The dSam Depth of Field Test Chart

By David Samuelson

The dSam Depth of Field Test Chart is a method for exploring and then assessing depth of field photographically by the use of a three-dimensional test chart which is based on a systematic optical-mathematical range of test chart distances and spatial frequency test targets on each test chart.

Before shooting a motion picture it is normal for the camera crew to make photographic tests using all the cameras and lenses that will be available to them. Usually they shoot both camera steadiness and lens focus tests using test charts especially designed and made for the purpose. In such a manner, many aspects of optical performance may be tested, even though such tests may be limited to only one plane of focus.

The cinematographer, however, is also critically interested in the depth of field in front of the camera. Until now there has been no systematic method of measuring this vital feature of lens performance.

The dSam Depth of Field Test Chart is an entirely new means to evaluate depth of field. Rather than just looking at lens definition, resolution, and contrast at a single plane of focus, the dSam chart system explores the way a lens photographs an object which has depth as well as height and width.

Lenses do not only photograph "in-focus" flat surfaces, but also include other very important parts of a scene which are nearer to and farther from the camera than a single plane of focus. Inevitably, objects that are away from the plane of focus will be less sharply defined, and the extent to which they are in or out of acceptable focus defines the "depth of field."

The dSam Depth of Field Test Chart enables a photographer to assess and explore the amount of available and usable depth of field.

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Editorial note: The dSam Depth of Field Chart is available for sale by the SMPTE. For price and delivery information, contact the SMPTE Test Materials Dept. at (914) 761-1100.

Aspects of a Lens and its Use that Most Affect Depth of Field

Depth of field depends upon the circumstances in which we select and use a lens:

Factors tending to **more** depth of field include:

- Shorter focal length lens
- Smaller lens aperture
- Larger acceptable circle of confusion*
- Distant plane of critical focus
- Smaller film format

Factors tending to **less** depth of field include:

- Longer focal length lens
- Larger lens aperture
- Smaller acceptable circle of confusion*
- Close plane of critical focus
- Larger film format

Perceived Depth of Field

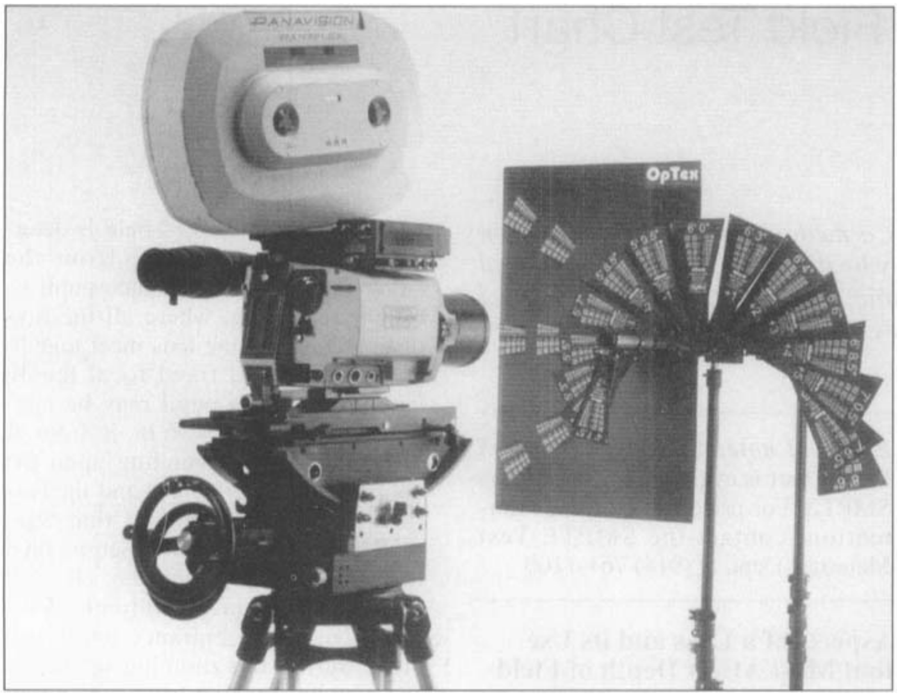
Acceptable depth of field is influenced by many factors:

- The inter-relationship of the optical functions of the lens and the way it is used, as above.
- The position of the entrance pupil of the lens relative to the focus plane in front of the camera.

