HDTV: The race begins…

Path to What the Eye Demands

by

Mark Fihn

January 17, 2008

SID New England Chapter Meeting

Mark Fihn currently heads a publishing company called Veritas et Visus, where he supports the flat panel display industry based on his expertise related to notebook PCs, Tablet PCs, touch technologies, the LCD TV market, and display related human factors, including high resolution and wide aspect ratios. Prior to Veritas et Visus, Mark worked for 3 years at the market research firm DisplaySearch. He additionally participated for 15 years in computer system and LCD-related procurement at Texas Instruments and Dell Computer while living in the United States and Taiwan. He has been active in many display-related areas, most specifically in publicly championing industry-wide adoption of high resolution displays, notebook LCD standardization, and video sub-system integration. Mark was educated at St. Olaf College (Northfield, Minnesota), the American Graduate School of International Management, (Phoenix, Arizona); St. Edward's University, (Austin, Texas), and in the University of Texas at Austin's doctoral program in International Business. Most recently, Mark has been an active supporter and lecturer at the DisplayMasters degree program in the UK, contributing course lectureships at Cambridge University, Dundee University, and The Nottingham-Trent University.

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Truth & Vision

Abstract

For the better part of 75 years, analog and CRT-based television dominated the world of home video entertainment. Spurred by government mandate and newer display technologies, the past 5 years has seen a massive switch to high definition digital TV. While many argue that this transition to HDTV is an endgame that will extend for several decades, this talk will expose realities that suggest HDTV is still very much in its infancy and that we will witness massive changes in home entertainment in the years to come.

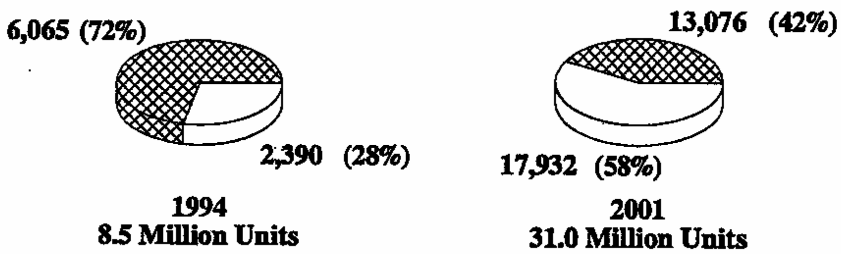
With a view to the future, this talk will take a pragmatic look at current market trends in terms of TV technology, ongoing standards battles, environmental activism, higher and higher display-related performance levels, 3DTV, and the ongoing question of convergence between the CE/PC industries.

The Problem with Forecasts…

Forecasts are based largely on historical experience…

Flat Information Displays - 1994

FLAT PANEL FORECAST: PORTABLE PCs
COLOR/MONOCHROME
Thousands of Units



Flat Information Displays - 1994

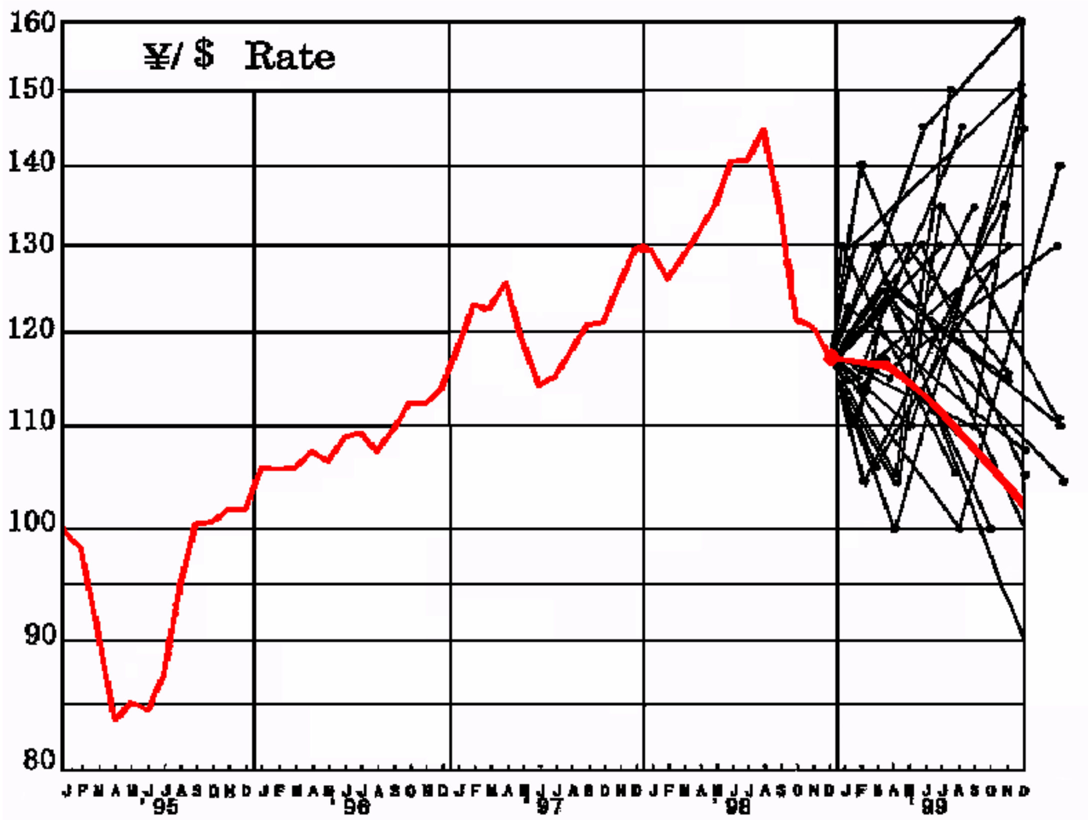
COMPUTER EQUIPMENT DISPLAYS IN 2001
Flat Panels vs CRTs
Pixel Format

	FLAT PANELS (Portable)	CRTs (Desktop)
VGA (640 x 480)	47%	5%
>640x480 <=1,024x768	30%	73%
>1,024 x 768	3%	22%
Others	20%	0%

- In 1994, Stanford Resources forecasted that 42% of 2001 notebook sales would still be monochrome.

