SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
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SURFACE VEHICLE RECOMMENDED PRACTICE

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(R) Instrumentation for Impact Test—Part 2: Photographic Instrumentation

1. ***Scope***—The purpose of this SAE Recommended Practice is to define criteria of performance for an optical data channel when numerical time and space data are taken from the images to analyze impact test results.

2. ***References***

2.1 Applicable Publications—The following publications form a part of this document to the extent specified herein. The latest issue of all publications shall apply. In the event of a conflict between the text of this document and references cited herein, the text of this document takes precedence.

2.1.1 ISO PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO/TC 22/SC12/WG3—Multimedia Data Exchange Format for Impact Tests

3. ***Definitions***

3.1 Analysis System—A system for measuring and collecting the coordinates of image points as a function of time and converting them into coordinates in object space.

3.2 Average Distortion Error—A quality parameter of the optical data channel that measures symmetrical image distortion independent of any noise and misalignment present.

3.3 Data Collection Error—A quality parameter of the optical data channel that measures the precision with which the analysis system can locate coordinates of image points. This is often referred to as the “noise” in the data collection process.

3.4 Horizontal Field of View (HFOV)—The longer of the two sides of a camera's image.

3.5 Imaging Rate—The frequency of renewal of information for a given point expressed in renewals per second.

3.6 Misalignment Error—A quality parameter of the optical data channel that measures the image distortion due to any camera-to-target pattern misalignment that may have existed when the target pattern was imaged, and any lens de-centering.

3.7 Optical Axis—A straight line which passes through the centers of curvature of the camera lens surfaces. In a perfectly aligned camera system, this line would intersect the image plane at the center of the image.

3.8 Optical Data Channel—A system composed of an image taking device (for example, camera and lenses), a recording medium for these images (film, disc, magnetic tape), an optical path (for example, fiber-optic cable) and a system for analyzing the images, including any analysis procedure.

3.9 Overall Error—An overall quality parameter of the optical data channel that quantifies image distortion, noise and misalignment present in the system.

3.10 Time Base System—A system to enable the determination of the time interval between any two recorded events.

3.11 Time Origin Identification—A method for identifying and recording the instant chosen as the time origin, usually the beginning of impact or other defined event.

3.12 Validation Target Pair—A pair of targets placed in the field of view such that the distance separating them remains constant, and that they are both visible throughout the impact test.

4. Performances—The performances of the optical channel should be evaluated initially to establish performance levels and repeated whenever the system is modified to an extent which could cause a change in accuracy or whenever indicated by degradation in a validation target pair assessment.

4.1 Optical Performance—The optical performance is determined by analyzing the variation of apparent distances between targets on the Target Pattern Drawing and the actual distances according to the procedure described in the Appendix A, or in an equivalent manner. These performance parameters provide the position errors in terms of a percentage of the HFOV. The error expressed in engineering units may then be calculated if the width of the area to be imaged during the test is known.

4.1.1 OVERALL ERROR—This parameter is useful in determining the maximum error present, regardless of the source. Each standard or specification that references this document should establish an upper limit for this parameter that is appropriate for the intended application. For reference, the maximum error produced by a typical high quality system is less than 0.25%.

4.1.2 DATA COLLECTION ERROR—This parameter quantifies the random errors that occur when determining the centers of the targets. This parameter is also useful for comparing the accuracy potential of various lens/ camera/analysis system combinations. Since the procedure used to derive this parameter is also sensitive to any camera to target misalignment, careful setup is required in order to make an accurate assessment.

4.1.3 AVERAGE DISTORTION ERROR—This parameter quantifies the error due to symmetric distortion, independent of other sources. This can be very useful in evaluating those systems that have a high Data Collection or Misalignment Error.

4.1.4 MISALIGNMENT ERROR—This parameter is useful in determining the source of a larger than expected Overall Error. A large misalignment error indicates that either the camera axis was not perpendicular to the Target plane, or there is a misalignment between the lens elements and the image plane (caused by a manufacturing defect in one or both). Since this parameter is also affected to some degree by the Data Collection Error, it should be compared with it to determine the dominant factor.

