Searching for the Perfect Aspect Ratio

By Mark Schubin

A debate is currently taking place over the appropriate aspect ratio for advanced television displays. Any selected aspect ratio is inherently incompatible with any other and will require the use of some form of accommodation technique. The derivation of the 16:9 (1.78:1) aspect ratio from accommodation techniques and display modes is explained, as is the relationship between aspect ratio and display memory. Research into the history of aspect ratios indicates that the 1.78:1 aspect ratio was adopted by the Standards Committee of the Society of Motion Picture Engineers (SMPE) in 1930. It also indicates that the factors that may initially have led to widescreen motion picture systems may no longer be applicable. The research for this paper found no clear indication of a preference for any particular aspect ratio for moving images nor any physiological reason to favor one over another. The research did show that cinematographers have not always favored the same aspect ratio.

A 1988 paper entitled "Another Method of Aspect-Ratio Conversion For Use In Receiver-Compatible EDTV Systems" begins: "Two systems with different aspect ratios are inherently incompatible."[1] (EDTV is extended-definition television.) The statement bears looking into.

For the purposes of this paper, aspect ratio will be defined as the ratio of an image's width to its height. Ever since there have been rectangular images, there have been aspect ratios (and it may be argued that even elliptical images have aspect ratios).

We are surrounded daily by multiple aspect ratios not seeming to cause any incompatibility problems. Images in newspapers and magazines have a variety of aspect ratios both greater and less than one; the same is true of paintings and photographs. Even some computer display screens may be rotated from a horizontal aspect ratio (landscape) to a vertical one (portrait). When theatrical motion picture and television screens are considered together for the purpose of displaying the same imagery, however, the inherent incompatibility becomes more clear.

That incompatibility became most noticeable in 1961, when the 1953 CinemaScope movie, *How to Marry a Millionaire*, was broadcast on the NBC television network.[2] Intended to be seen at an aspect ratio of 2.55:1 (and with image composition intentionally filling the wide frame), the movie was truncated to television's 4:3 (1.33:1). Almost immediately, technical publications began to carry information about how best to deal with the "conversion" of one aspect ratio to another.[3]

Aspect Ratio Accommodation

In fact, imagery is not "converted" from one aspect ratio to another; one aspect ratio is merely accommodated by another, almost invariably with some degradation of the imagery involved.[4] There are only three basic methods of accommodating existing material shot in a fixed aspect ratio on a display of a different fixed aspect ratio, though the techniques may be combined. These three basic techniques are shown in Fig. 1.

Figure 1a shows the truncation method, a variant of which is sometimes referred to as "pan and scan." When going from a wider aspect ratio to a narrower one in this method, the heights of the two images are matched, and any excess width in the wider image is removed from the display. The position of the displayed rectangle in the pan-and-scan mode may vary either by gradual panning (or tilting, in the case of accommodation of a narrower aspect ratio) or by rapid repositioning (cutting) between frames.

Figure 1b shows the shrinking method, referred to as "letterbox," due to the shape of the shrunken image window when a wider aspect ratio is being accommodated on a narrower display. The black bands need not be evenly spaced. It is often the case that the lower band (when a wider aspect ratio is being accommodated) is made larger for the purpose of carrying subtitles, and, as will be discussed later in this paper, when a narrower ratio is being accommodated, the elimination

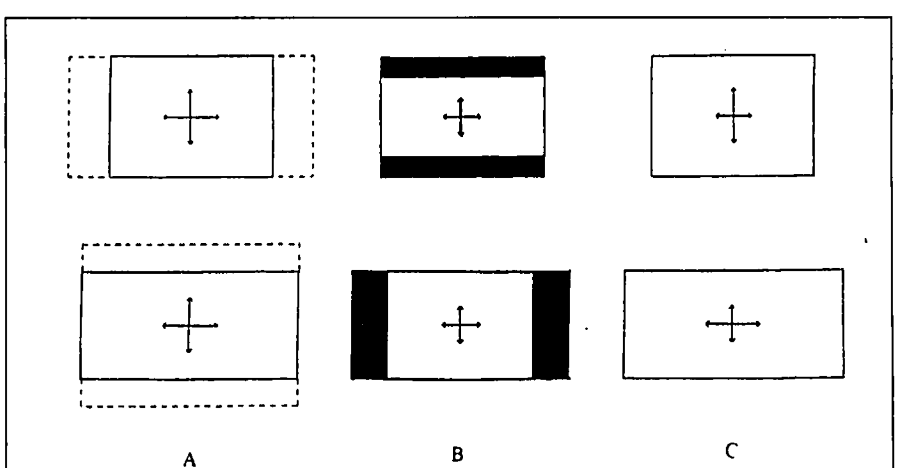

Figure 1. Aspect ratio accommodation: (a) truncation ; (b) shrinking; and (c) distortion.

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of one of the side bands offers the possibility of stacking additional images in the other side band, a technique that has been referred to as multiple picture-in-picture (MPIP).

Figure 1c shows the distortion method, whereby the linearity of the geometry of the image is changed to squeeze it into a different display shape. In a recent variation on this technique, a nonlinear distortion is used, affecting the edges of the image more than the center (e.g., in two of JVC's consumer widescreen projection receivers).

As can be seen from the two rows of Fig. 1, the same basic methods apply whether the original image is wider than the display or narrower. In fact, the same techniques apply whether the two aspect ratios are both film, both video, or one of each. From 1961 to date, however, generally only the techniques of the upper row have been seen, as widescreen movies have been shown on narrower video screens in homes, aircraft, or other venues. Unless otherwise specified, the word *widescreen*, for the purposes of this paper, will be used as defined by the British Kinematograph Sound and Television Society (BKSTS): "in general, pictures presented with an aspect ratio greater than 1.4:1."[5]

All of the accommodation techniques of Fig. 1 are problematic. Sometimes aspect ratio accommodation is demonstrated with so-called "neutral" imagery: pictures that appear no less desirable when cropped. Motion pictures and television shows are not shot to be neutral, however. The truncation technique clearly causes portions of the image to be lost, and the variants associated with pan and scan introduce motion or cutting never intended in the original.

The distortion technique clearly changes the shape of not only the image but also people and objects contained within it. An informal survey conducted in association with the research for this paper found that distortion in the range of 2 to 6% may be considered acceptable, but that is much less than the amount needed to accommodate a typical widescreen movie on a conventional television display or vice versa.

The shrinking technique (letterbox) preserves the original image composition but reduces the visual angle available to the viewer and, often, resolution as well. Detail that is just perceptible in an image when it is viewed at a particular display resolution will be lost if the same image is shrunk on the same display.

In most cases when the viewing screen is video-based, this shrinking results in noticeably empty portions of the display device, a condition that has been considered objectionable to audiences by some television programmers.[6] One television set manufacturer (JVC) has introduced a widescreen model with a mechanical masking system that covers the unused portions of the display much as drapes mask unused portions of some motion picture theater screens, possibly resulting in the reduction or elimination of such objections.[7]

A potentially more serious problem related to the shrinking technique is differential phosphor luminance decay, a reduction in the light output of the cathode ray tube phosphors in the active picture section relative to that in the blank section, often affecting blue phosphors more than red or green.[8] As a result, when the full display area is viewed, the shrunken image area can become visible as a stripe somewhat yellower than the rest of the display. The effect is greater in projection displays than in direct-view displays due to the higher beam currents of the former.

It has been suggested that the differential phosphor luminance decay problem may be eliminated by making the inactive sections of the display gray instead of black, but in one experiment, the outline of an inactive section of a direct-view picture tube was visible after 5,000 hours, even though that section had been excited with a 50% gray signal. Techniques have been developed for excitation of the unused areas with signals that vary to match average picture level, however, and those techniques appear to eliminate image striping.[9] No investigation of viewer acceptance of display stripes with varying brightness was found in the research for this paper.

The differential phosphor luminance decay issue is related only to displays using phosphors, such as those based on typical direct-view or projection cathode-ray tubes. Some video projectors, such as the Schlieren-optics-based Eidophor,[10] have never used phosphors, and advanced television displays may be able to take advantage of other phosphor-free technologies.[11,12]

There are two other techniques associated with aspect ratio accommodation, but they require that either the image or the display be effectively nonfixed in shape. One of these techniques is sometimes used in video walls. As shown in Fig. 2, a video wall comprised of 4:3 image modules can create a 4:3 image when stacked in a 3 x 3 or 4 x 4 module configuration, but the same modules can create a 16:9 (1.78:1) image when stacked in a 4 x 3 configuration.

When the goal has been not aspect ratio accommodation but the creation of a different aspect ratio than is commonly used in a particular medium, similar modular-screen techniques have been used in many film and video projection systems. These range from the 19th-century Cineorama system (using ten interlocked motion picture film projectors)[13] to the current Geographica theater (using three synchronized video sources) at the National Geographic Society's Explorers Hall in Washington, D.C. The original Cinerama widescreen movie process, using three synchronized film projectors, is probably the most famous of these systems.[2] It has been suggested that, at some

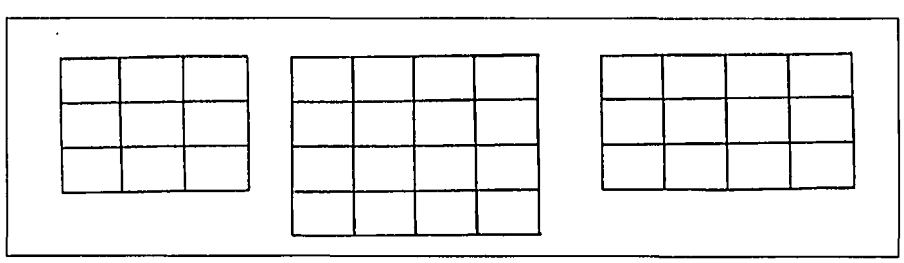

Figure 2. Modular display configurations.

future date, consumers will be able to avail themselves of low-cost, nonfixed-aspect-ratio displays, but at the moment, this technique does not appear to be applicable to most homes.

Shoot and Protect

The other technique of aspect ratio accommodation may, in fact, be the most common used today, but it cannot be used for existing material shot with just one aspect ratio intended. The technique is sometimes called "shoot and protect." It has been used to accommodate different aspect ratios both for theatrical film projection and for video display.

In such a system, during production the captured image is framed so as to make images appear in a desired fashion in one aspect ratio while additional area is suitably protected in the overall frame to allow the images to be seen in a different aspect ratio without lighting instruments, masking, microphones, puppeteers, or the edges of set pieces becoming visible. Such framing is facilitated by the presence of reference lines (reticles) on the camera viewfinder for the desired (action) aspect ratio.[15] Thus, the inner action area is sometimes referred to as the reticle region, and the outer frame is sometimes referred to as the aperture.[16] The area between the reticle and the aperture, where significant action is to be avoided, has been referred to as "fluff."

Reconsidering Fig. 1b, in a shoot-and-protect system, the black bands would not be black but would contain, instead, a continuation of the background of the image, the continuation area avoiding anything critical to the action. This is shown in Fig. 3.

A shoot-and-protect system allows aspect ratio accommodation without image truncation (and its associated additional pans or cuts), image shrinking (and its associated reduced viewing angle, reduced resolution, objectionable blank screen bars, and potential differential phosphor decay), and/or image distortion. On the other hand, it creates major restrictions in the way sets can be dressed and lit, the way sound can be picked up, and the way action can be framed. A character cannot be positioned at the edge of a frame, for example, if that edge will not appear in one of the aspect ratios.