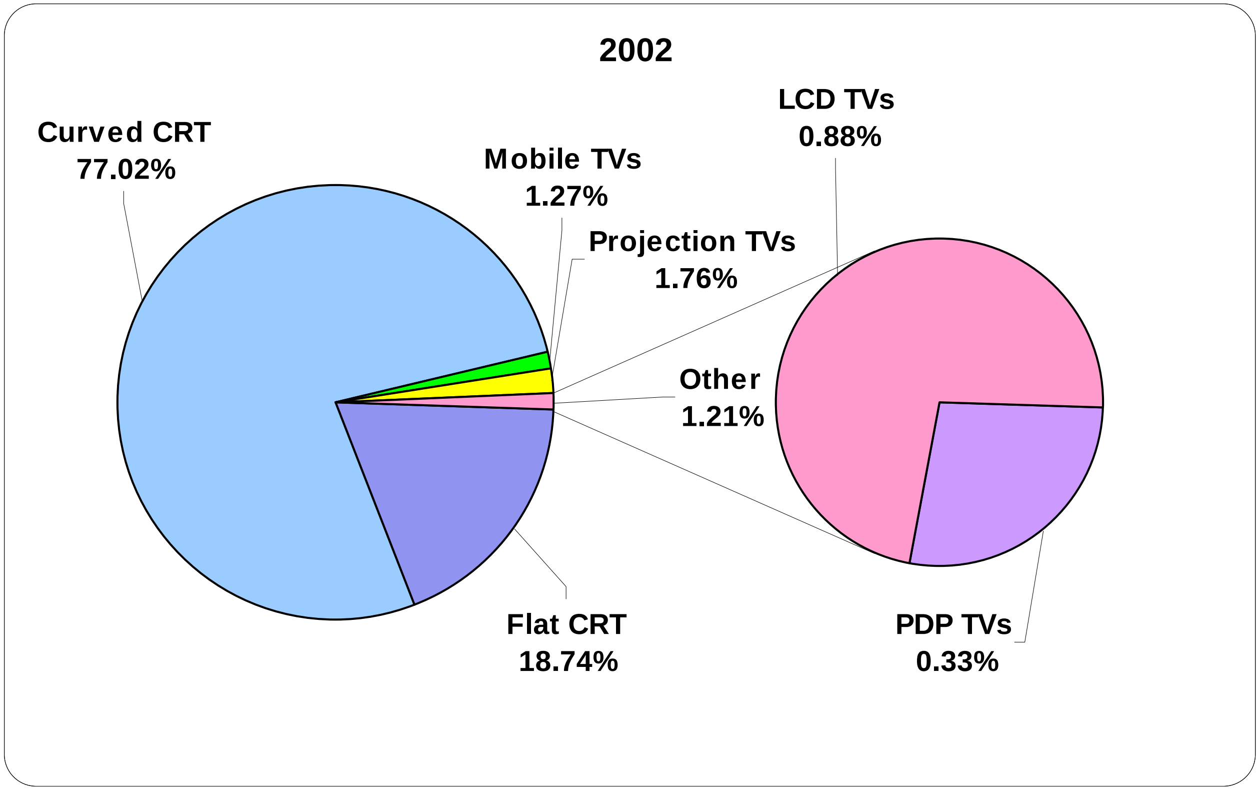
- In 1994, Stanford Resources did not even forecast LCD monitors, with half the portable market still at 640x480 pixels

There are just too many variables…



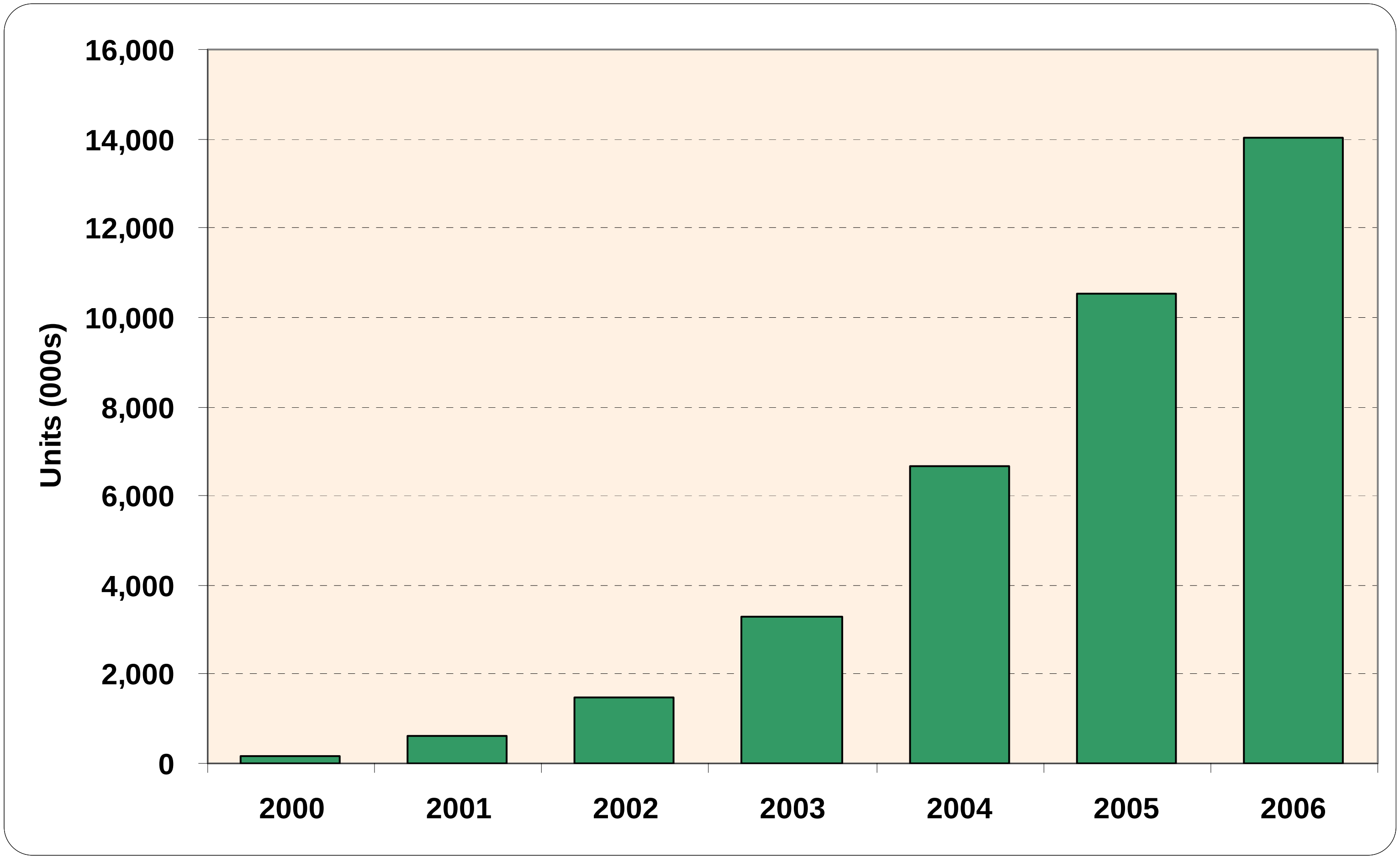
This is dated, but shows the predictions of leading financial firm for the yen/dollar rate in 1999.