In cinematography we traditionally measure focusing distances from the film plane, but depth of field is determined by the distance from the entrance pupil. The entrance pupil is, roughly speaking, where all the rays of light entering the lens meet together. For a normal fixed focal length lens the entrance pupil may be anything from about 2 to 6 in. in front of the focal plane, depending upon the optical design of the lens and the lens focal length. This means that with such lenses, when we are focused on 6 ft, the entrance pupil may be, say, 5 ft 6 in. away from the object. With zoom lenses the entrance pupil will move during the zooming operation and may be anything from, say, a foot or more in front of the focal plane at the wide angle end, to somewhere behind the camera operator at the long focal length end. All this influences the depth of field.

- The optical properties of the lens. A "soft" lens will appear to have greater depth of field because what is out of focus is less noticeable when compared to the critical point of focus than with, particularly, the latest types of lenses where anything the least bit out of focus stands out like a sore thumb. Hence with the newer lenses it may be appropriate to work to, say, a 1/2000-in. circle of confusion.
- The subject and the lighting. If the principal subject in sharp focus is a hairy, a spiky, or, in some other way, a well defined and contrasty object, and if in the background there is a well-lit out-of-focus object, then, subjectively, that out-of-focus object may dominate the scene and there will appear to be less depth of field.
- The recording and/or the delivery medium. Modern fine grain film stocks are very "sharp," contributing greatly to the need to work to a smaller circle of confusion than used to be the case. TV systems are less critical.
- Mechanical errors. If the film is not at the correct distance from the lens flange, or does not lie perfectly flat and square to the optical axis, the depth of field will be affected. So crit-

* The circle of confusion (C of C) may be defined as the diameter of the blur circle at the film plane created by an infinitely small spot of light in the field of view in front of the camera. For professional 35mm cinematography a C of C of 1/1000 in. (0.0254mm) is a common standard to define depth of focus.



The dSam Depth of Field Focus Chart Array.

ical are these factors that camera manufacturers set their flange focal distances slightly less than those set by the lens manufacturers so that the lenses focus in the middle of the film emulsion layer.

• Camera and projector steadiness. If the camera and/or projector, and the placement of the film in the gate or aperture are not perfectly stationary during the entire time that the camera or projector shutter is open, then the resolution will be adversely affected.

(In the case of cine film in the gate it will be the resolution of horizontal lines that will be most affected.)

• The proximity of the audience to the viewing screen and their viewing angle. When viewing a widescreen movie in a large theatre the average person in the audience may be one screen width, or even less, away from the screen, whereas when watching a domestic TV screen at home the average audience may be five screen widths away. This can make an enormous difference to the perception of acceptable focus.

Finally, focus bias may require that the near and far distances of a focus split are not equally sharp. It sometimes happens that there is, say, a conversation between two people of which one person is more important than the other. In this case it may be desirable to subtly bias the focus split towards the more important person.

Judging Depth of Field

Depth of field cannot be judged satisfactorily through a ground glass viewfinder system. Finely textured focusing screens are good for assessing if a lens is set at its optimum position for sharp focus, and also for showing if an image is out of focus, but they are not very good for quantifying the limits of acceptable focus in-between.

This is mainly because the human eye can adapt to different focus positions and therefore accommodate to see images which are out of focus at the film/focusing screen plane. It is also because modern lenses resolve finer detail than the film camera-negative-print-projector-screen chain can record and reproduce and because most focusing screens have the finest possible texture in order to ensure the brightest and best optical quality for the video assist image.

Methods of Testing Depth of Field

Photographing a single, flat test chart does not help to test or predict depth of field in any way.