This restriction can affect not merely aesthetic shooting preferences but also plot. In the play, *Largely New York* (1989), for example, a character trapped in a television signal tries to get out by pushing on the edges of the frame; if that material was captured in a shoot-and-protect system, in at least one of the aspect ratios those frame edges would not be properly located, so the plot device could not be used. Dramatic and comedic timing is sometimes affected by the moment when a particular character enters a frame; in a shoot-and-protect system, a character may appear at different times on different displays.

There is an additional problem associated with shoot and protect of the form where the action area is the wider aspect ratio (upper portion of Fig. 3). This problem relates to theatrical projection framing. With no visual indication of the upper and lower limits of the wider frame, a projectionist must guess at the correct framing, and that framing is not necessarily intended to be centered in the protected aperture.[17,18,19] Despite all of these problems, because home video, alone, has resulted, since 1986, in greater domestic wholesale gross revenues for movie distributors than has theatrical release,[20] there is a strong financial incentive for this form of aspect ratio accommodation, whatever its problems. Aside from its other negative aspects, in 1987, pan and scan (and associated) costs ran as high as $8,000 per feature at one cable television network.[2] There is also a need to consider accommodation of films shot in very wide aspect ratios on much narrower theatrical screens.[17]

It should be pointed out that the viewfinder markings of a shoot-and-protect system may be used even when there is only one intended aspect ratio, simply to allow the use of imaging equipment designed for a different aspect ratio. The Sony Jumbotron screen at the Skydome in Toronto has an aspect ratio of 10:3 (3.33:1), but its images come from conventional 4:3 television cameras with appropriate viewfinder reticles. In fact, many widescreen films shot this way (with a reticle framing a widescreen image in a conventional 4:3 frame) have been shown on 4:3 screens as though they had been created in a shoot-and-protect mode.

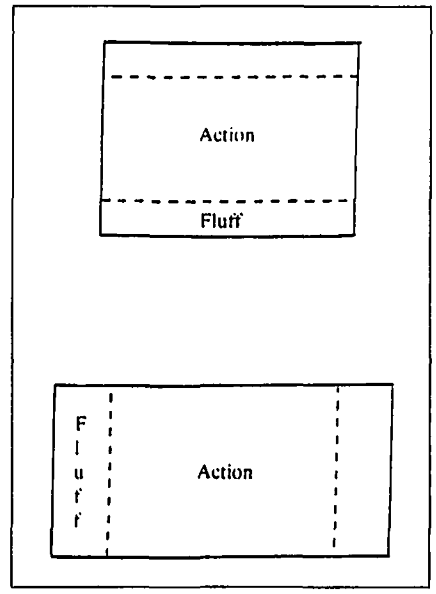

Figure 3. Shoot and protect.

Unfortunately, such presentation often shows viewers image areas intended by the director and cinematographer not to be seen. It is possible to see a microphone intruding into the top of the image in *Hatari!* (1962), for example, when that movie, intended to be seen on a wider aspect ratio theatrical screen, has its full film frame exhibited on a 4:3 display. Theatrical projection masking would have kept the microphone out of the shot. Nudity intended not to be seen in *Bonnie and Clyde* (1967) is similarly a result of full-frame exhibition of material shot to be shown with much less of the film frame visible. In *Psycho* (1960), set masking is visible when the full 4:3 frame is presented.[2] Such visible microphone booms, masking, set edges, and even lighting instruments have been attributed, in some cases, to sloppy filmmaking; the real cause is exhibition in an aspect ratio never intended by the director or cinematographer.

In addition to the shoot-and-protect systems of Fig. 3, it is also possible to create a shoot-and-protect system matching the shape of neither of the aspect ratios needing accommodation but providing both with "equal pain." Such a system would have an outer protection frame (aperture) as high as the narrowest desired aspect ratio and as wide as the widest (when both have

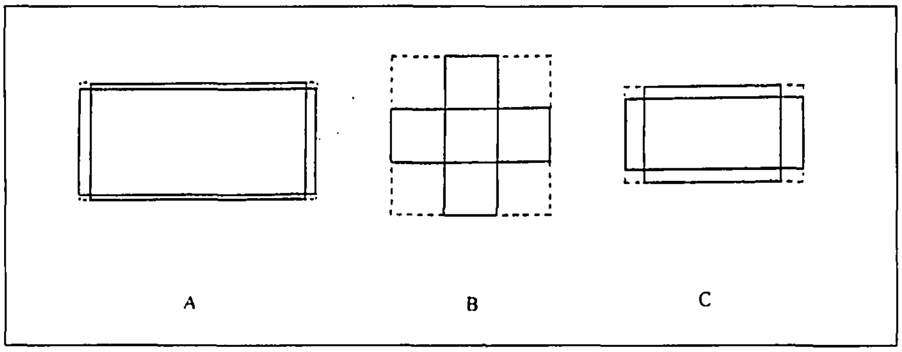

Figure 4. Equal-area shoot and protect.

equal area), and an inner action frame (reticle) as high as the widest aspect ratio and as wide as the narrowest. The outer and inner frames would have the same aspect ratio. This new shooting aspect ratio is derived from the following formula:

$$D = W * (1/W)^{1/2}/(1/N)^{1/2} \qquad (1)$$

where D is a derived compromise aspect ratio, W is the widest of a range of desired aspect ratios, and N is the narrowest of the range.

The benefit of such a system would be to reduce the amount of nonaction linear dimension in all aspect ratios between the narrowest and widest selected. Since the shoot-and-protect systems of Fig. 3 have no nonaction area for one aspect ratio (the reticle), however, that aspect ratio would actually suffer an increase in nonaction area through this plan. Of course, if a display screen happened to have the same aspect ratio as the derived shooting system, it could be perfectly framed, with no nonaction area.

Figure 4 shows three possibilities for such equal-area-based shoot-and-protect systems. Figure 4a shows what might be considered a sublime example of such a system. The two extreme aspect ratios being accommodated are so close that the inner action frame is proportionally even larger than that of the SMPTE Safe Action area accommodating overscanning in TV sets.

Figure 4b shows what might be considered a ridiculous application of such a system. The inner action frame is so small relative to the outer protection frame that it is difficult to see how any director or cinematographer could make meaningful use of such restricted framing.

16:9

Figure 4c shows the actual equal-area-based shoot-and-protect shape proposed by Kerns Powers, then with RCA Laboratories, at the meeting of the SMPTE Working Group on High Definition Electronic Production on May 4, 1984. It is clearly closer to that of Fig. 4a than to that of Fig. 4b. The aspect ratio was derived from the above formula through the substitution of 4:3 for the narrowest aspect ratio and 2.35:1 (then the projected shape of anamorphically expanded 35mm theatrical movies, commonly referred to as "scope," from the CinemaScope system) for the widest. The resulting ratio is just over 1.77:1, which was rounded up to 16:9 (somewhat less than 1.78:1) for convenient circuit design.

At the same time, the Motion Picture Association of America was evaluating a new anamorphic projection format using an anamorphic expansion ratio of 1.5:1 instead of the scope 2:1 to improve screen illumination efficiency and reduce projected jitter. That format would have had an aspect ratio of 1.5/2 times the 2.35:1 aspect ratio, or 1.7625:1, very close to the derived shoot and protect 1.77:1.[16]

As a proposed electronic production format, 16:9 need not ever have been used in a shoot-and-protect mode. Given sufficient resolution, a 16:9 electronic imager could be used to capture single-aspect-ratio moving pictures in any desired aspect ratio. For the extremes of 4:3 and 2.35:1, the 1.77:1 shape would allow minimum waste of photosensitive area (for a multiaspect-ratio imager) and simplify lens design. In single-aspect-ratio use, the action area could fill the intended display aspect ratio.

Other beneficial properties have been claimed for the 16:9 aspect ratio. The two most common widescreen nonanamorphic theatrical projection aspect ratios worldwide are 1.85:1 and 1.66:1.[19] A linear average of the two is 1.755:1, again close to 1.77:1 (but closer still to the theatrical projection ratio of 1.75:1 adopted by some major film distributors[21] and standardized by 1956).[18] There is also an interesting mathematical progression from 4:3 to 16:9 (4/3 * 4/3) to approximately 2.35:1 (4/3 * 4/3 * 4/3).

It has been reported that the 16:9 aspect ratio was unanimously approved by the Working Group and that a number of cinematographers were involved.[15,16] Such reports have also been disputed.[22] Some of the conflict may simply be semantic (e.g., what makes a person a cinematographer?). For the purposes of this paper, the arguments over who knew or approved what when are not significant. Interested readers are referred to sources listed here and elsewhere in this paper.[23,24]

Even before the Working Group meeting, in 1983 Joseph Nadan, then with Philips Laboratories in the U.S., illustrated possible advantages for a consumer high-definition television (HDTV) set that had a display shape of 16:9. In a "polyscreen" mode, the 16:9 shape could be divided into twelve 4:3 images (an inverse of Fig. 2's video wall); in MPIP mode, it could provide three stacked 4:3 images adjacent to one larger one.[25] (Note that some in the consumer electronics industry refer to this mode as "picture-outside-picture," or POP.) These display modes are shown in Fig. 5.

It was also pointed out that 16:9 was "friendly" to two international recommendations: that HDTV have twice the resolution of non-HD TV; and that digital component non-HD TV have 720 active picture elements (pixels) per scanning line. Twice 720 is 1440 for a 4:3 aspect ratio. For a 16:9 aspect ratio, it would be 1920, and equivalent vertical picture element resolution (square pixels) would dictate 1080 active scanning lines, for a total of 2,073,600 pixels. A 2-Mpixel memory has 2^{21} pixels: 2,097,152, a near-perfect match.[26] Even a slight aspect ratio increase to the common widescreen 1.85:1 would require 2,157,840 pixels, a poor fit to common random access memory (RAM) sizes.

The 16:9 aspect ratio also allowed for a form of simplified dual aspect ratio transmission. If a 16:9 image is transmitted at the common composite video digital sampling rate of four times the color subcarrier frequency ($4f_{sc}$), a receiver can recover the full 16:9 image by reading its memory at $4f_{sc}$ or can get a 4:3 truncated version (potentially in a pan-and-scan mode) by reading the memory at $3f_{sc}$.[27] Only aspect ratios that have a 4/3 relationship (as do 16:9 to 4:3 and 2.37:1 to 16:9) can make use of this technique with common sampling rates.

Since "1.85 is far and away the most common aspect ratio for motion pictures filmed in the United States,"[19] the proximity of 16:9 to 1.85:1 (less than 4% difference) could also be considered beneficial for the display of movies. Circuit design generally requires integer values for multipliers and dividers. The 1.85:1 ratio can be expressed as the complex 37:20. The simpler 9:5 ratio is a very close 1.8:1, but it could not make use of the simplified dual-aspect-ratio transmission system described in the last paragraph, nor would it be able to double digital component resolution and still fit in a 2-Mpixel memory. The 16:9 shape is the closest aspect ratio to 1.85:1 offering those other electronic system design benefits.

The 16:9 aspect ratio is also well matched to the technique of economizing by shooting film frames three perforations high instead of the usual four.[28,29,30] Again, it is the 4/3 relationship between the 4:3 aspect ratio and the 16:9 aspect ratio that makes 16:9 an appropriate three-perforation (3-perf) aspect ratio. The same 4/3 relationship also makes possible the modular display shape modification shown in Fig. 2.