TV Market Forecast by Type



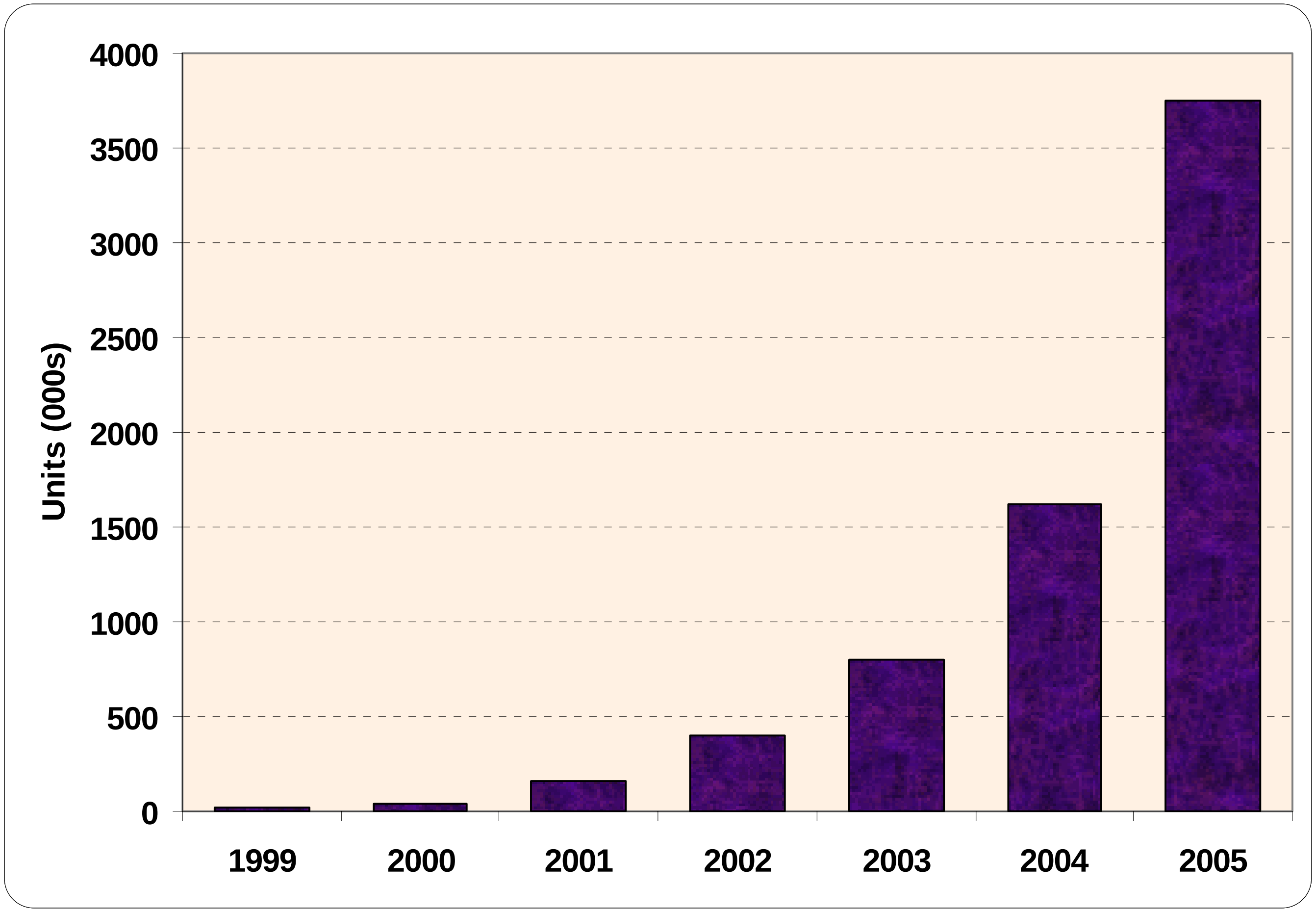
DisplaySearch, December 2002

LCD TV Shipment Forecast



DisplaySearch, December 2002

PDP TV Market Growth



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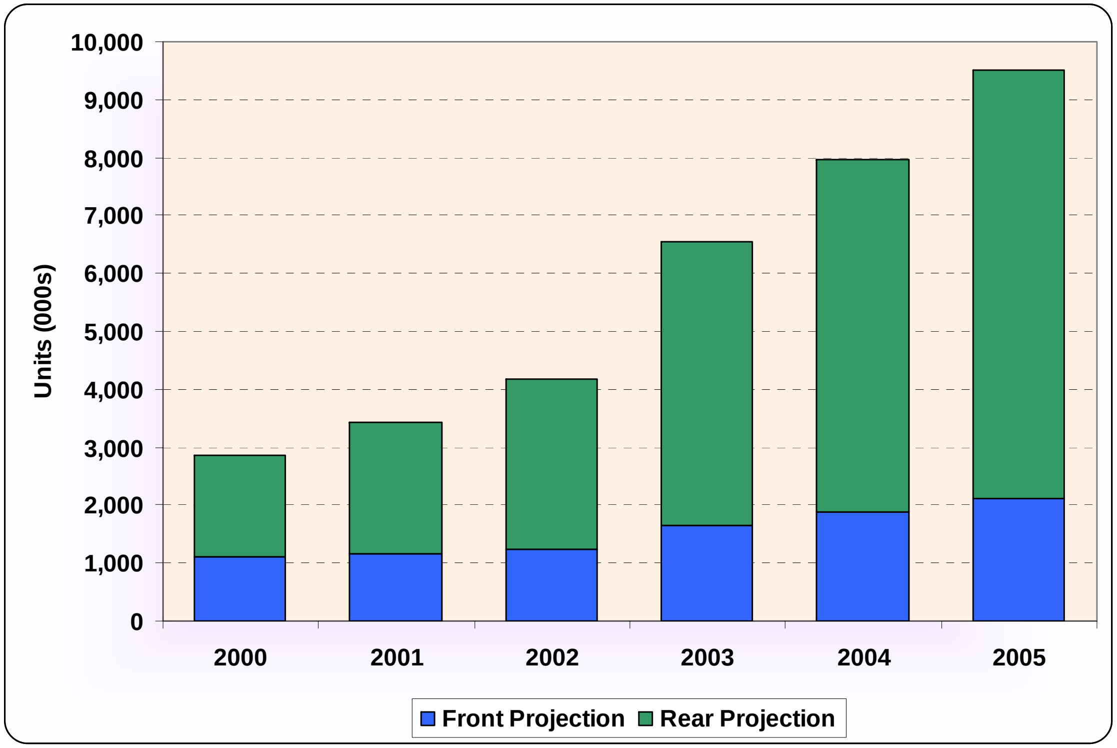
Projection TV