4.2 Time Base—A time base is required. It shall permit the determination of the time between recorded events with an error of less than 10% of the reciprocal of the imaging rate or 0.2% of the actual time, whichever is greater.

4.3 Time Origin Identification—The accuracy of the method shall be at least equal to the value expressed in seconds of the reciprocal of the imaging rate.

4.4 Imaging Rate—The imaging rate shall be left to the user's initiative, taking into account the intent of the imaging coverage and the following main four factors:

a. Aliasing
b. The limitations due to the equipment (blur, etc.)
c. The need to combine data from several image taking devices and from electronic recordings of the impact test.
d. Expected object motion frequencies of interest

4.5 Length Reference

4.5.1 A length calibration shall be performed which permits the determination of lengths within any requirements set for their accuracy. Each standard or specification that references this document should establish an accuracy requirement that is appropriate for the intended application.

4.5.2 The accuracy of length calculations may be assessed for each impact test by comparing the determined distance between two points with the actual distance between them. This validation target pair should be separated by at least 1/6 of the horizontal field of view, be fixed with respect to one another, and not be the only points used for length calibration. When viewed by cameras that do not travel with the test subject, target pairs should be placed so that they are oriented perpendicular to the direction of motion, traverse the field of view during the impact test, and remain visible in all frames of interest. When tracked throughout the test, the determined distance between these targets should remain constant and be equal to the actual distance.

5. Image File Format—To permit universal access to high-speed images for analysis, archiving, and interchange, image files should be producible that conform to the requirements of ISO/TC 22/SC12/WG3 Multimedia Data Exchange Format for Impact Tests.

6. Notes

6.1 Marginal Indicia—The (R) is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

6.2 Key Words—Instrumentation, photographic, impact test, distortion, error, accuracy, file format.

PREPARED BY THE SAE SAFETY TEST INSTRUMENTATION STANDARDS COMMITTEE

APPENDIX A

RECOMMENDED PROCEDURE FOR DETERMINING THE PERFORMANCE OF AN OPTICAL DATA CHANNEL

***A.1 Test Equipment*—**A Target Pattern Drawing shall be used that is of the appropriate shape for the imager being tested and has dimensions in conformity with the specifications:

The drawing consists of a target at the center of the FOV, four groups of 3 targets located along the outermost portion of each diagonal, and a centered circle of eight equally spaced targets. The narrowest dimension of the imaged area (Target Height) shall be 750 mm. The other dimension (Target Width) shall be as required to fit the aspect ratio of the camera image. Frame edge markers (25 mm tall, filled triangles) are placed at the mid- point of each imaged area sides. The circle radius and the spacing of the target marks along each diagonal shall be calculated using Equation A1, then rounded to the nearest millimeter.

$$\text{Spacing} = \langle \left\{ [(\text{Target Height})^2 + (\text{Target Width})^2]^{1/2}/2 \right\} - 25 \rangle / 4 \qquad \text{(Eq. A1)}$$

The heavy border shall be 5 mm wide with its centerline 20 mm beyond the imaged area. The targets used shall be 25 mm in diameter.

Each of the circle targets shall be rotated such that its primary axis is tangent to the circle.

Drawings meeting these specifications for 4/3 or square aspect ratios are shown in Figures A1 and A2. CAD files of the two drawings are available from SAE. Other targets, as required for specific analysis software or procedures, may be substituted for those shown in the Figures. This drawing must be printed on a stable based material and bonded to a flat surface to avoid dimensional errors. If desired, a sub-scale size of the drawing may be used.

***A.2 Test Procedure*—**The drawing shall be exposed "full frame" by the camera forming one of the elements of the data channel to be tested. Framing shall be such that the image shows the frame edge markers and all of the targets but not the heavy border. Also, the camera must be aligned such that the optical axis is perpendicular to the drawing plane.

If film or video tape is used to store images for evaluation, it shall be of the same type and quality as that used for impact testing.