One more rationale for the selection of 16:9 was probably unknown to proponents of the ratio in the 1980s. In 1930, the standards committee of the Society of Motion Picture Engineers (SMPE), recommended a new method of projecting large-screen movies from wider, 50mm film. The screen shape used for the Society's viewing purposes was 41 ft by 23 ft, 1.78:1 (the Society rounded off its widescreen film aspect ratio recommendation to 1.8:1). The aspect ratio was said to be in line with the desires of the Academy of Motion Picture Arts and Sciences (AMPAS).[31] In 1953, an aspect ratio of approximately 16:9 was again considered as a standard ratio for theatrical projection.[32]

This plethora of beneficial aspects of 16:9 has sometimes been carried too far. It has been claimed, for example, that 16:9 is the only aspect ratio that causes the inner reticles and outer apertures of Fig. 4 to have the same shape; a mere glance at Fig. 4 indicates that all equal-area shoot-and-protect aspect ratios have the same property.

The linear position of 16:9 between 1.66:1 and 1.85:1 is also of questionable benefit. A linear average of the extreme aspect ratios of 4:3 and 2.35:1 is just over 1.84:1, a near-perfect match for the existing theatrical widescreen aspect ratio of 1.85:1 (though it may be argued that, to obtain the benefits of a 4/3 relationship with 4:30, 16:9, less than 4% smaller, might have been chosen even if the desired aspect ratio were 1.85:1).

The polyscreen and MPIP advantages of 16:9 may also have been overemphasized. While it is true that only 16:9 yields a polyscreen of twelve 4:3 images and an MPIP of 3, Fig. 6 indicates some polyscreen and MPIP possibilities of the 2:1 and 5:3 aspect ratios, and Table 1 shows that there are many other possibilities.

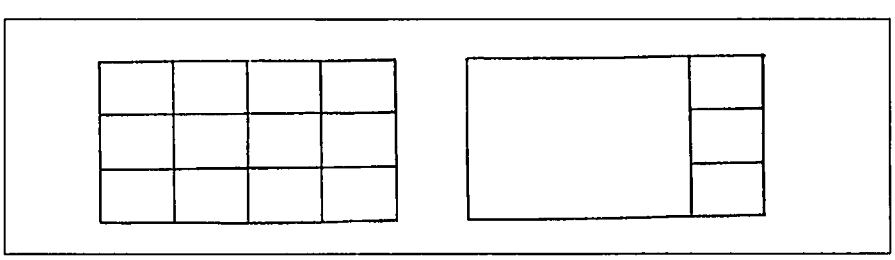

Figure 5. 16:9 alternative display modes.

Still more combinations are possible if there are multiple columns of MPIP or if the images are not contiguous on the screen. Though it has a 16:9 screen, for example, a recent RCA television receiver allows up to five MPIP images, not merely three.[33]

The display-memory-size benefits of 16:9 HDTV are also predicated on the very specific requirement of doubling the 720 active horizontal pixels of ITU-R Rec. 601 for a widescreen display. If the common practice of using 704 pixels to represent the picture width is considered instead, even a 1.85:1 display can use common memory devices (twice 704 divided by 4/3 is 1056; 1056^2 times 1.85 is 2,063,002, well within the 2-Mpixel limit of 2,097,152). Furthermore, while the 1920 active pixels/line of some 16:9 HDTV systems have a very simple relationship to the 720 active pixels of Rec. 601, there is no such simple relationship between 1080 active scanning lines and the active scanning lines of either 525/59.94 or 625/50 television systems. Even if only 480 active lines are considered for 525/59.94 instead of the more traditional 483 or 484, the resulting simple relationship, 9:4, is different from the horizontal relationship. If a relationship with Rec. 601 is ignored, a 2:1 display offers a perfect match to 2-Mpixel memories (2048 x 1024), albeit with somewhat less vertical resolution than 1080 active lines.

Benefits derived from 3-perf production have also been questioned. The 3-perf format has been said to be potentially more unsteady than 4-perf, to offer poorer audio frequency response, and to require difficult projector conversion.[34] For the moment, it also has additional costs associated with its being a nonstandard format.[35]

A rarely discussed issue is associated with the concept of using identical scanning characteristics in both an equal-area shoot-and-protect production format and a display. In the case of 16:9, for example, the shoot-and-protect system would allow the extraction of a 2.35:1 image with 25% nonaction area at the sides or a 1.33:1 image with 25% nonaction area at the top and bottom. A 16:9 display occupying only the action area would be perfectly framed,

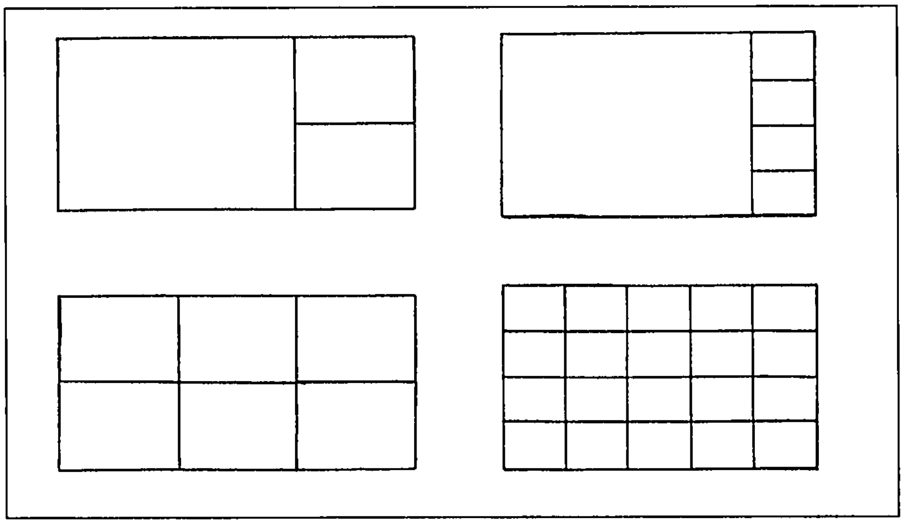

Figure 6. Alternative MPIP and polyscreen.

with zero "fluff." If, however, the camera and display have identical scanning characteristics, the display cannot be perfectly framed in the action reticule; it must occupy the entire aperture and will, therefore, suffer 43% nonaction area — considerably more than either a 4:3 or a 2.35:1 display.

This problem is not specific to the 16:9 aspect ratio, only to the concept of an equal-area shoot-and-protect production system sharing scanning characteristics with a display. Even the 4:3 aspect ratio suffers similarly in some film shoot-and-protect systems.[35]

That shoot-and-protect display scanning issue notwithstanding, for any or all of its benefits, real or imagined, and perhaps for other reasons (such as political or economic considerations), within a few years after its 1984 introduction as a production technique, the 16:9 aspect ratio had been adopted for ATV/HDTV display not only in the U.S. (except for some HDTV transmission system proponents) but also in Europe and Japan, where different aspect ratios had originally been proposed.[36,37] By 1994, 16:9 appeared to be universally accepted, not only for HDTV but also for widescreen video of ordinary resolution in such systems as the European PALplus and Japanese Clearvision.

Questioning 16:9

In April 1994, however, the American Society of Cinematographers (ASC) presented positions on aspect ratio of advanced television (ATV) distribution and displays at the Artists Rights Symposium, portions of which are excerpted here:

"While the ASC would prefer an aspect that matches our current widest screen production standard of 2.40:1, we realize that practical engineering and manufacturing requirements must also be considered. Thus, the ASC advocates 2:1 as an adequate, if not ideal, standard ratio." [*Author's note:* The 2:1 expansion of the current 35mm anamorphic projection aperture yields a 2.4:1 image rather than 2.35:1, and the proposed anamorphic theatrical projection system with a 1.5:1 squeeze/expansion, therefore, now yields a 1.8:1 image rather than 1.76:1.][38]

"Every original film work would be mastered and distributed over U.S. ATV (Advanced Television) in its native aspect ratio. This might be 2.4:1, 2.2:1, 1.85:1, 1.66:1, or 1.33:1 (or 1.78:1 if in the current HDTV format)."

"The ATV system should be deployed so that all ATV receivers have a 2.0:1 aspect ratio, at any and all standards at which they might operate."[39]

It is worth separating this position into the two parts that affect the choice of a 16:9 aspect ratio. First, the ASC would like all "films" (the term is clearly used loosely, since it is meant to include HDTV productions) mastered and distributed in the aspect ratio for which they were shot. Second, they would like ATV receivers to have a 2:1 aspect ratio display.

The first position, excluding any economic issues that may be associated with it (from the mass manufacture of single-aspect-ratio electronic imagers or from potentially increased bit rates for constant-vertical-resolution transmission of wider aspect ratios, for example), is one that should clearly be favored by both filmmakers and viewers. Filmmakers have long complained of the need to compromise their theatrical framing to accommodate television.[2,40] Consumers are already being offered choices for aspect ratio accommodation in some displays and videodiscs. The cable television channel American Movie Classics (AMC) currently offers its widescreen movies in repeated showings on the same day, once in a pan-and-scan format and the following time in letterbox; if ATV receivers offered the capability of locally accommodating different aspect ratios, consumers could opt for their choice at any time.

A digital transmission system, as is supposed to be used for HDTV, lends itself to the encoding of movies in any aspect ratio. A few bits can indicate to receivers what the picture aspect ratio is as well as carrying any pan-and-scan or other accommodation information that the filmmaker, distributor, and/or programmer choose to offer. The display memory (necessary in the receiver for inverse bit-rate reduction) can be read in whatever manner the viewer desires, subject to the capabilities of the TV set, of course.

2:1

The second ASC position, adopting a 2:1 display aspect ratio, is not as obviously beneficial to either filmmakers or viewers. A 2:1 display aspect ratio solves none of the aspect ratio accommodation problems, except that it favors the widest aspect ratios to the detriment of narrower ones.

As was noted previously, a 2:1 aspect ratio either uses picture memory circuitry poorly or must use horizontal resolution lower than twice that of digital component video. For any given screen width or diagonal measurement, a 2:1 aspect ratio will provide a *smaller* image than will 16:9. Even a screen of equal area will appear shorter. Only a screen of equal height will clearly be bigger, but, if it is direct-view picture-tube-based, it

Table 1 — Polyscreen and MPIP Possibilities

Aspect Ratio	:9	:1	Polyscreen	MPIP
8:3	24	2.67	2	1
2:1	18	2	6	2
16:9	16	1.78	12	3
5:3	15	1.67	20	4
8:5	14.4	1.6	30	5
14:9	14	1.56	42	6
32.21	13.7	1.52	56	7
3:2	13.5	1.5	72	8

will also be deeper, heavier, and more expensive.

The cost of direct-view picture tube displays is related to a number of factors. The costs of phosphor screens and shadow masks are related to their area. The cost of electron beam deflection circuitry is related to display width. The cost of a glass bulb is related to its volume, a specification derived from screen area times depth, with depth based on deflection, which is width-related. The overall display cost, therefore, is based somewhere between area and width, or, roughly (for aspect ratios greater than 1:1), on diagonal measurement.

For any given diagonal measurement, the largest possible rectangular display will be square. Narrower aspect ratio displays (of 1:1 or greater) will be larger in area than wider ones. Table 2 shows the combined effects of a fixed diagonal-based screen size and "letterbox" image display on overall image size for five common motion picture image shapes (expressed as ratios to one, as is common currently in cinematography) and five common existing or proposed display aspect ratios (expressed as integer ratios, as is common in display engineering). The data have been normalized so that a 1.33:1 image on a 4:3 display is considered 100%.

While the 2:1 display provides the largest 2.4:1 and 2.2:1 images, it provides the smallest 1.33:1 images. The center column, representing the most common U.S. theatrical film aspect ratio of 1.85:1, indicates that not only does a 16:9 display provide a much larger image than would a 2:1 display but even a 3:2 display provides a larger letterboxed 1.85:1 image than would a 2:1 display. As it was intended to do, the 16:9 ratio provides approximately equal-sized images for both extremes of image shape.