Front vs Rear Projection Market Outlook



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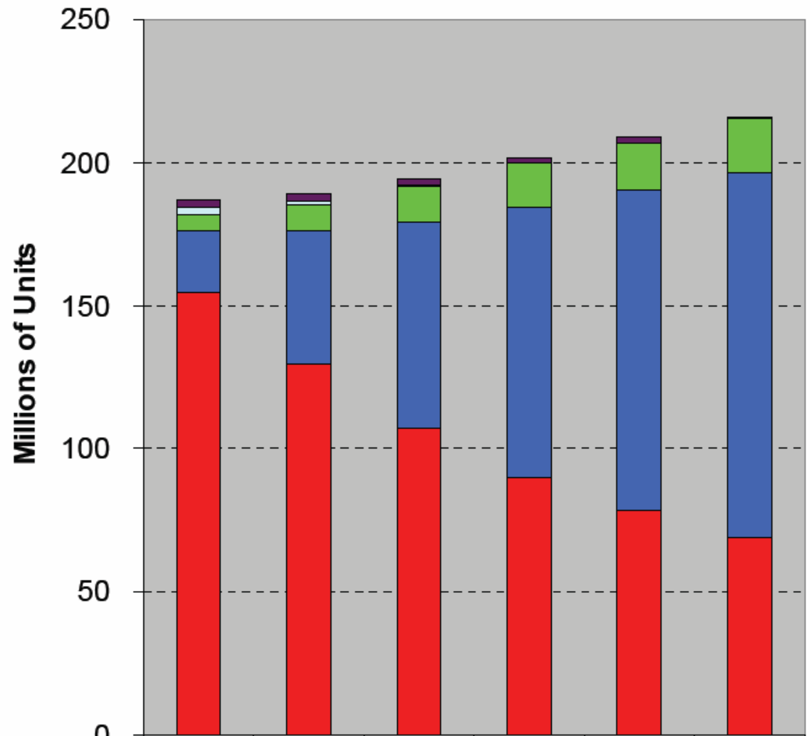
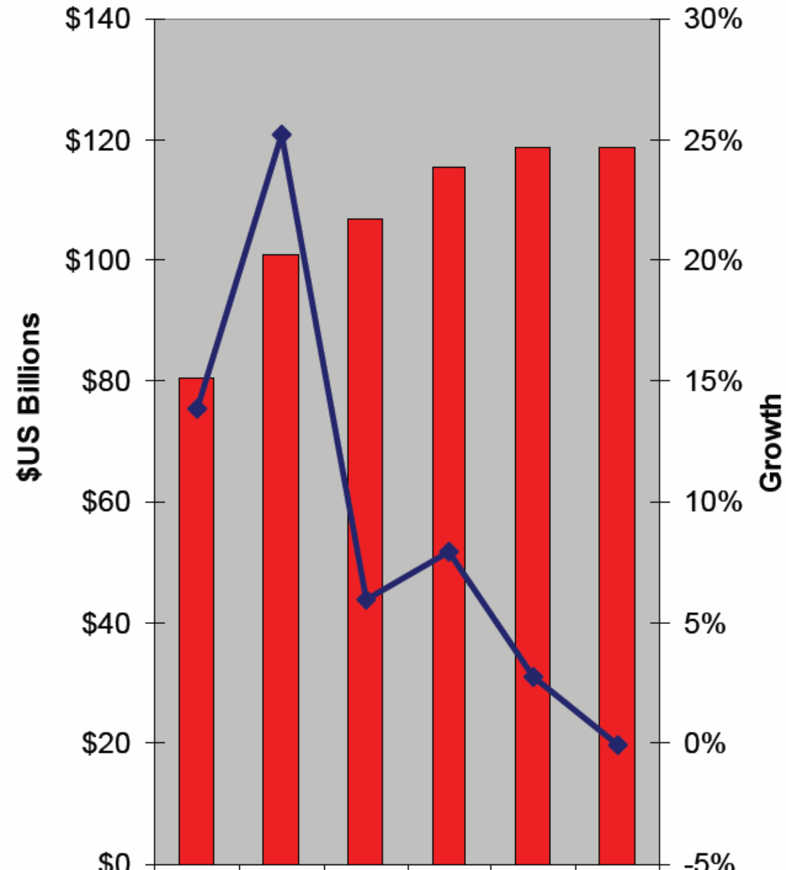
Current TV Market