In the past, depth of field has been tested by means of what is often know as a "harp" chart. This comprises a frame with parallel strings or wires drawn from one side of the frame to the other. The frame is then placed obliquely through the field of focus and in this manner the fall-off in focus on either side of the plane of critical focus can be seen. Sometimes small tags are attached to the strings to mark specific distances. This system is of limited use unless there is an optical-mathematical co-ordination between the spacing of the strings and the sizes of the tags. It is the author's experience that charts of this type are rarely calibrated in this way, and if they are they do not conform to any systematic standard.

The dSam Depth of Field Focus Chart Array

The system comprises a series of triangular shaped test charts of systematically graded size, set spirally and at accurately pre-determined focus distances along the length of a pole, so that when viewed from the end of the pole they appear to be all of the same size and together form a circular array of charts in the field of view of the camera.

The test chart at the nominal plane of focus is set vertically in the top centre of the image area. The others are set nearer and farther from the camera in cork-screw fashion, so that when they are all viewed from the end of the pole the charts that are closer to the camera appear as a semicircle on the left and those that are farther away from the camera are on the right. There are 15 charts in all, seven on each side of the plane of critical focus.

The two most important aspects of the dSam test chart system are:

• The distances that the pairs of nearer and farther charts are away from the central critical focus chart are just those distances that are required to achieve an equal degree of acceptable focus.

By adjusting the lens aperture setting by one whole stop, this acceptable degree of focus then extends between the next pair of nearer and farther charts, giving a smaller or greater depth of field, depending on

Table 1. Comparative Lens Performance

	Test Pattern Number to Achieve 1/000-in. C of C						
	n-3	n-2	n-1	n	n+1	n+2	n+3
Test Chart Array	**Lens Focal Length (mm)**						
3 ft 0 in. or 1 m	17.5	20	22	**25**	28	32	35
6 ft 0 in. or 2 m	35	40	45	**50**	55	65	70
12 ft 0 in or 4 m	70	80	90	**100**	112	125	140

Where n = the test pattern number resolved by the standard focal length lens.

whether the lens iris has been opened or closed by one stop.

• The sizes of the focus charts are scaled, relative to the central chart, so that when viewed from the camera position all the charts, and the range of resolution targets displayed on them, appear to be of exactly the same size.

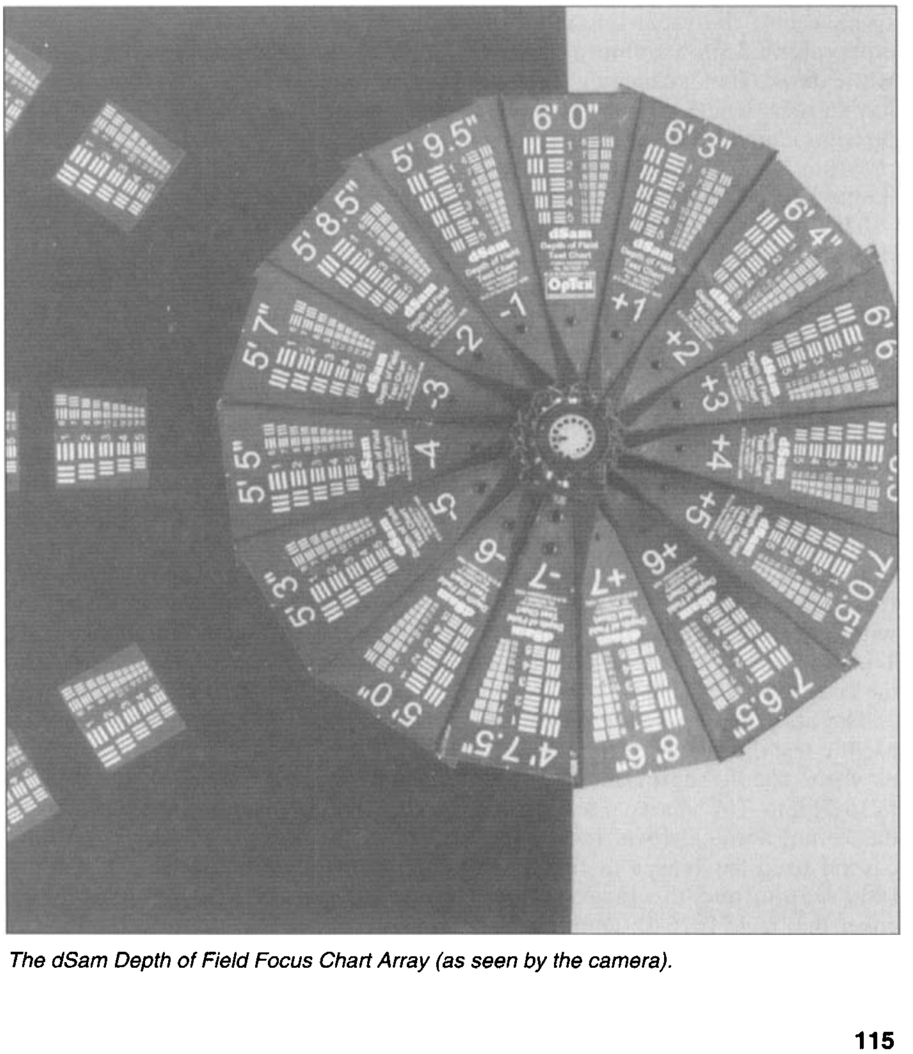
The individual charts are each inscribed with their distance from the entrance pupil of the lens and with their sequential number relative to the central chart. In this way the charts nearer to the camera are numbered (starting at the center chart) -1, -2, -3, -4, -5, -6 and -7, and beyond the central chart they are numbered +1, +2, +3, +4, +5, +6 and +7.