A nonpicture-tube-based display technology might not have a diagonal size-related cost basis, however. Tables 3 and 4 compare the same image and display shapes for screens of any size.

Table 3 shows the amount of screen area left blank to fit images into displays of a different aspect ratio. The same figures indicate the amount of resolution reduction from the maximum that the display can deliver. The boxed area indicates reduction of vertical resolution (traditional letterbox); the unboxed area indicates reduction of horizontal resolution (blank screen areas at the sides of the image).

Again, the 2:1 display offers the best results for the widest aspect ratio images and the worst results for the narrowest. Again, for 1.85:1 images, the 16:9 display is superior to all others. Again, the 16:9 display provides roughly equivalent results for the extremes of image shape.

Table 4 shows display resolution reduction caused by letterbox and fixed display memory size. As in Table 3, screens may be of any size. For a fixed memory size, a narrower aspect ratio offers more vertical resolution and a wider aspect ratio offers more horizontal resolution. The data have been normalized so that the narrowest image (1.33:1) on the narrowest display (4:3) shows zero vertical resolution reduction and the widest image (2.4:1) on the widest display (2:1) shows zero horizontal resolution reduction.

Again, the 2:1 display offers the best results for 2.2:1 and 2.4:1 images and the worst for 1.33:1 images. Again, the 16:9 display offers the best results for 1.85:1 images.

Tables 2, 3, and 4 all show, as probably seems obvious, a perfect fit for 1.33:1 images on 4:3 display screens. There is a very large installed base of 4:3 displays in TV sets and computer monitors worldwide, as well as very large libraries of roughly 1.33:1 moving image programming — virtually all pre-1953 movies, virtually all television programming to date, virtually all nontheatrical films, and many post-1953 movies. In 1958, 750 pre-1948 movies were sold by Paramount to MCA for $50 million; in 1994, another Paramount transfer, this time of 4,000 4:3 TV episodes (as well as feature films and other desirable properties) was valued at $9.6 billion.[20]

If ATV brings a wider aspect ratio into the home, it may be expected that sports coverage, shopping programs, game and talk shows, other entertainment programming, and even news coverage will eventually migrate to the wider aspect ratio. The older movies and television programs that form the

Table 2 — Image Sizes for Letterboxed Equal-Diagonal Displays

Display					
4:3	100%	80%	72%	61%	56%
3:2	85%	87%	78%	66%	60%
5:3	73%	92%	83%	70%	64%
16:9	67%	83%	86%	72%	66%
2:1	55%	69%	77%	76%	69%
	1:33:1	1.66:1	1.85:1	2.2:1	2.4:1
			Image		

Table 3 — Blank Screen Area and Screen-Based Resolution Reduction for Letterboxed Displays

Display					
4:3	0%	**20%**	**28%**	**39%**	**44%**
3:2	11%	**10%**	**19%**	**32%**	**38%**
5:3	20%	0%	**10%**	**24%**	**31%**
16:9	25%	7%	**4%**	**19%**	**26%**
2:1	34%	17%	8%	**9%**	**17%**
	1.33:1	1.66:1	1.85:1 **Image**	2.2:1	2.4:1

Table 4 — Fixed Memory Size Resolution Reduction for Letterboxed Displays

Vertical Resolution Reduction						**Horizontal Resolution Reduction**				
					Display					
0%	20%	28%	39%	44%	4:3	18%	18%	18%	18%	18%
6%	15%	24%	36%	41%	3:2	23%	13%	13%	13%	13%
11%	11%	19%	32%	38%	5:3	27%	9%	9%	9%	9%
13%	13%	17%	30%	36%	16:9	29%	12%	6%	6%	6%
18%	18%	18%	26%	32%	2:1	34%	17%	8%	0%	0%
1.33.1	1.66:1	1.85:1	2.2:1	2.4:1	**Image**	1.33:1	1.66:1	1.85:1	2.2:1	2.4:1

basis of much of the programming of such channels as American Movie Classics, Nick-at-Nite, and Turner Classic Movies will remain 1.33:1, however.

Table 2 also shows that, of common existing or proposed display shapes, 4:3 offers the largest screen for a given cost for technologies with cost related to diagonal measurement, such as direct-view picture tubes. A transition of television to any widescreen aspect ratio will introduce problems relative to the existing 4:3 display and 1.33:1 programming bases.[4] Thus, it has been argued that a 4:3 aspect ratio should be retained for ATV displays.[41]

Unfortunately, as Tables 2, 3, and 4 show, a 4:3 display offers the smallest images, the lowest resolution, and the greatest blank screen area when displaying the widest aspect ratio imagery. Since it is unlikely that homes will have different ATV displays optimized for different aspect ratios of programming, it seems that a compromise display aspect ratio may be desirable.

Using the same formula from which the 16:9 compromise aspect ratio was derived, 2:1 may be seen to be just under the ideal equal-area compromise aspect ratio for the extremes of 1.85:1 on the narrow end and 2.2:1 on the wide end. Those are the widest commonly projected nonanamorphic 35mm theatrical aspect ratio and the normal 70mm theatrical projection aspect ratio, respectively. While more favorable to 2.2:1 and 2.4:1 image aspect ratios than is 16:9, 2:1 is less favorable to the most common theatrical 1.85:1 and 1.66:1 aspect ratios[19] and is much less favorable to the 1.33:1 aspect ratio. It would, therefore, be an appropriate compromise display format only if there is some reason to favor the 2.2:1 and 2.4:1 aspect ratios over 1.85:1, 1.66:1, and 1.33:1.

It has been reported in the past that wider aspect ratio films (2.4:1) earn more theatrical revenues than other films.[34] That is definitely *not* the case at the time of this writing. The highest grossing film of all time, as reported by *Variety* in its February 20-26, 1995, issue, is *E.T. — The Extraterrestrial* (1982), a movie shot nonanamorphically on 35mm film and intended for projection at an aspect ratio not exceeding 1.85:1. The second highest grossing film of all time, *Jurassic Park* (1993), was made the same way. The *Variety* list of the highest grossing films of all time may be compared with a listing of their aspect ratios.[42] Such a comparison indicates that while many of the top 100 films were made at a 2.4:1 aspect ratio, they account for much less theatrical revenues than do the narrower aspect ratio films on the list. Lists of the top-grossing films of 1994 in both domestic and foreign markets in the February 13-19, 1995, issue of *Variety* yield similar results.

While a 2:1 aspect ratio is more favorable to the 2.4:1 theatrical aspect ratio than is 16:9 or any narrower aspect ratio, it does not match it in the same way that a 4:3 display matches 1.33:1 programming. The 2:1 (16:8) aspect ratio is, in fact, considerably closer to 16:9 than it is to 2.4:1. Whatever its disadvantages, a hypothetical 2.4:1 display would at least have the advantage of allowing side panels or drapes to mask unused portions of a screen for all but the few movies that were wider than that aspect ratio. On a 2:1 display, however, side masking fails for the many 2.2:1 or 2.4:1 movies, which would have to be shown in a letterbox format if their aspect ratio were to be preserved.

Part of the dissatisfaction with 16:9 may be related to the fact that the ratio was introduced as a shoot-and-protect production format, and the concept of shoot and protect involves cropping of nonaction area. It has been suggested that the use of 16:9 as a display format precludes the use of letterbox to preserve the composition of material shot in a wider aspect ratio. That is, of course, not true. Any of the aspect ratio accommodation techniques described in this paper can be used on displays of any aspect ratio. A 2:1 display aspect ratio will be no more free of accommodation techniques than is a 16:9 display, and the 2:1 display will have to use those techniques to a greater extent on 1.33:1, 1.66:1, and 1.85:1 programming than will a 16:9 display.

The ASC call for a specific 2:1 display aspect ratio appears to have originated in a presentation by the cinematographer Vittorio Storaro at a formats seminar conducted by the Technology Council of the Motion Picture/Television Industries on January 29, 1994. Seeking standardization on a single aspect ratio, Storaro suggested a linear compromise between HDTV at approximately 1.8:1 and 70mm theatrical projection at 2.2:1.[43]

Using linear averaging rather than equal area could be one reason to reject a 16:9 aspect ratio, but again, a linear average between the same limits of 1.33:1 and 2.35:1 is just over 1.84:1, not 2:1. Another option would be changing the limits. Given the vast libraries of 1.33:1 programming, it seems unreasonable not to consider that ratio, but the upper limit could be extended to the 2.75:1 aspect ratio of such movies as the 1965 epic, *The Greatest Story Ever Told* (because such movies were meant to be seen theatrically on curved screens, it is difficult to attribute a particular aspect ratio to them; the chord and the arc of the screen will yield different figures for width).[44] An equal-area compromise between those aspect ratios would be just over 1.91:1; a linear compromise would be just over 2.04:1.

If the few movies with 2.75:1 aspect ratios are to be considered, however, what about those created in the years between the advent of the sound track and the institution of the Academy aperture in 1932, films with an aspect ratio said to be as narrow as 1.15:1?[45,46,47] While a linear compromise between the two new extremes remains near 2:1 (1.95:1), an equal-area compromise reverts, again, to 16:9 (1.78:1).

History of the Perfect Aspect Ratio

Since accommodation of different aspect ratios necessarily adversely affects the images involved, perhaps it would be worth ignoring issues of compromise between existing aspect ratios and searching for an ideal aspect ratio. In addition to references already listed, there is a wealth of literature on the history of widescreen movies.[48-59] Most references attribute the impetus behind the current era of widescreen movies to competition with television. In other words, the problem of showing widescreen movies on television was intentional. A study of the literature indicates some other unusual facts:

- Widescreen motion pictures are at least a century old.
- The impetus for many widescreen developments had nothing to do with a preference for a wider aspect ratio.
- The terms *wide* and *widescreen* have not always indicated a wider aspect ratio.
- Cinematographers and directors have not always favored aspect ratios even as wide as 2:1.

It might be useful to start at the beginning, but it is difficult to say where that beginning is. Motion picture antecedents have been traced to ancient Rome[55,56] and even earlier.[57] Since aspect ratios are as old as rectangular imagery, however, if there is a human preference for a particular aspect ratio, that preference may be considerably older than motion pictures.

A technical paper in 1931 traced an indication of aspect ratio preference to an Egyptian papyrus document dated to 4750 B.C.;[58] that paper was referenced (indirectly) in a debate about the appropriate aspect ratio for advanced television that took place in 1940.[59] Another technical paper, this time referenced directly in the same debate, listed 16 especially "powerful aspect ratios" between 1.236:1 and 3.618:1 in addition to some others that were merely powerful. Both 1.309:1 and 1.809:1 fell into the most powerful category; so did 2.4472:1 and 2.472:1, aspect ratios differing by just 1%, but, according to the paper, having no preferred aspect ratio between them.[60]

The Golden Ratio

One of the most powerful aspect ratios listed was 1.618:1, a rounded version of a mathematical relationship technically called the division in extreme and mean ratio (DEMR) but more commonly referred to as the Golden Section.[61] It is worth noting some of the many names used for this quantity, because they appear frequently in the history of moving picture aspect ratios.

Names for DEMR can be created by combining the adjectives *continuous, divine, golden, medial,* or *sacred* with the nouns *cut, mean, number, proportion, quotient, ratio, rectangle,* or *section.* It has also been called simply the *section, the jewel of geometry,* the *middle and two ends,* the *proportional division, the whirling squares,* and the more bizarre *he who understands, Faratra, phi,* and *Victoria. Dynamic symmetry,* a term that has been incorrectly used to identify DEMR, refers to an aspect ratio of a rectangle that cannot be divided into squares. While a Golden Rectangle meets the criterion of dynamic symmetry, so do rectangles with aspect ratios of the square roots of 2, 3, or 5, all within the range of aspect ratios from 4:3 to 2.35:1. In contrast, 4:3, 3:2, 5:3, 16:9, 1.85:1, 2:1, 2.2:1, and 2.4:1 do *not* meet the requirements of dynamic symmetry.