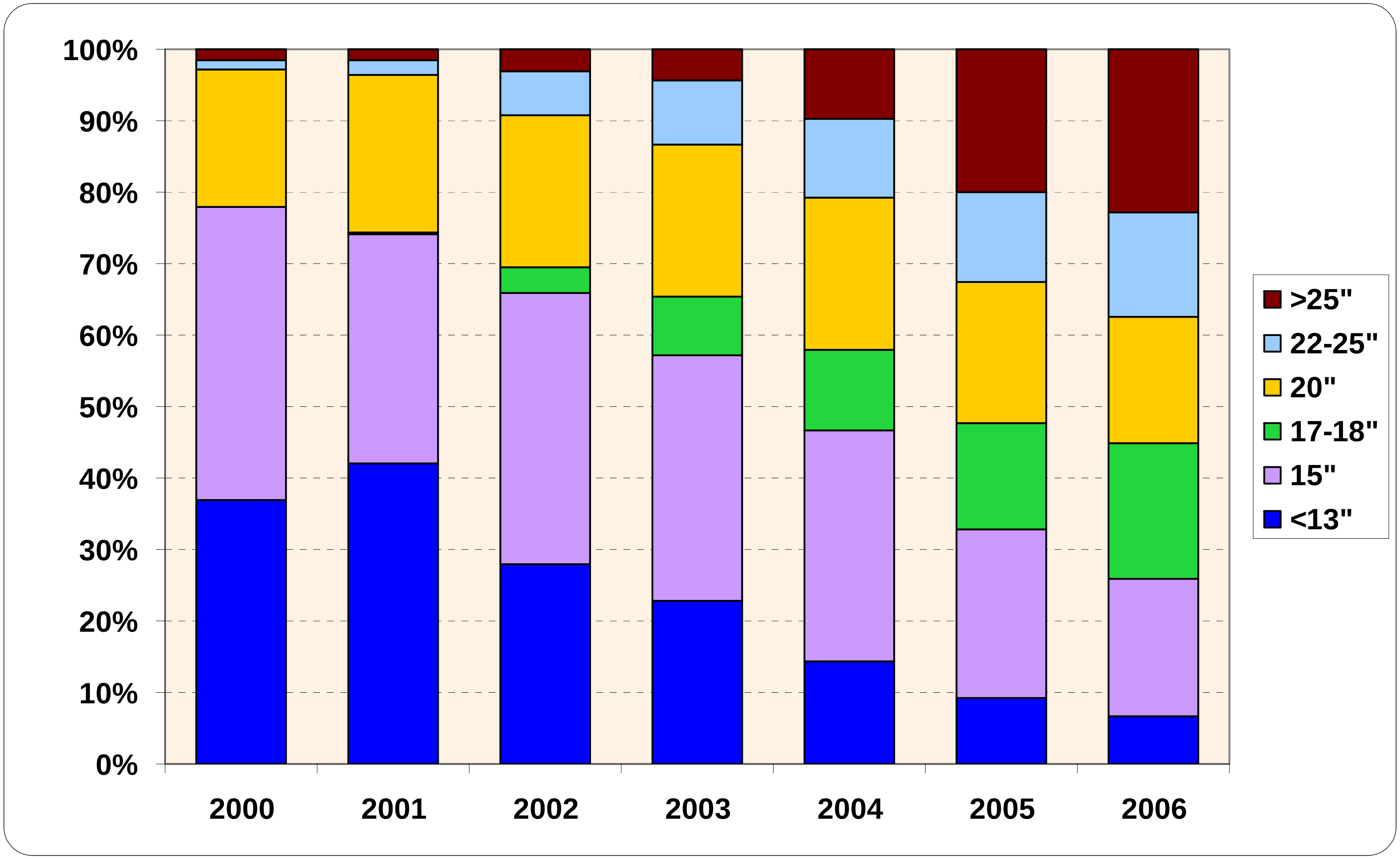
	2005	2006	2007	2008	2009	2010
MD RP	2.5	2.8	2.3	1.8	1.4	1.1
CRT RP	2.4	1.2	0.3	0.1	0.0	0.0
PDP	5.9	9.2	12.3	15.0	17.0	18.2
LCD	21.2	46.0	72.2	94.6	112.1	128.2
CRT	154.9	129.9	107.2	90.0	78.2	68.7



	2005	2006	2007	2008	2009	2010
TVs	$81	$101	$107	$115	$119	$119
Growth	14%	25%	6%	8%	3%	0%

DisplaySearch, November 2007

LCD TV Forecast by Size



DisplaySearch, December 2002

Pop Quiz #1

What is the most important factor related to the performance of a display?

The Human Factor

Truth & Vision

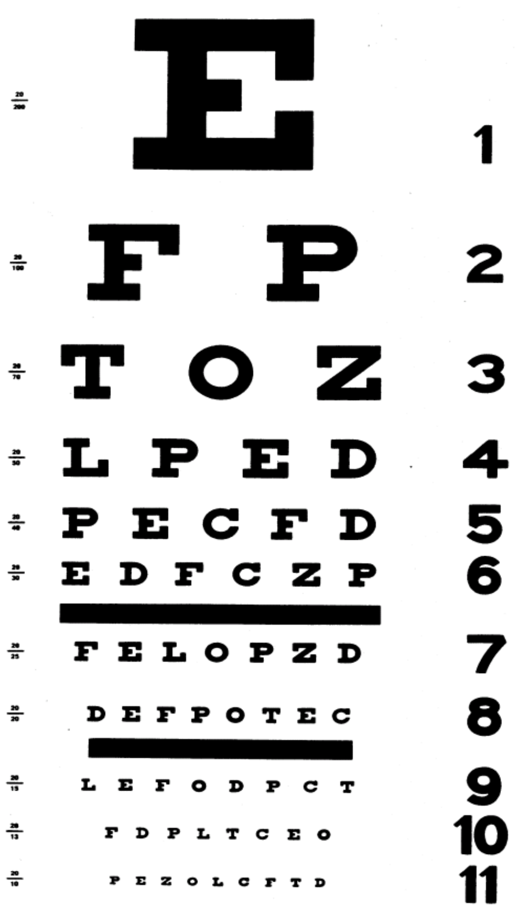
Pop Quiz #2

When were eyeglasses first worn?

The History of Eyeglasses

Visual Acuity

Snellen Eye Chart



"Optical Infinity"

U.S.	**20/20 (feet)**
Rest of World	**6/6 (meters)**

Optical Infinity is the least distance at which there is no significant accommodation by the crystalline lenses of a patient's eyes, (to represent parallel lines of light).

20/20 visual acuity resolves 1 arcmin.

Note: Traditionally, optical infinity has been accepted to be 20 feet. However, at this distance, there is an accommodative demand on the eye of about 1/6 D (one-sixth of a diopter), which can be significant. Many experts maintain that optical infinity, for purposes of examining the refractive error of the human eye, should be at least 8 meters or 26 feet.