The distances each pair of charts are placed at relative to the camera correspond to the near and far limits of the depth of field as calculated from the position of the central critical focus chart, and spaced in increments of distance which correspond to steps of one stop in aperture for a specific C of C at the film.

For example, for a 50mm focal length lens covering an Academy cine frame, a central critical focus test chart of 10 in. (254 mm) radial length, placed 6 ft (1829 mm) away from the entrance pupil of the lens proves to be a convenient choice, in that the polygonal image of the complete array of test charts will have a diameter of 14.28 mm on the film, whereas the maximum possible picture height is 16.03 mm, so allowing clearance for a range of lens focal lengths around 50mm to be tested using the same test chart array. Thus, with the standard chart array a range of focal lengths from 35mm to 75mm may be tested. With the 75mm lens the circular film test image will be larger because the chart is positioned at the same distance from the camera as for the 50mm lens, and for the 35mm lens it will be smaller, and so the C of C of interest at the film in each case will correspond to the finer and coarser resolution targets displayed on each of the test charts respectively. The lens entrance pupil is the datum point for positioning the test charts' critical plane of focus.

The entrance pupil is also the datum point from which the relative sizes of the individual resolution charts are calculated, so that they all have the same angular size as seen from that point. This means that when the camera is positioned such that the entrance pupil of the lens is at the correct position all the charts appear to be the same size when viewed through the camera viewfinder.

Thus, the entrance pupil of the lens can be positioned by moving the camera forwards and backwards until the nearest and farthest charts (-7 and +7) have the same size as seen through the camera viewfinder. Chart numbers -7 and +7 have an arrow on them and the procedure to locate the entrance pupil is to align the two arrows, as seen through the viewfinder. The entrance pupil is then at the correct position. For reference purposes it is often useful to record the entrance pupil position that is revealed by this adjustment. The entrance pupil position is 6



The dSam Depth of Field Focus Chart Array (as seen by the camera).

ft away from the critical focus chart in the case of the standard array of charts, and at the equivalent distance away from the critical focus chart in the case of the other arrays. The entrance pupil position is not only important because it is the datum point for depth of field, but also because it is the point about which the camera can be panned and tilted to avoid parallax displacement between the images of objects at different distances in front of the camera.

The dSam Depth of Field Test Chart is primarily intended for use with 35mm motion picture film formats, but it can just as well be used for the 16mm or 65/70mm formats, or for video or still cameras. With these alternative formats the C of C diameters will usually be different, but one can work with the chart in such a way that the size of the chart image is the same proportion of picture height as it is in the case of the 35mm film format. In this way, 16mm camera lenses used with the dSam chart will generally have half the focal length of the equivalent 35mm camera lenses, while the 65/70mm camera lenses will have a focal length which will usually be approximately one and a half times the focal length of the equivalent 35mm lens.