The coordinates shall be measured with the same analysis equipment and procedures that are used for impact testing.

The coordinates of all targets shall be measured on the same frame.

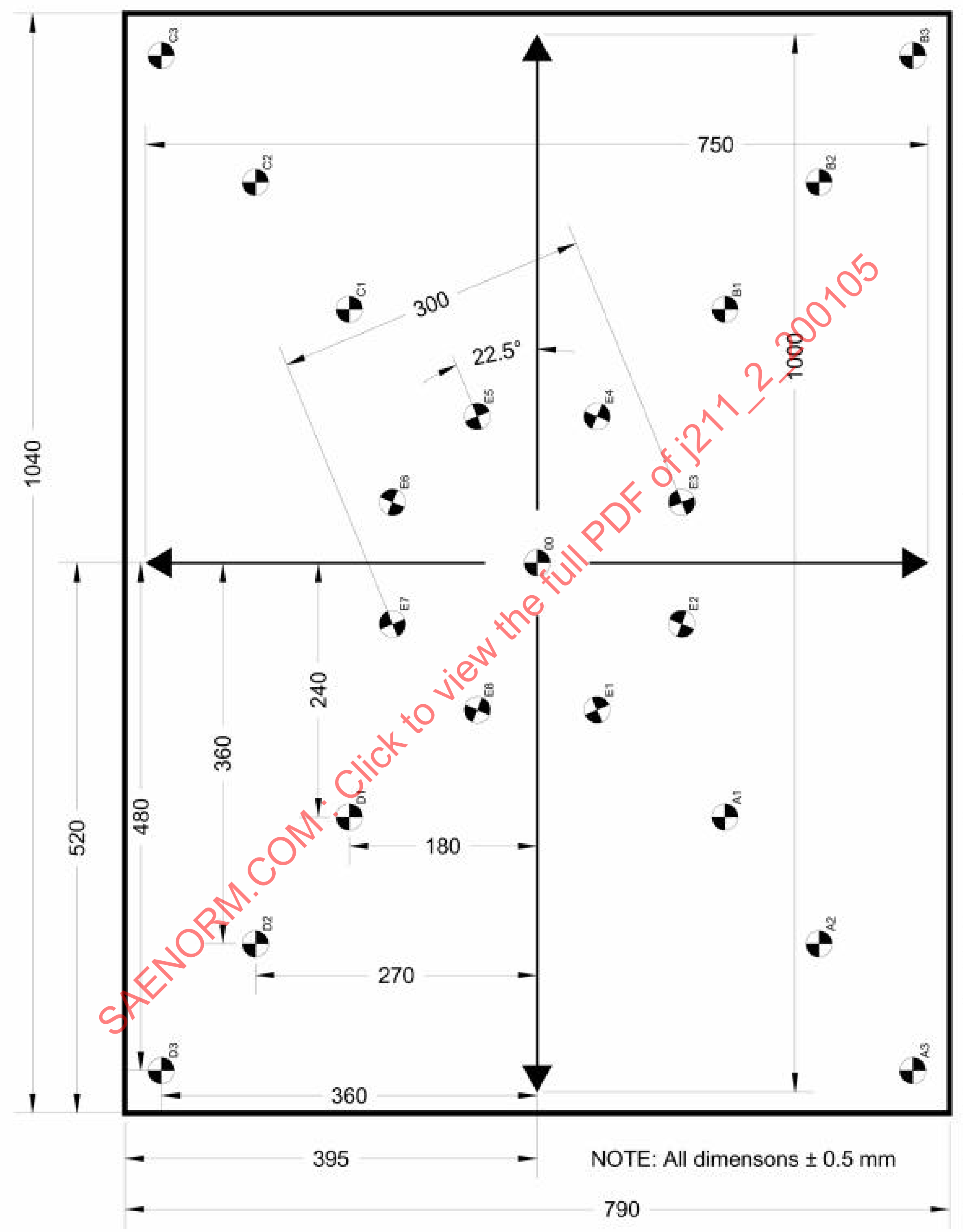

FIGURE A1—4 BY 3 RATIO TARGET PATTERN DRAWING