20/20 Ignores Many Factors

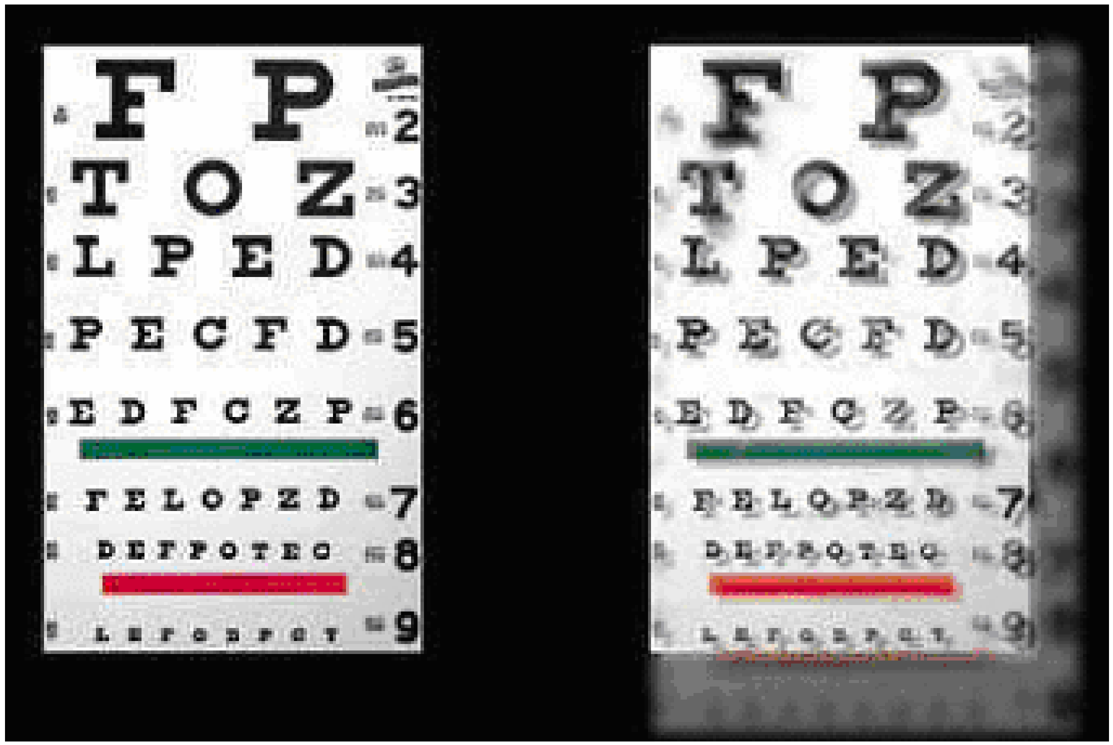
However, 20/20 is defined for a room maintained at a very dim ambient illumination (e.g. 100 lx). In Nature the range of illumination is many orders of magnitude higher (0.01-100,000 lx) and luminance contrast is often sufficient to resolve objects smaller than 50 arc seconds.

Also, 20/20 is defined for black/white luminance contrast and ignores color, 3D, and motion as image resolving features of human vision.

Human visual acuity is much finer than 20/20 implies. Stars subtend far less than 50 arc seconds, perhaps as small as 5 arc seconds in some cases, yet people see stars. Similarly, glint from a highly reflective surface is readily visible, but often subtends 20-25 arc seconds or less.

Visual Acuity vs. Visual Quality

An eye exam requires more than the Snellen Test…



Hyperacuity

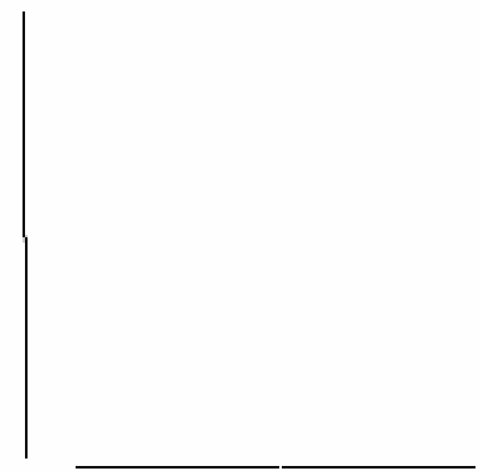
The most famous example of hyperacuity is Vernier acuity, also known as positional acuity. An attribute of Vernier acuity is the ability to perceive colinearity between two line segments. Humans can resolve two line segments as being distinct if they differ by as little as 1 second of an arc:

Vernier acuity represents the smallest detectable displacement among resolvable features, (less than the separation between each cone in the fovea).

- **about 2 sec of arc in adults (Berry, 1948)**
- **less than 1 sec of arc in optimal conditions (Klein & Levi, 198?)**

<u>Vernier Acuity vs. Visual Acuity</u>

It's obvious for most people the vertical lines are disjoint, with a one-pixel separation around the midpoint. This is the example of Vernier acuity. It's less obvious that the horizontal lines are separated by one pixel at the midpoint, which is a measure of visual acuity.



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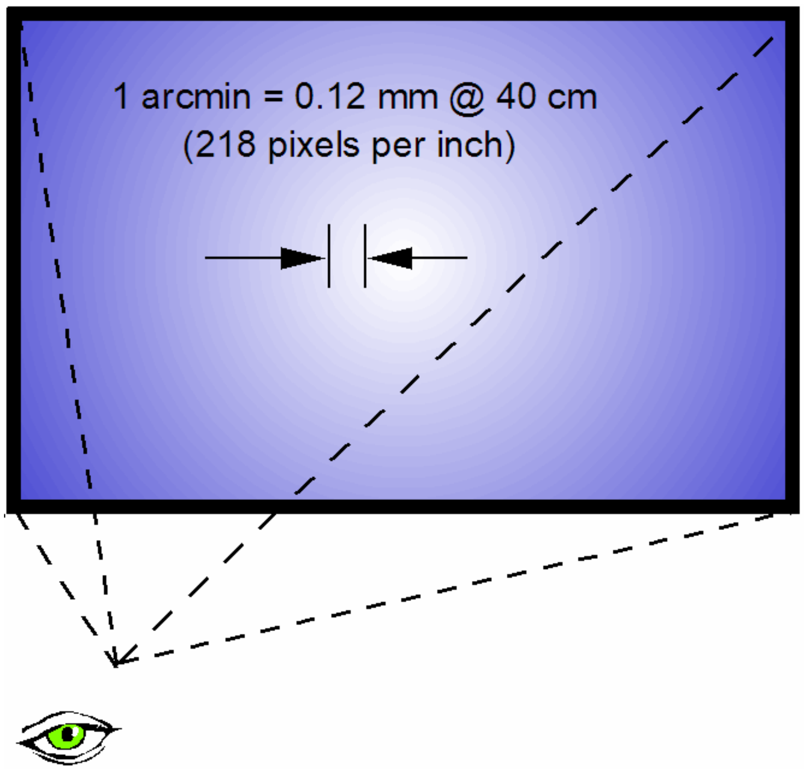
Visual Acuity – the “wrong” conclusion?

20/20 visual acuity resolves 1 arcmin



Problem: This calculation leads many to conclude that for devices that are typically viewed from greater distances, the human eye is “satisfied” with low display pixel densities.

