of View Determination

indication as to the limitations of the view of the operator when driving the robot. 10° resolution is adequate.φ

6.1.5 If the robot is equipped with multiple cameras, all cameras used for remote driving shall be measured.

6.2 Visual Acuity—Far Vision with Ambient Illumination:

6.2.1 This test determines the visual acuity available to the operator at the operator control unit when the camera on the robot is focused on distant objects (more than a few metres or so distant from the robot). The display on the screen at the

operator control unit integrates the effects of camera, the sensor within the camera, digitization of the signals, transmission of the data, reconstruction of the images, and resolution of the display screen. Since the visual image as presented to the operator is the key issue in remote operation, there is no need from the user's perspective to resolve these various contributing factors. Developers of robots, on the other hand, may need to analyze each of these factors separately. This standard is written from the standpoint of evaluation and procurement by the user.

6.2.2 Eye charts are placed on a wall with illumination >1000 lux (typical of room lighting). The optotypes of a standard eye chart for use at 3 m (10 ft) or 6 m (20 ft) typically cover a range from 6/3 to 6/60 or 6/100 (20/10 to 20/200 or 20/300; 2.0 to 0.1 or 0.07). The optotypes thus subtend 2.5 min of arc at the smallest to 50 or 75 min of arc at the largest. As noted earlier, a 3 m eye chart can be used at 6 m and the results scaled (the 6/6 line on a chart designed for 3 m represents 6/3 acuity when used at 6 m). If necessary, larger optotypes can be printed to extend the measurement range to 6/180 (20/600; 0.03), at which point the optotypes would subtend 2.5°. If the robot has zoom capability, a close range eye chart (for testing reading ability, typically for use at 40 cm (16 in.)) should be mounted below the larger eye chart. Using the 40 cm chart at 6 m and successfully reading the 6/4.5 (20/15, 1.33) line with a zoom lens would be equivalent to 6/0.3 (20/1, 20.0) vision since  $600/40 = 15$ ;  $15 \times 1.33 = 20.0$ .