The principle of DEMR is quite simple. A line is cut in such a way that the ratio of the whole line to the larger section is the same as that of the larger section to the smaller section. This may be expressed mathematically as

$$x/y = (x+y)/x \qquad (2)$$

where x is the larger section of a line and y is the smaller section. If the whole line is said to have a unit length, then

$$x+y = 1 \qquad (3)$$

and a quadratic equation is the result:

$$x^2+x-1 = 0 \qquad (4)$$

If the smaller section becomes the height of a rectangle and the larger the width, the resulting rectangle has an aspect ratio of approximately 1.618:1

(the absolute value of one solution of the equation); if the opposite is done, the resulting rectangle has an aspect ratio of approximately 0.618:1 (the other solution). Both shapes are Golden Rectangles.

The mathematical principle of DEMR has been known for centuries. In the 19th century, Gustav Fechner conducted experiments to find out whether there was a most preferred aspect ratio, and his results seemed to show a preference in the vicinity of the Golden Ratio.[62] A noted physicist and stimulus/sensation investigator, Fechner is considered a pioneer of psychophysics and contributed much to the technologies of both film and video, including the principle that, within certain limits, the intensity of visual stimulation increases as the logarithm of the stimulus (a principle reiterated frequently in the technical literature).[63]

After Fechner's publication of a seemingly preferred aspect ratio, what appeared to be evidence of that ratio was said to be found in works of art dating back to ancient times, and such reports appeared (and continue to appear) in the literature of aesthetics, architecture, art, mathematics, perception, and psychology, e.g., "Much evidence of the conscious use of the proportions of Golden Rectangles can be found in early Greek art and architecture."[64] Even one of the ATV systems proposed to the Federal Communications Commission selected the Golden Section as its aspect ratio.[65]

There appears to be a similarly large body of literature debunking the Golden Ratio as an aesthetic preference, however. One researcher repeated Fechner's experiments and found that the supposed preference appeared to be an artifact of the experimental technique.[66] Another found that any shape even vaguely near the Golden Ratio had been considered to be evidence of its use; he nevertheless acknowledged that the raw data "would support hypotheses that suggest that preferred rectangles often have ratios associated with a spread of values containing points from the interval between 0.6 and 0.7" [horizontally oriented ratios between 1.43:1 and 1.67:1].[67]

Indeed, there have been numerous experiments performed with different techniques at different locations, and all seem to show a preference for an aspect ratio in that range for still pictures.[68] For a "Wide Film" symposium conducted by the Technicians, Producers, and Directors branches of AMPAS on September 17, 1930, the Academy's assistant secretary distributed a memorandum stating that "Howell and Dubray, Lane, Westerberg, and Dieterich agree that the most desirable proportions are those approximating 1.618:1, which correspond to those of the so-called 'whirling square' rectangle (also known as the Golden Cut), based on the principles of dynamic symmetry which have predominated in the arts for centuries."

The director Sergei Eisenstein responded in a speech at the meeting that "'Predomination in the arts for centuries' should in itself be a cause for the profoundest suspicion when application is considered to an entirely and basically new form of art, such as the youngest art, the art of cinema." Eisenstein went on to point out that cinema is based on dynamics.[69]

It is easy to see why a dynamic image medium may elicit different aspect ratio preferences from those of a static image medium. A photograph of a skyscraper may be appropriately framed in a vertical image format, while one of a python is more appropriately framed horizontally. In a dynamic medium, however, a horizontal format can tilt down from the tip of the skyscraper to its base; the vertical format can pan the python from tip of tongue to tip of tail. Furthermore, a character may walk into or across a frame or may rise from a chair or descend stairs. It would seem important, therefore, to study aspect ratio preferences specifically for moving image media; unfortunately, it is difficult to find such studies.

Static vs. Dynamic Image Aspect Ratio Preferences

It has been stated that there is a preference for wider aspect ratios in moving image media, even if that means sacrificing resolution.[70] A classic case is the Techniscope film format, developed by Technicolor Italiana in 1960, essentially dividing a standard film frame into two much wider aspect ratio frames, thereby losing half the available vertical resolution.[13,45,54] Although used by a number of directors, including Sergio Leone and George Lucas, Techniscope is not commonly used today.

The previously mentioned 1994 Technology Council formats seminar offers anecdotal evidence of aspect ratio preference for moving pictures. As reported in *International Photographer*, "The votes were consistent. The audience always preferred the widest format with the largest image area."[71] The largest image area presented, however, was the 70mm format at 2.2:1, while the widest was anamorphic 35mm at 2.4:1. Thus, the largest image area was not the widest; yet, according to that report and others, the largest was preferred.

The test did not include IMAX, with an image area much larger than anything tested but one of the narrowest aspect ratios (1.43:1).[72] From IMAX and other formats, there is anecdotal evidence that viewers may prefer narrower aspect ratios when they are presented on screens very much larger than those of wider aspect ratios.

In a staged event held at Radio City Music Hall in April 1954, Paramount was able to demonstrate its relatively narrower aspect ratio VistaVision format very favorably by comparing it with CinemaScope's wider aspect ratio projected on a smaller area.[2] (It's impossible to assign a specific aspect ratio to VistaVision because Paramount allowed "a great deal of latitude with respect to aspect ratio. Our pictures can be played in anything from 4 to 3 up to 2 to 1 in aspect ratio.")[73] Much later, the author's contemporary report of a demonstration of the narrower aspect ratio FuturVision 360 film format at the SMPTE convention on October 28, 1986, stated, "As the FuturVision screen is lowered after the demonstration, the normal, wide theater screen behind it looks as tiny as a television set."[74]

A more formal study found a clear preference for 16:9 moving images over 4:3, even when the 16:9 images are smaller.[75] Unfortunately, only those two aspect ratios were tested, so while the study may show a preference for widescreen imagery, it does not necessarily identify the preferred aspect ratio. It is also possible that the programming selected affected the out-come. The movies chosen were all said to have been selected partly on the basis of their having been shot with both theatrical presentation and television in mind. Thus, shoot and protect was used, with key action likely to be kept within the confines of the wider aspect ratio. The preference shown for the wider imagery may have been a preference for less fluff in the frame; it is also conceivable that it was a preference for something different from ordinary television.

An unpublished study conducted for Philips using moving images found that aspect ratio viewing preference was influenced slightly by the originally intended aspect ratio. It was also influenced slightly by viewer habit (TV viewers who saw few movies preferred narrower aspect ratios; movie goers who watched little TV preferred wider aspect ratios) and by viewing angle.[76] The previously mentioned study found no relationship between aspect ratio preference and screen size and contradictory preferences based on viewing distance (screen size and viewing distance are the only factors affecting viewing angle).[75] A third study found a correlation between preferred screen sizes and viewing distances but one that contradicts the results of the other studies.[77] The research for this paper found no clear indication of any particular aspect ratio preference for moving images.

The AMPAS meeting of directors, cinematographers, producers, engineers, and technicians in 1930 was held to determine the best action to take on aspect ratio following the introduction of the sound track. The 4:3 35mm frame, essentially unchanged since its 1889 introduction in the Edison Kinetoscope, was suddenly narrowed by the addition of a sound track. At approximately the same time, numerous widescreen film techniques were being tried. Virtually the entirety of the January 1930 issue of the *Journal of the SMPE* was devoted to the topic of aspect ratio. No one, it seemed, liked the newer, squarer ratio formed by the sound track, and this seemed an opportune time to change it to something even wider than 4:3.

Communication No. 410 from the Kodak Research Laboratories was reprinted in the *Journal* as "Rectangle Proportions In Pictorial Composition." The paper came up with yet another term for 1.618:1, "the Golden Rule," and it performed statistical analyses on some 250 museum paintings, specifically excluding those with vertically oriented aspect ratios. A frequency curve was plotted, similar to that in Fig. 7.

The thrust of the paper was to have provided impetus for a change in motion picture aspect ratio, but the average of the aspect ratios shown was just over 1.4:1, and by far the greatest frequencies noted were in the range of the presound-track 4:3 aspect ratio.[47] Perhaps curiously, the exact same technique, averaging the aspect ratios of museum artworks, was used by Paramount's Lorenzo del Riccio to justify the creation of a 1.85:1 aspect ratio.[78] The differences between the two studies may be related to the artworks selected and/or the measurement techniques used. The inclusion of picture frames results in a narrower aspect ratio, as shown in Fig. 8.

Another paper in the January 1930 *Journal* was from the Bell & Howell Camera Co. and suggested three different film widths, all with a 5:3 aspect ratio.[79] That proposal was particularly significant coming from an organization that previously "had an ironclad company policy to refuse to manufacture, modify, or repair any cinemachine not of the standard 35 mm gauge."[80]

That 5:3 ratio was also referred to as the Golden Rule, a fact explained by the Academy's memorandum: "For simplicity, the ratios 5:3 (which equals 1.667:1) or 8:5 (equaling 1.6:1) are generally advocated instead of 1.618:1."[69] Part of the current aspect ratio debate seems to involve nomenclature,[23] so it is worth pointing out that cinematographers (even ASC members) frequently referred to ratios as 5:3 or 8:5 (or 3:5 and 5:8) at the time of the 1930 debates.[81] It is true that a ratio relating to one provides a more immediate sense of the shape of an aspect ratio than does an integer ratio like 4:3, 16:9, or 64:27; there is a small technical difference, however, between 1.33:1 and 4:3 and an even larger dif-

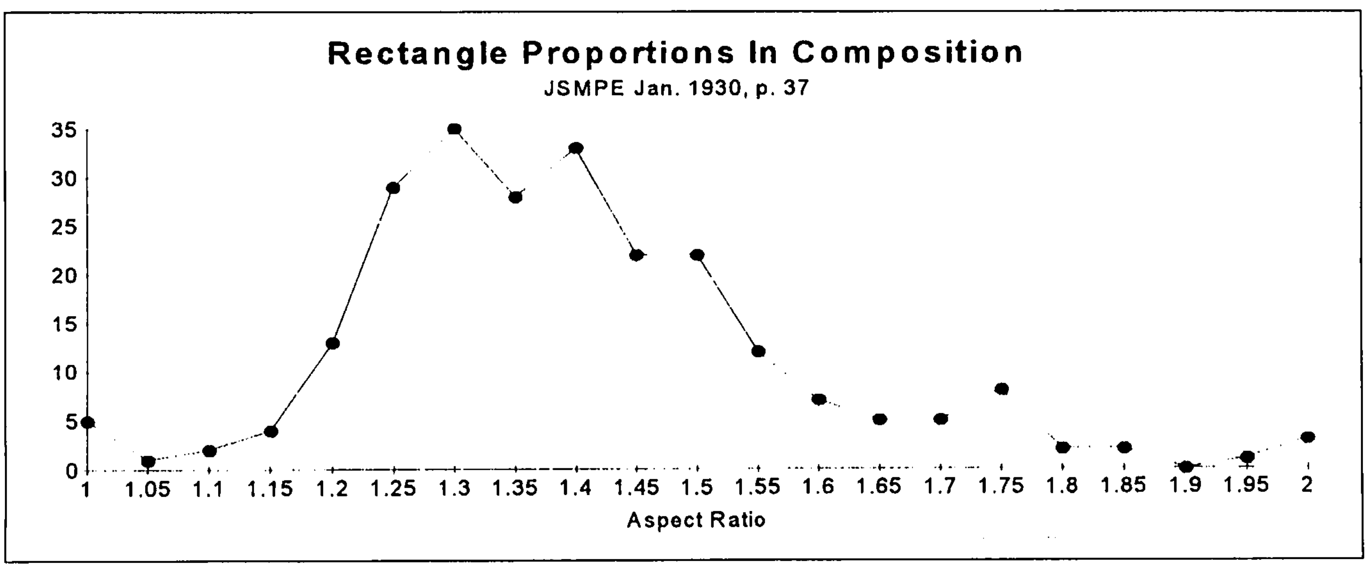

Figure 7. Aspect ratio frequency in museum paintings.