But, in nature, we:

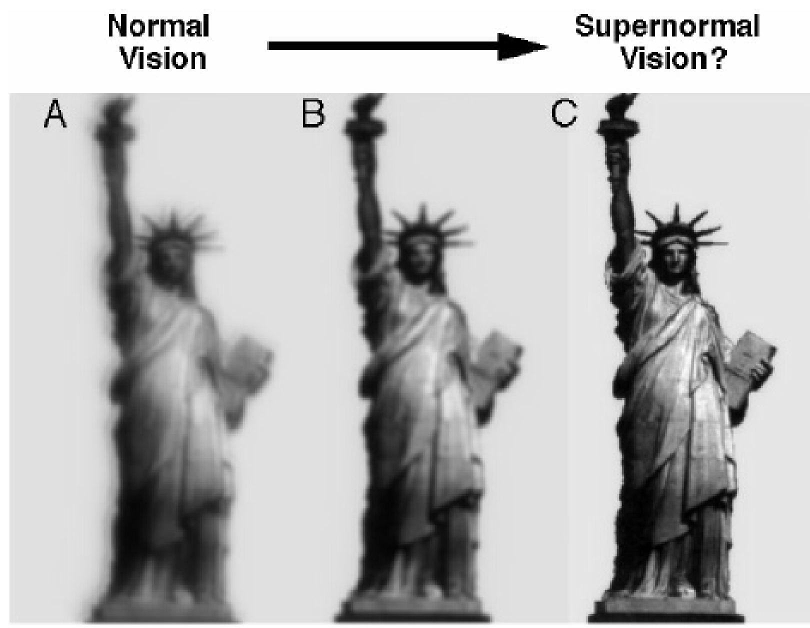
- **Don’t have an assumed viewing distance…**
- **Can move closer if we can’t see adequately…**
- **Can magnify images…**

Supernormal Vision

Dr. Donald Miller, in studies at Indiana University has suggested there are ways in which we can significantly improve visual acuity.

Typical limits to human visual acuity are about 20/15, but perhaps with "supernormal optics", acuity can be improved to as much as 20/2.5.

To illustrate what the retinal image would be like with supernormal optics, imagine yourself viewing the Statue of Liberty at a distance of 3 kilometers from a boat in the New York Harbor. At this distance the statue subtends almost 0.9 degrees, which is equivalent to that of a US quarter at 5 feet away. Under optimal viewing conditions and 20/15 vision (i.e. a normal 3 mm pupil), your retinal image of the statue would look like Figure A. If you view the statue through adaptive optics, programmed to fully correct all ocular aberrations across your 3 mm pupil, then the retinal image of the statue would look like Figure B. Notice the finer detail and higher contrast in the retinal image when the eye's aberrations are corrected. This illustrates that retinal image quality can be noticeably increased even for pupil sizes as small as 3 mm. Maximum retinal image quality can be obtained with the largest physiological pupil diameter (8 mm) and full correction of all ocular aberrations. This situation is depicted in Figure C, which shows that the theoretical maximum optical bandwidth that can be achieved with the human eye is six times greater than the optical cutoff of a normal eye with a 3 mm pupil (i.e. 20/2.5 versus 20/15).



The latest way to avoid eye-care costs…

LASIK surgery you can do at home

A new product called LASIK@Home claims to affordably enable people to do the surgery themselves. The key to the LASIK@Home system is the Scal-Pal Scanning Adjusting Laparascopic Personal Laser.

First the Scal-Pal femtosecond laser cuts a small flap in the cornea of your eye. Then the excimer laser vaporizes a tiny section of the lens without damaging the surrounding tissue. The whole procedure takes only a few minutes and is virtually painless. LASIK@Home claims to "100% safe, but is only possible with the Scal-Pal laser".

The complete LASIK@Home kit includes everything you need to complete the procedure: Scal-Pal Hand-Operated Combination Femtosecond/Excimer Laser, mild sedative (diazepam 4mg), No-Blink brand Eye Drops, detailed instructions and QuickStart Guide, and a protective post-op sleep mask. The Scal-Pal laser comes pre-programmed to correct your individual prescription. The kit can be ordered online for $99.95. www.lasikathome.com

Pop Quiz #3

What display resolution do we need to achieve 20/20 vision?

High Resolution → High Productivity

Word Comprehension Study

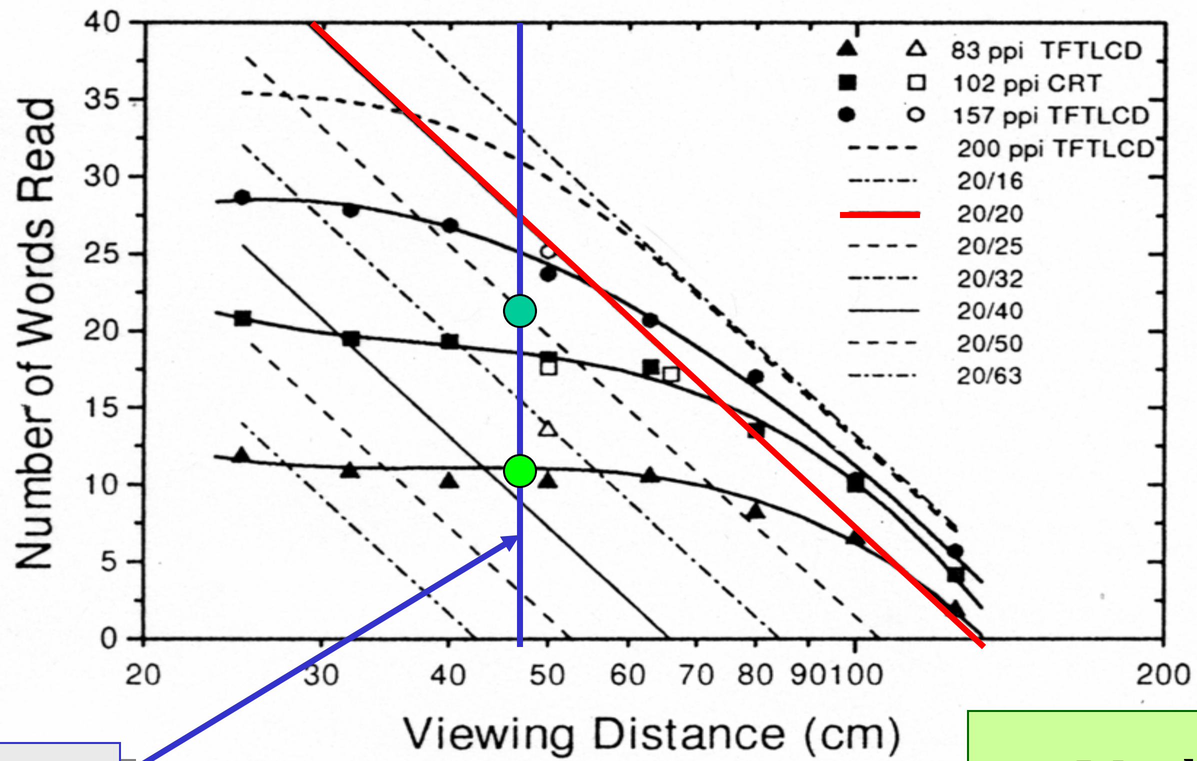


Figure 1. Display Legibility

18" Viewing Distance

Wright, S.L., et. al. (1999) SID'99 Digest, 346-349.