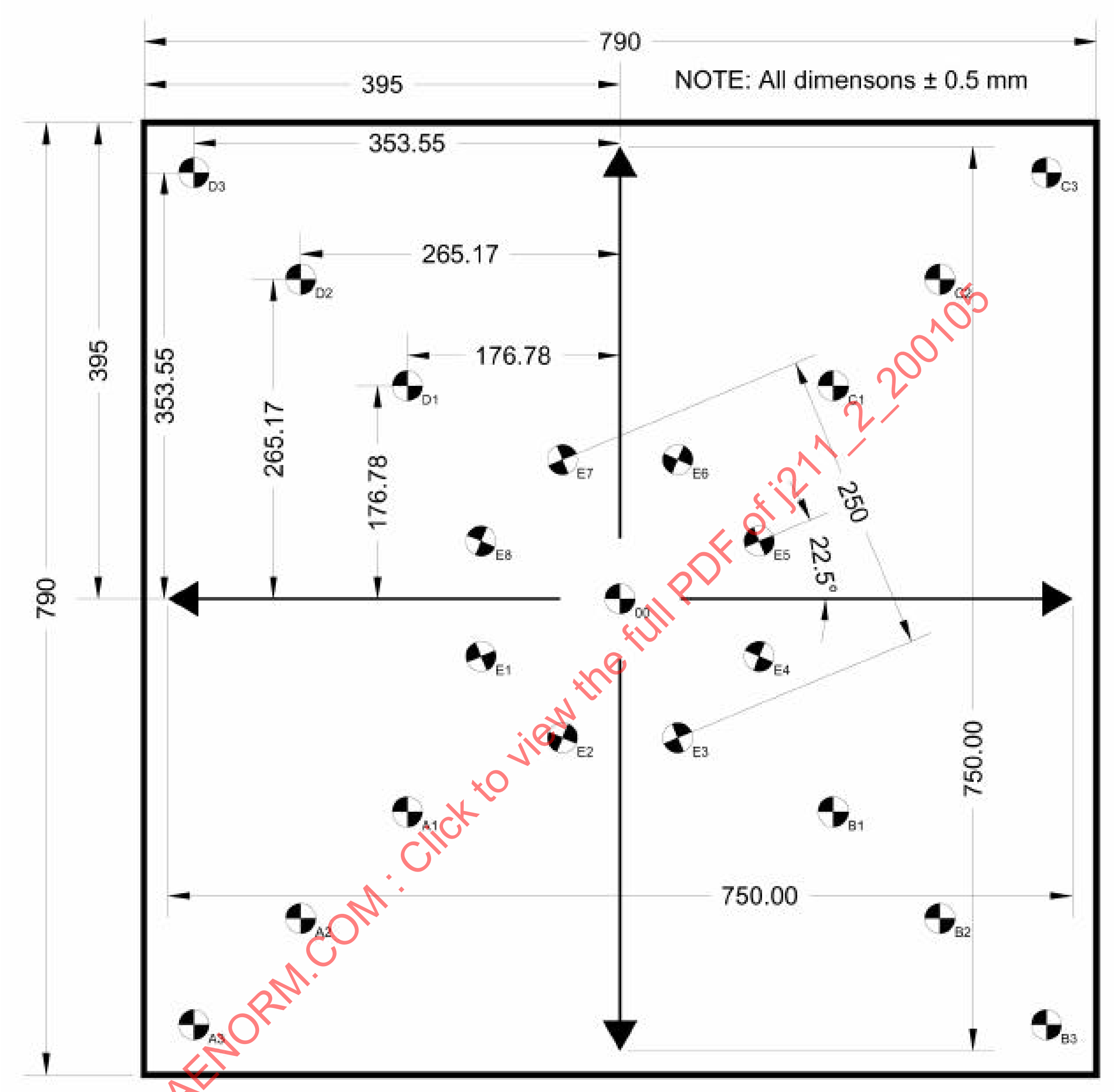

FIGURE A2—SQUARE TARGET PATTERN DRAWING

***A.3 Analysis*—**For each diagonal, i = 1 to 4, label the 3 targets j = 1 to 3, from the center outward. For the circle, i = 5, label the targets j = 1 to 8. Calculate optical accuracy as follows:

A.3.1 Data Collection Error—The measured diameters (d_{ij}) of the circle shall be calculated using Equation A2:

$$d_{ij} = [(x_{ij} - x_{i,j+4})^2 + (y_{ij} - y_{i,j+4})^2]^{1/2} \quad \text{(Eq. A2)}$$

where:

i = 5
j= 1,2,3,4

The mean diameter (D) and the standard deviation (S) shall be calculated taking the 4 diameter values (d_{ij}) into account per Equations A3 and A4:

$$D = \left(\sum_{j=1}^{4} d_{ij}\right) / 4 \quad \text{(Eq. A3)}$$

$$S = \left\{\left[\sum_{j=1}^{4} (d_{ij} - D)^2\right] / 3\right\}^{1/2} \quad \text{(Eq. A4)}$$

Calculate the scale factor (F) per Equation A5:

$$F = D / L \quad \text{(Eq. A5)}$$

where:

L= 300 for Figure A1
L= 250 for Figure A2

The Data Collection Error, expressed as a percentage of the Horizontal Field of View, is (2*S)/(F*Target Width) multiplied by 100%.

A.3.2 Overall Error—The actual location of each target (a_{ij}, b_{ij}) with respect to the center target, and the measured location of each target (x_{ij}, y_{ij}) corresponding to the Target Pattern Drawing imaged shall be used in Equations A6 and A7. Calculate the measured radial distances (r_{ij}) and the actual scaled radial distances (R_{ij}) per Equations A6 and A7:

$$r_{ij} = [(x_{ij} - x_{00})^2 + (y_{ij} - y_{00})^2]^{1/2} \quad \text{(Eq. A6)}$$

$$R_{ij} = F[(a_{ij})^2 + (b_{ij})^2]^{1/2} \quad \text{(Eq. A7)}$$

where:

i = 1,2,3,4
j = 1,2,3

The maximum error (E), calculated per Equation A8 is the maximum difference between the measured radial distance (r) and actual scaled radial distance (R) from the center target to each target.

$$E = MAX[ABS(r_{ij} - R_{ij})] \quad \text{(Eq. A8)}$$

where:

i = 1,2,3,4
j = 1,2,3

The Overall Error, expressed as a percentage of the Horizontal Field of View, is E/(F*Target Width) multiplied by 100%.

A.3.3 Average Distortion Error—The average radial error (A_j) for each group of symmetrically dispersed targets j = 1 to 3, is calculated using Equation A9:

$$A_j = \left[\sum_{i=1}^{4} (r_{ij} - R_{ij})\right] / 4 \quad \text{(Eq. A9)}$$

where:

i = 1,2,3,4

The maximum average error (A) is calculated using Equation A10:

$$A = MAX[ABS(A_j)] \quad \text{(Eq. A10)}$$

where:

j = 1,2,3

The Average Distortion Error, expressed as a percentage of the Horizontal Field of View, is A/(F*Target Width) multiplied by 100%.

A.3.4 Misalignment Error—The maximum misalignment error (M), calculated per Equation A11, is the maximum error (E) less the maximum average error (A):

$$M = E - A \quad \text{(Eq. A11)}$$

The Misalignment Error, expressed as a percentage of the Horizontal Field of View, is M/(F*Target Width) multiplied by 100%.

***A.4 Alternate Procedure*—**Other target pattern drawings with different sizes or patterns of targets may be used, in which case the user has to determine the accuracy in an indirect way.

There is then also a need to show that the indirect method gives a result equivalent to the use of the pattern specified in this appendix.

Development of an alternate procedure may be advantageous if a specific pattern of targets is employed for the determination of lens corrections, which is needed for some wide-angle lenses.