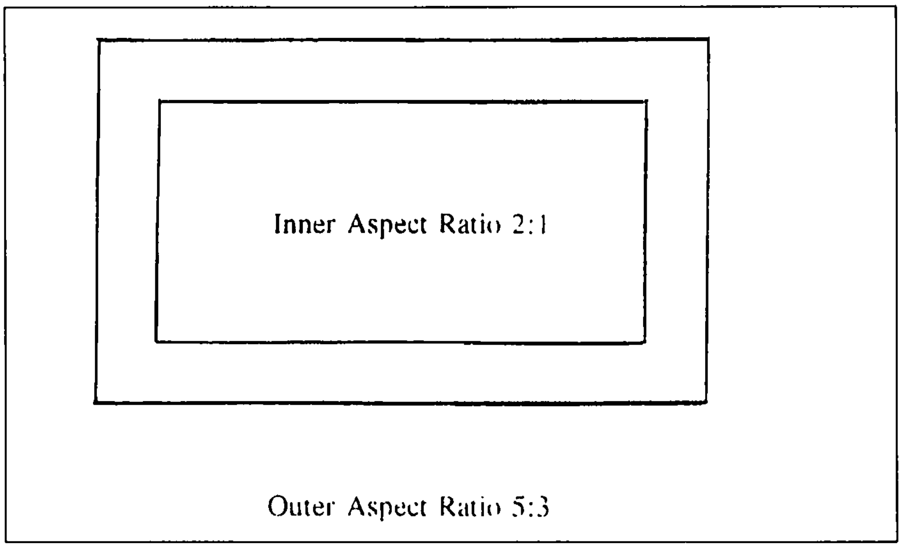

Figure 8. Picture frame effect on aspect ratio.

ference between 1.66:1 and 5:3. Again, circuit design also commonly requires integer factors for multiplication or division.

Perhaps the most urgent paper in the January 1930 *Journal* was from AMPAS. It described a situation in which standardization had broken down, and both theater owners and movie studios were taking matters into their own hands. Nine different projection apertures and 11 different viewfinder reticles were noted to be in use, none matching any standard, and many with different aspect ratios.[82]

The stage seemed to be set for the first major change in motion picture aspect ratio. Heads and feet were sometimes being chopped off by arbitrary projection apertures that varied as much as 14% from the standard. There were many proponents of an aspect ratio approximating the Golden Section and some for aspect ratios even wider. Eisenstein's call at the Academy symposium for a "Dynamic Square" has been misinterpreted as a lone call for square imagery. Instead, Eisenstein wanted a square frame into which filmmakers could place any chosen aspect ratio, whether vertical or horizontal.[69] D. W. Griffith in the U.S. and Germaine Dulac in France had previously masked images to highlight certain areas and, well after the Academy symposium, Eisenstein's dream was realized in the Soviet Union's Vario film systems, the most flexible of which, Vario-70, could deal with any aspect ratio from 0.46:1 to 2.35:1. A short film sponsored by the British Film Institute, *The Door in the Wall* (1955), later also made use of varying aspect ratios, both horizontal and vertical, in a single movie.[13,49]

4:3

The amazing result of all the aspect ratio discussions circa 1930 was the Academy aperture, standardized by SMPE in 1932, based on the desires of AMPAS. The projection aperture was precisely 11:8 (1.375:1), very close to the presound-track 4:3[83] (it has since changed to 1.37:1).[39] It was not the first time the roughly 1.33:1 aspect ratio would survive a challenge, and it wouldn't be the last. It is difficult to explain why AMPAS and SMPE reverted to 1.375:1, especially since projection focal lengths and apertures had to be changed anyway. It may have been the case that 11:8 was the only shape on which agreement could be reached (both AMPAS and SMPE had previously tentatively decided on 4:3,[84] but SMPE wanted a firm decision from producers),[81] and agreement on something was certainly necessary, as an article by an ASC member in the 1931 *Journal* noted.[85] That article called for a 4:3 aperture, despite its author's previously expressed preference for the Golden Section.[86]

The widescreen historian John Belton suggests that knowledge of the Golden Section helped create the 4:3 motion picture aspect ratio in the first place. William Dickson, in developing for Thomas Edison the first motion picture camera to use flexible transparent film, ordered film 1.375 in. wide (almost 3 mm), because that could be obtained by slitting existing photographic film stock down the middle. Running the film vertically and perforating it dictated an image width of 1 in. The height of the image was not dictated mechanically, however. Dickson's probable desire for the Golden Section as an aspect ratio in 1889 was tempered by another desire to work in 1/4-in. picture increments. Therefore, the first movie frame, 1 in. by 3/4 in., 4:3, was as close as he could get to 1.618:1.[2,87]

Unfortunately, some parts of the hypothesis seem weak. Dickson did, indeed, report increasing picture size in 1/4-in. increments,[88] but his perforations appeared 64 times/ft, or every 3/16 in., proving that he worked in increments other than 1/4-in. As far as picture size is concerned, Edison's first patent caveat, submitted in 1888, describes images just 1/32-in. in size; the third caveat specifies 1/8-in. images.[89]

Had Dickson felt strongly enough about the Golden Section, he could easily have masked the height of the image to that ratio. If that would be considered a waste of film, he could have, as has more recently been suggested,[28,29] made images three perforations high instead of four, thus saving a great deal of film. Though it would have required a different design, the film could also have been moved horizontally through the camera aperture (as in Fear's Super Pictures, Glamorama, VistaVision, Technirama, and IMAX, for example)[54] instead of vertically, thereby removing the 1-in. width restriction.

Belton suggests that Dickson may have been influenced by Ottomar Anschutz,[2] whose 1887 animated photography display system used large transparencies in a 3:4 aspect ratio (the opposite of 4:3).[13] One might then question why Anschutz selected 3:4. It may have had to do with the shape of his apparatus or with the recurring ancient Pythagorean 3-4-5 right triangle (a loop of flexible material 12 units of length long, with each unit marked, can be used to create a perfect right angle repeatedly, a principle that was used in the construction of the pyramids). The 4:3 aspect ratio was attributed in 1940 to the ancient Greeks.[59]

There was a plethora of different shapes for photography and animation prior to Dickson's 4:3, and there was a similar plethora afterward. An 1899 survey listed 89 different movie projection systems in its "Present-Day Apparatus" section, many with different aspect ratios, then added another 56 announced systems.[90]

Even though they were using 35mm film, Auguste and Louis Lumiere began with a 5:4 aspect ratio frame.[91] For compatibility with Edison's movies, they later adopted both a 4:3 aspect ratio and the use of four perforations per side per frame. In 1898, however, when they developed the widest film motion picture format (75mm), for special projections at the Paris Exhibition of 1900, they retained the 4:3 aspect ratio, even though the camera, screen, and projector were all unique and needed no compatibility with anything else.[13] Similarly, Max and Emil Skladanowsky, independent of Edison compatibility and seemingly independent of mechanical requirements, adopted a 4:3 aspect ratio for their first Bioskop projection system.[92]

One of the first post-Kinetoscope wide-aspect-ratio systems, the Latham Eidoloscope (1895), was developed by Dickson, who is said to have adopted a wider film, frame, and aspect ratio specifically to avoid infringing Edison patents.[2] Dickson may well have sought to avoid infringing aspects of Edison's patent claims, but none of those claims specified any film size or aspect ratio.[93] Other film systems developed at the time — even those using wider film — did not always have an aspect ratio wider than 4:3.[13,54,94]

There was a strong impetus for wider film (but not necessarily wider aspect ratios) regardless of patent infringement issues. That impetus was the requirements of projection versus those of the "peep show" Kinetoscope viewers for which Dickson had first developed the 4:3 35mm format.

In an era of nitrate film stock, brightness could not be increased indefinitely without danger of fire; a larger frame, therefore, meant a brighter image. A larger frame also offered benefits related to jitter, resolution, lens magnification, camera and projector mechanical design, and, if the theater could accommodate it, even a larger image.[95] Similar benefits remain true today for larger film formats.[71] Another driving factor for wider film width had nothing to do with pictures; the wider the sound track, the higher the sound quality (a position disputed, however, at the 1930 Academy symposium).[81]

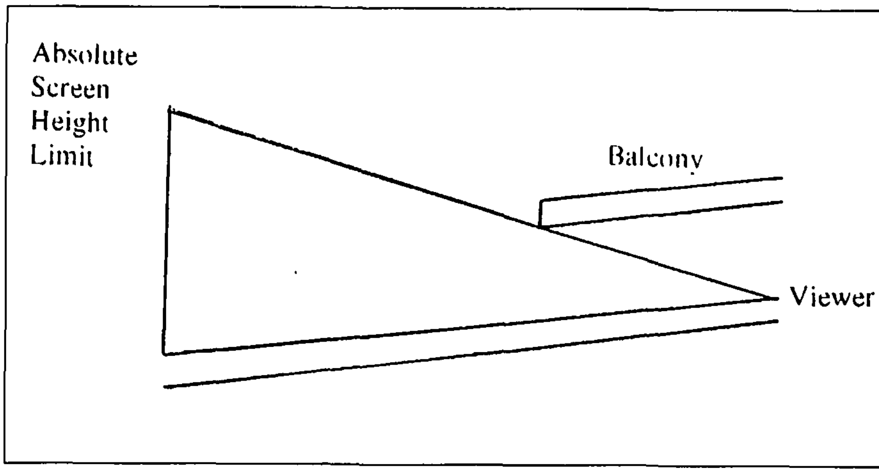

Figure 9. Balcony overhang screen height limitation.

The term *wide film* was clearly defined in an Academy publication: "Wide Film has a width greater than the standard 35mm."[96] By that definition, current scope movies are not wide film.

There are also references to *wide screens* that indicate simply larger images, not necessarily with a wider aspect ratio.[2,48,97] A publication of the National Association of Theatre Owners states, "'Wide-screen' became the industry watchword for an array of filmmaking techniques and projection systems that delivered *high*, wide, and mighty images that dwarfed the typical 16-foot by 20-foot theatre screen of the day" [emphasis added].[98]

Why Wide

There were, however, considerations favoring wider projected aspect ratios. Key among those was the architecture of the auditoriums in which movies were projected, especially the existence of balconies in movie theaters.[52,53,95,99,100] The overhanging balconies limited sightlines from the rear of the auditorium, placing an absolute limit on picture height, as shown in Fig. 9. As movie theaters changed from small, single-level nickelodeons to huge, multilevel palaces, the balcony problem became a serious issue. Today, however, balconies are becoming ever more rare, removing perhaps the major reason for the advent of wider aspect ratios. Belton notes the change in subheadings of his last chapter, "The Return of the Nickelodeon," regarding multiplex theater complexes with small auditoriums, and "The Return of the Peepshow," regarding video.[2]

There were also supposed economic considerations pushing a wider aspect ratio. "Though the opinions of cinematographers were not canvassed, art directors favored the wider frame as it meant they did not have to build sets as high, and production managers favored it because it was felt the larger, clearer images would eliminate the need for closeups and the additional time to shoot them."[53] Even today, it has become necessary to point out that aspect ratio does not determine the height of a scene being shot.[19]

Similar arguments have been made about video production in a high-definition, wider aspect ratio format — that it will be possible to use fewer cameras and less editing. Like the impetus created by balconies, the impetus created by any real or imagined economic benefits associated with widescreen production has also vanished, as the publicity about 1995's record-cost widescreen (1.85:1) *Waterworld* indicates.