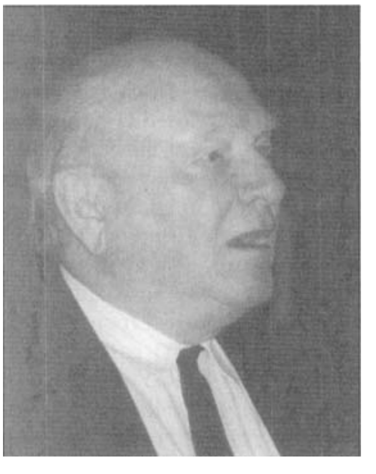
The standard test chart array, as described above, is based on a nominal lens focal length of 50mm used on a 35mm cine camera filling an Academy format, with the critical focus chart set at 6 ft or 2 m, depending upon whether the imperial dimensioned chart array or the metric array is being used. In addition to these two chart arrays there are also two other pairs of chart arrays: one for a nominal focal lens focal length of 25mm and the other pair for a nominal lens focal length of 100mm. The former is set with its critical focus chart at 3 ft or 1 m from the lens entrance pupil and the latter are set at 12 ft or 4 m.

The standard chart arrays can be used to test the depths of field of lenses with focal lengths in the range f=35-75mm The charts intended for the 25mm nominal focal length lens can be used for lenses in the range f=17-35mm and the larger charts cover the range f=75-150mm. For the 16mm format the lens focal length suitability is half the foregoing, and for 65mm it is about one and a half times the foregoing for a similar vertical lens angle.

When the charts are used with lenses which have a longer or shorter focal length than the nominal focal length value around which the chart was designed, the depth of field will be different. In the case of a shorter focal length lens the depth of field will be greater, and for a longer focal length lens the depth of field will be smaller. So, for example, if the standard chart array, which is designed around an f=50mm f/2 lens, is used with an f=35mm, f/2 lens the depth of field, for a C of C of 1/1000 in., will stretch not from the -1 chart to the +1 chart but from the -3 chart to the +3 chart. If one then stops this lens down from f/2 to f/2.8 the depth of field will stretch from the -4 chart to the +4 chart, and so on, with the + and - chart numbers then increasing by 1 for each further reduction in aperture by one stop, in the normal way.

In the case of a lens with a focal length longer than 50mm, it is clear that the depth of field is reduced relative to the 50 mm lens. In this case one would naturally look for a pair of charts closer to the central charts than the +1 and -1 charts, where of course there are no charts (Table 1). In addition to the array of focus charts a critical plane of focus field of view board is also supplied. This is fitted on the left hand side of the array in the same plane of focus as the central chart. This board has a number of resolution targets on it, of the same size as on the centre chart, which can be used to compare the centre-field focus and resolution with edge-field focus and resolution. The board can also be used to compare the image widths of different types of lenses (that is fixed focal length and zoom) and for displaying essential test data such as lens type, serial number and the aperture used.

THE AUTHOR



David Samuelson was born in London in 1924, the eldest son of pioneer film producer, G.B. Samuelson. He entered the British Film Industry in 1941 and has been a projectionist, a cutting room assistant, a film cameraman, a facilities company executive, a consultant on the technology of film making, a computer program writer, and an author on the subject of film production technology.

Samuelson is a Fellow of the Royal Photographic Society, a Fellow of the British Kinematograph, Sound and Television Society, and a Life Fellow of SMPTE. He was awarded the Society's Special Commendation Award for Outstanding Contributions to Motion Picture Technology in 1978 and in 1984, the Presidential Proclama-tion Award of the SMPTE for continued support of the industry on an international level and his long standing contributions as a writer and a lecturer. AMPAS presented him with a Scientific and Technical Award for the Development of the Louma Camera Crane and Remote Control System for Motion Picture Production in 1980 and an Academy Technical Achievement Award for the Development of the Cinematographers Computer Programs in 1987.

As a film cameraman he has filmed in more than 40 countries.