Visual Aspect Ratio

Periodically, during aspect ratio debates, allusions have been made to the human visual system — that there is something about it that would favor one aspect ratio over another (separately from any psychological preferences). As is the case with the Golden Section, however, arguments are often made on both sides. One researcher found that the maximum visual field is approximately twice as wide as it is high,[76] while another found it to be only 1.6:1 for the range captured by the eyes individually and 1:1 for both eyes together.[101]

"A widely spread opinion has it that the screen with a horizontal location, with an aspect ratio of approximately 1:2 [2:1] constitutes the optimum psychophysiological condition. Some authors believe that such a screen format best satisfies the requirements of a full field of view for the two stationary eyes. Such a conclusion is incorrect, however, because the field of distinct vision of the eye is equal to only 2 or 3 degrees. It is only within this small angle that the acuity of vision is approximately 50-100%."[102]

The preceding appeared in the *Journal of the SMPTE* in 1969. Earlier, an article in *Film Quarterly* expressed similar views but expanded them to include wider visual fields, all the way out to peripheral vision, and found that even the widest screens stimulate only a tiny portion of the visual field.[103] Another paper published in the *SMPTE Journal* found important contributions to "sensation of reality" from a wide-field display, however, and that paper, in part, forms the basis for the desire for a wider aspect ratio for HDTV.[104]

Whether a sensation of reality is valuable or not (a director/film-system inventor recently suggested that it can actually *interfere* with traditional fictional filmmaking),[105] and regardless of how we see, the key to arguments about visual field is the fact that aspect ratio has little or no effect on the retinal angle stimulated by an image. The horizontal visual field angle is determined primarily by the display width and the viewer's distance from it (there are also off-axis contributions); the vertical field is determined by the same distance and the height of the screen. The principle is similar to that used to argue that aspect ratio is not a determinant of scene width during shooting.[19]

The BKSTS recommended theatrical seating plan has the front row no closer than twice the screen width and the rear no farther than six widths.[5] That is a much greater range than the difference in aspect ratios between 4:3 and 2.4:1. Wide angular ranges can also be found in a SMPTE theatrical presentation manual,[106] and common theatrical practice exceeds both BKSTS and SMPTE recommendations. Television also offers widely varying visual angles. Though the preceding argument renders the fact irrelevant, it may be pointed out that the largest motion picture screens have always had aspect ratios less than 1.4:1.[72,107,108]

Stimulated retinal angle is not the only shape-related aspect of vision. Panel 2 of the National Television System Committee (NTSC) in 1940 set itself the following task as its question number 1: "Considering the shape and nature of the binocular visual field of view, can there be deduced any preferred aspect ratio for television pictures? Are there any other theoretical bases for the selection of any particular preferred aspect ratio?"[59]

The panel investigated various art forms and vision. In retinal isopters (intensity perception contours) an "aspect ratio" (a slight favoring of the horizontal versus the vertical) between 1:1 and 1.2:1 was found. In color fields, it was 1.3:1. Visual acuity offered the widest "aspect ratio" disparity, between 1.5:1 and 1.6:1 (a possible reason that the poor vertical resolution due to television's 2:1 interlace has not been as much of a problem as it might otherwise have been). An effect called the vertical-horizontal illusion was said to favor 1.1:1, and field of fixation (said to be related to eye movement) 1.2:1. No other vision-related differences that would suggest a bias for a particular aspect ratio were reported.

The NTSC also surveyed 31 existing television systems around the world. There were one with an 11:8 aspect ratio, 19 with 4:3, 7 with 5:4, one with 6:5, 2 with 3:4, and one with an unspecified aspect ratio.

A clear preference for a horizontally oriented aspect ratio was expressed: "Since most of man's activities occur in a horizontal plane, it is reasonable that there should be more freedom of motion horizontally than vertically." For aesthetic reasons, there were proponents on the NTSC of an aspect ratio of the Golden Section. That was considered too wasteful of the surface area of then-round picture tubes, however. To cope with the roundness problem, the committee set itself an aspect ratio limit of 1.4:1.

In the end, having found no compelling physiological or aesthetic reason to adopt a widescreen format, the NTSC selected a 4:3 aspect ratio and declared that the controlling factor was that it "has all advantages found in motion picture practice." The other cited advantage was that it "permits motion picture scanning without waste." It was a slightly curious choice, given that the motion picture industry had changed to 11:8 (the Soviet TV aspect ratio investigated by the NTSC) a decade earlier.

The Eventual Advent of Widescreen

Today's problems of aspect ratio accommodation might be even worse had the NTSC met in 1929 instead of 1940. A technical paper published that year[109] also tried to rationalize an aspect ratio for television and came to the same conclusion as did the NTSC — that motion picture practice should be the deciding factor. Since, at the time, sound tracks had eaten into the 4:3 frame, the selected aspect ratio was 6:5.

By the time of the sound-track crisis, circa 1930, wide-aspect-ratio film technology was relatively advanced. All of the techniques that would later be used in the current widescreen era — anamorphic squeezes and expansions, wider film, masked frames, multiple film strands — had been demonstrated, sometimes used for theatrical release, and generally found to be technically successful.

Even before the Academy's standardization on an 11:8 (1.375:1) aspect ratio, however, the early era of wide film appeared to be going nowhere. The earliest wide-aspect-ratio systems (e.g., Eidoloscope) failed either because they were technically flawed or because the Motion Picture Patents Co. dominated the industry.[2] As early as 1913, however, it was suggested to exhibitors in Britain to try masking 4:3 frames to create a wider aspect ratio. According to the article, "the result is a better shaped picture — more artistic. The portion masked off will never be missed."[110] There does not appear to be any evidence of mass defections from 4:3 prior to the introduction of the sound track, however.

The 1920s saw a great deal of large-screen experimentation, each new form of which was supposed to herald a new era. Magnascope was simply an enlarging lens system. When dropped in front of an ordinary projection lens, it caused the picture to double linearly in size both horizontally and vertically (and become much dimmer), retaining a 4:3 aspect ratio or changing (through cropping) to whatever size the theater architecture would allow. It was said that it received a standing ovation when it was first used.[78]

The Fox Grandeur system was very much like today's 70mm systems. Henri Chretien's Hypergonar anamorphic lens, used in production in 1927, is, in fact, the same lens that made CinemaScope possible (it had been used to create both wider and narrower aspect ratios, the latter by rotating the squeeze axis by 90°). The triptych presentation in Abel Gance's *Napoleon* (1927) was in some ways a precursor of Cinerama (though it wasn't used the same way). In 1929, SMPE's Standards Committee considered four large-frame widescreen systems ranging in film width from 35mm (horizontal film travel, 10 perforations/frame) to 70mm and in aspect ratio from 1.84:1 to 2.27:1.[111] (As it has been recently suggested that 16:9 was developed as a linear compromise between the sound-track aperture and 2.35:1 and 1.85:1 as a compromise between 4:3 and 2.35:1,[112,113] it is worth noting that 1.85:1 was proposed as a preferred aspect ratio by two unrelated organizations long before the existence of 2.35:1.)

An article called "Wide Film" in *The 1931 Film Daily Yearbook of Motion Pictures* summarized the situation succinctly: "Dormant condition of the subject is attributable to two major reasons. First, the fact that recent-year experiments failed to convince producers that enlarged pictures exercise a definite influence at the box office. Second, gigantic costs would be involved in changing the industry over to accommodate them."[114] There was an economic depression, and the industry had just begun to accommodate sound. Wide film, and wider aspect ratios, would have to wait.

After the NTSC's standardization of U.S. television (with a 4:3 aspect ratio) in 1941 and the end of World War II, the movie exhibition situation changed. Average weekly movie theater attendance in 1929, when SMPE's Standards Committee met to discuss wide film, was 95 million. In 1946, right after the war, it was about 90 million, about the same as in 1930, despite a growing population. By 1953, however, it had dropped to just 46 million, a reduction generally attributed to television.[115] The movie industry decided to fight the audience loss by offering sensations that could not be experienced by watching television at home.[100]

"From an historical point of view both the so-called 3-D — stereoscopic films — and wide screen pictures are not new, dating back as they do to the earliest days of the art and industry. However, 3-D and wide screen pictures burst upon the American motion picture scene in the closing weeks of 1952 with all the suddenness of new-found comets. Each week, indeed, almost every day of 1953 was marked with an announcement of a new method, process or scheme."[51] One such process, Scanoscope, applied CinemaScope's 2:1 anamorphic principles to television;[116] 3-D television was also broadcast at the time.[117]

It wasn't only 3-D and widescreen that exhibitors tried. The 19th-century Cineorama technique of completely encircling viewers with synchronized movie screens was revived at Disneyland in 1955. Cinerama and Todd-AO both used higher frame rates (26 and 30 frames/sec, respectively). Those systems and others used deeply curved screens, sometimes extending into the seating area. During a rockslide sequence in *It Came From Outer Space* (1953), some theatrical viewers were pelted with foam rocks. Vibrators administered "shocks" to some seats when viewers watched *The Tingler* (1959), a technique recently revived in one of the motion picture attractions at the Luxor Hotel in Las Vegas (the same theater's screen has a 0.5:1 or 1:2 aspect ratio). *Behind the Great Wall* (1959) was exhibited in Aromarama, featuring 72 different smells.[48]

None of these techniques was able to restore movie attendance to pre-1950 levels. In fact, it continued to fall, reaching a low of 15,800,000 in 1971. Nevertheless, wide-aspect ratios, in at least some versions (cropping and anamorphic projection, neither of which was particularly expensive for an exhibitor to implement), endured, or perhaps more precisely, thrived (more expensive processes, such as three-projector Cinerama and the multichannel sound version of Cinema Scope were less successful).

Recognizing a need for revenues beyond a limited market of specially equipped theaters, producers of movies in some of the new systems also shot the same scenes on ordinary 35mm frames, thereby eliminating aspect-ratio (and, in some cases, frame-rate) accommodation problems. Producers of ordinary 35mm movies, seeking to cash in on the attraction of widescreen, faced a different problem.

Shane (1953), composed and intended for viewing in a 1.375:1 aspect ratio, was projected instead at 1.66:1 when it was premiered at Radio City Music Hall, a ratio Paramount found tolerable, as it involved cropping just 10% from the top and bottom of a 4:3 image. (Paramount adamantly opposed projection at any ratio greater than 2:1, even for VistaVision movies, which were composed for wider aspect ratios.)[118] *The Band Wagon* (1953) fared less well in cropped exhibition, with complaints received about the loss of the dancing feet of Fred Astaire and Cyd Charisse. Nevertheless, cropping of existing movies became common practice. "The fact that many actors found their heads chopped off and many dancers found that their feet were not on the screen didn't seem to bother the exhibitor or the theater patron to any degree. The public was fascinated with the wide screen."[51]

Distributors were very flexible about aspect ratio, lest they lose the business of some exhibitors. A Universal-International promotional document for *Imitation of Life* (1959) informs exhibitors "Aspect ratio: any ratio up to 2:1."

Acceptance of cropping continues to the present, regardless of the intended or displayed aspect ratios. The most commonly noticed form of cropping occurs when widescreen movies are shown on television screens via the truncation method. A scope movie converted to a flat print for theatrical projection at between 1.66:1 and 1.85:1 also undergoes cropping, however, even though no video is involved.[17] Ordinary 4:3 U.S. television coverage of the 1992 World Series baseball championship was shown on the 10:3 (3.33:1) Jumbotron screen of the Toronto Skydome to accommodate fans. Although the uncropped picture was available free of charge on broadcast television, viewers paid to watch the cropped version in the stadium (on a giant screen but one with a small visual angle due to its great distance from viewers).

Filmmakers' Acceptance of Widescreen

It is readily understandable why a filmmaker would not favor cropping. Even when cropping was not an issue, however, there were initial objections to wide aspect ratios among cinematographers and directors.

Cinematographer Fred Westerberg actively opposed ratios as wide as 2:1 during the sound-track aspect ratio debates circa 1930. During the same debates, cinematographer Karl Struss, who favored 5:3, said 2:1 would result in smaller images and its lack of proportional height was problematic; and Joseph Dubray, described as a "motion picture engineer and erstwhile cameraman," said that the consensus in Hollywood was that 2:1 was "neither pretty nor desirable."[81] More recently, cinematographer Lee Garmes said, "I found working in CinemaScope a horror — shallow focus, very wide angles, everyone lining up, awful."[119]

Other cinematographers in the same period had somewhat more forgiving comments. Walter Lassally: "I think 'scope is all right. I'm not mad about it personally, but it is suitable for certain subjects. It's very good for outdoor subjects, Westerns, scenes of epic proportions, but it's no good for intimate subjects." Paul Beeson: "I think if you've got a very small intimate subject it's crazy doing it in Panavision; you're just wasting the process. Panavision is really for a large canvas. When you're in close-up all the time it's very difficult to compose for Panavision. There's a lot of wasted space on either side, but these difficulties can be overcome if the director requires this format, although I don't think the subject gains anything."[40] Lucien Ballard: "I like 1.75, 1.8, almost the old screen ratio best."[120]

Director George Stevens was perhaps the most acerbic, referring to the CinemaScope aspect ratio as "a system of photography that pictures a boa constrictor to better advantage than a man." He also provided the adage that "no screen is larger than its smallest dimension."[107]

In 1994, director Stanley Kubrick released a restored version of *Dr. Strangelove or: How I Learned to Stop Worrying and Love the Bomb* (1964). Film Forum in New York screened the release in "the squarish 1.66:1 ratio Kubrick originally intended, with more detail now visible at the top and bottom of the screen."[121] As recently as 1995, Lassally wrote, "The adoption of, say, 1.75:1 as a universal new standard... would in my opinion greatly benefit the industry as a whole."[122]

Except for those in the preceding paragraph, however, it has been roughly 25 years since the most recent of those sentiments was expressed, and, as the ASC's position on displays indicates, there has clearly been a shift of position. It was Stevens's *Shane* that had been cropped at the beginning of the current widescreen era; he went on to direct (and produce) the very wide aspect ratio (2.75:1) epic *The Greatest Story Ever Told* (1965).

Some of the unfavorable comments may be attributed simply to a change in traditional methods. In an article called "New Medium — New Methods," Director Jean Negulesco wrote of his experiences with CinemaScope. "'Writing for the new wide screen should be easy,' I told my script writer. 'All you have to do is put your paper in the typewriter sideways.' Well, he didn't laugh either."

Henry Koster, director of the first CinemaScope movie, *The Robe* (1953), said the process made "a director at last free of the camera" without having "to worry about 'dolly shots' and 'pan shots' and 'boom shots' and all other camera movements." Negulesco added that Cinema-Scope freed a director from concern about cuts, dissolves, closeups, and inserts.[52] Clearly, even such favorable comments have aged; today, scope cameras are dollied, panned, and boomed often, and the resulting shots are intercut, dissolved, and inserted; there are even widescreen closeups.

The Perfect Aspect Ratio

It is normal for opinions and techniques to change with time. Standardization of a particular display shape, however, especially when that shape is imposed upon a large glass bulb, locks in a specific preference well into the future. Therefore, it is worth very carefully considering any proposed display aspect ratio for ATV/HDTV.

IMAX was designed originally to allow nine 35mm film images to appear simultaneously on a single screen,[123] and it retains its basic non-widescreen camera aperture[38] (its projector aperture has been variously specified, and its screens vary, too, but they are usually near 4:3 and are never even as wide as 1.66:1).[72] It is an extremely popular film format,[124] and has recently added feature-length and star-cast fictional/ dramatic movies. Does this indicate a trend towards narrower aspect ratios in motion picture film? Should such a trend be considered?

HDTV is said to have a need to be interoperable with other media. The most common computer picture tube display shape is 4:3, though such displays vary between 1:1 and 1.5:1 (and may be rotated 90° to create aspect ratios less than 1:1). In print, the familiar U.S. 8-1/2 x 11-in. piece of paper has an aspect ratio of 0.77:1 or, rotated 90°, 1.29:1; its international counterpart, the A4 size, is 210 x 297 mm, with an aspect ratio of 0.71:1, or, rotated 90°, 1.41:1 ($2^{1/2}$:1). In a book on the history of papermaking, there is no evidence of any aspect ratio of 2:1 or greater.[125] Photographic aspect ratios commonly used (ignoring vertical orientations) range from a minimum of 1:1 to a maximum of 1.5:1, except for rarer panoramic formats.[126]

Here is a list of some currently used or proposed aspect ratios for moving image media displays:

- **Infinite.** This is one way to describe the cylindrical surround theaters such as those found at Disney amusement parks. It seems highly impractical for a home advanced television display.

• **48:9 (5.33:1).** This is the ratio of Toshiba's HD Horizon system, using three 16:9 projected HDTV images placed end to end. The first use of the system was documentation of the restored Michelangelo-painted ceiling of the Sistine Chapel.

• **4:1.** This ratio is commonly created when three 4:3 images are combined, as at the Geographica video theater in Washington, D.C. In the Tokyo Audio Visual Center Superwide-Vision system, the combination is internal to a video camera, so a single lens may be used.

• **10:3 (3.33:1).** This is the shape of the Jumbotron display at the Toronto Skydome.

• **2.75:1 to 2.55:1.** Some anamorphic film projection and most anamorphic video projection falls within this range, the latter because it is the result of applying a common 2:1 anamorphic expansion to television's 4:3 aspect ratio, resulting in 8:3 (2.67:1).

• **2.4:1 to 2.35:1.** This is the projection range most commonly recommended for 35mm anamorphic movies. Theaters do not always abide by recommendations. If it is accepted that this is the widest commonly found aspect ratio, then a display of this shape offers the benefit of allowing masking for narrower images to be drawn in from the sides (like theatrical curtains), rather than from the sides, top, and bottom.

• **2.2:1.** This is the recommended shape of projected 70mm movies; again, theaters do not always abide by recommendations.

• **2:1.** This is the display aspect ratio proposed by the ASC. A few widescreen movies were shot in this aspect ratio. For comparison purposes, it may be expressed as either 18:9 or 16:8 (2:1 is already an integer ratio).

• **1.85:1.** This is the projection aspect ratio most commonly recommended in the U.S. for nonanamorphic 35mm widescreen movies.[19] There is less than 4% difference between this aspect ratio and 16:9 (there is a comparable difference between the original Academy aperture of 1.375:1 and 1.33:1).

• **1.8:1.** This ratio was selected by SMPE in 1930 on the basis on an AMPAS recommendation to be used with wide film. For its tests, SMPE used a 1.78:1 (16:9) screen. In the current edition of the *American Cinematographer Manual* (1993), 1.8:1 is listed as the aspect ratio of a proposed theatrical anamorphic projection system designed to replace the current 2.4:1.[38] There is much less difference between this ratio and 16:9 than between the Academy aperture of 1.37:1 and 1.33:1. There is also much less difference between 1.8:1 and 16:9 than between 2.4:1 and 2.35:1.

• **16:9 (1.78:1).** This is the aspect ratio of the standards SMPTE 240M and SMPTE 260M. It has also been adopted by other countries around the world for both HDTV and other forms of widescreen television.

• **1.75:1.** This is a popular projection aspect ratio in some theaters around the world. It was once called "the widest screen possible without changes in camera technique" [from that used for nonwidescreen movies].[52]

• **1.66:1 (5:3).** This is a popular widescreen projection aspect ratio in many theaters outside the U.S. Some HDTV programming has been shot in this aspect ratio.

• **14:9 (1.56:1).** This is a very common aspect ratio used to mitigate the effects of letterbox when HDTV is downconverted to non-HD TV.[127] It is so commonly desired that it exists as a preset function in some aspect ratio conversion equipment.[128]

•**16:10.7 (1.5:1).** This strangely enumerated ratio (an integer ratio of 3:2), also called Cinema Wide, is offered by Pioneer in projection television receivers.[129] Like 14:9, it is intended as a compromise ratio between HDTV and non-HD TV. The method of numbering the ratio appears intended to promote it as having even larger numbers than 16:9, lending some credence to a complaint about the promotional use of the 16:9 ratio relative to others in press releases.[22] As 1.5:1, this aspect ratio is also the shape of the VistaVision frame[38] and has been suggested as a shape for the future.[130]

• **1.375:1 (11:8) to 1.37:1.** This is the shape of almost all movies shot between 1933 and 1953 and many thereafter. It is sometimes described as being 4:3 or 1.33:1 even though it differs from that aspect ratio by 3.2%, almost as much as the difference between 1.85:1 and 16:9.

• **4:3 (1.33:1).** This is the shape of virtually all television programming and display screens, virtually all CRT-based computer display screens, and many movies. As the narrowest commonly used or recommended aspect ratio, it is the most efficient for the manufacture of cathode-ray tubes (1:1 would be even more efficient, if such displays were commonly used). It is the longest-lived aspect ratio for moving imagery and continues to be chosen for recent large-format film systems, such as the 70mm IMAX and Dynavision systems.[38]

• **Narrower than 4:3.** This is the shape of some post-sound-track, pre-Academy-aperture movies, some computer display screens, and some special venue films. Data Check, a manufacturer of television monitoring equipment, in 1995 introduced tiny 1:1 picture-tube-based monitors on which even 4:3 images are displayed in a letterbox format.

Conclusion

This paper began with the statement that two aspect ratios are inherently incompatible and has ended with a list of well over a dozen different aspect ratios. The techniques of aspect ratio accommodation are equally applicable to any. There is no clear evidence of an aesthetic or physiological reason to choose any one aspect ratio over another.

For the particular ranges of aspect ratios between 4:3 and 2.35:1 (or between 1.15:1 and 2.75:1), a display shape of approximately 16:9 will require the least aspect ratio accommodation for both extremes of the range. For the specific requirement of doubling ITU-R Rec. 601 (720 active pixels/line) resolution for HDTV, 16:9 best matches random access memory (RAM) capacities.

If those characteristics and the others listed in this paper are considered insignificant or become outweighed by other considerations, there may no longer be a strong reason to choose 16:9. The 16:9 aspect ratio has already been chosen, however, and is in use around the world. The research for this paper has not found any compelling reason to change any existing choice of aspect ratio.

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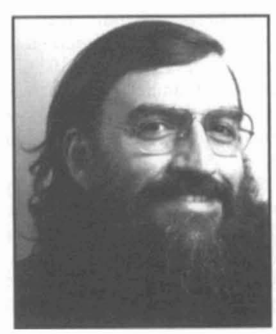

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