Word Recognition

●	**15.0" 1600x1200**	**22 words**
●	**15.0" 1024x768**	**12 words**

Spatial Resolution and the Display

Text Legibility

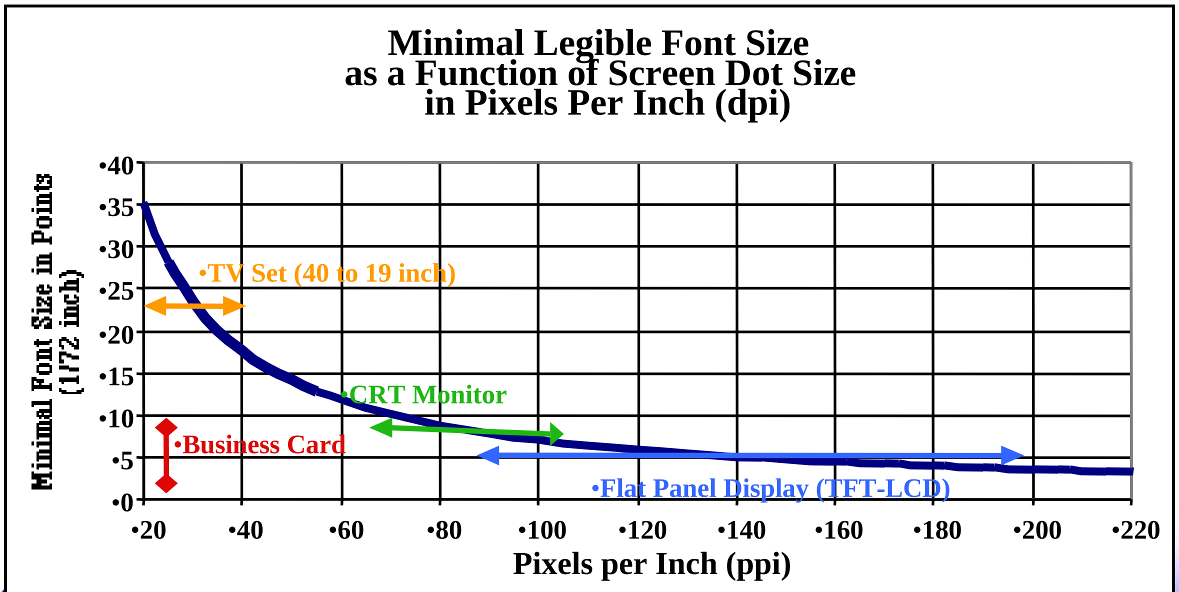
- Gordon Legge (University of Minnesota) has shown that text is legible if there is a minimum of 2.5 to 3.5 cycles of spatial information per letter width.

- Typical fonts have an aspect ratio of 5:7.

- A font point is 1/72 of an inch

- Using the 3.5 cycle rule, then a font must be no smaller than 7 resolvable pixels wide. Based on a 5:7 aspect ratio, a letter must be at least 9.8 resolvable pixels high to be legible.

- Therefore: Minimal Legible Font Size = 705.6 / ppi.



15.0" Example:

Resolution	PPI	Font
XGA	85	8pt
SXGA+	117	6pt
UXGA	133	5pt

Resolvable Font Sizes.

3pt fonts are readable at 200ppi.

Good Enough Image Quality

The Human Condition

By Rene Magritte (1934)

The Eye is NOT a Camera…

Camera exposed for interior view

Camera exposed for exterior view

What we see…

Pop Quiz #4

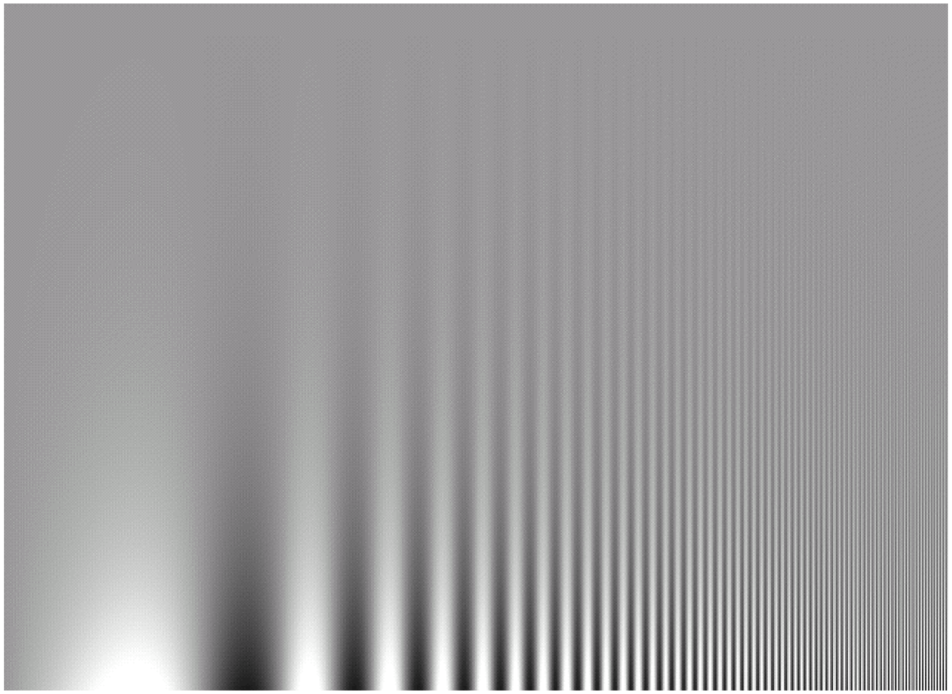
What is more important, contrast or resolution?

Contrast Sensitivity

Contrast sensitivity refers to the ability of the visual system to distinguish between an object and its background. For example, imagine a black cat on a white snowy background (high contrast) vs. a white cat on a white snowy background (low contrast).

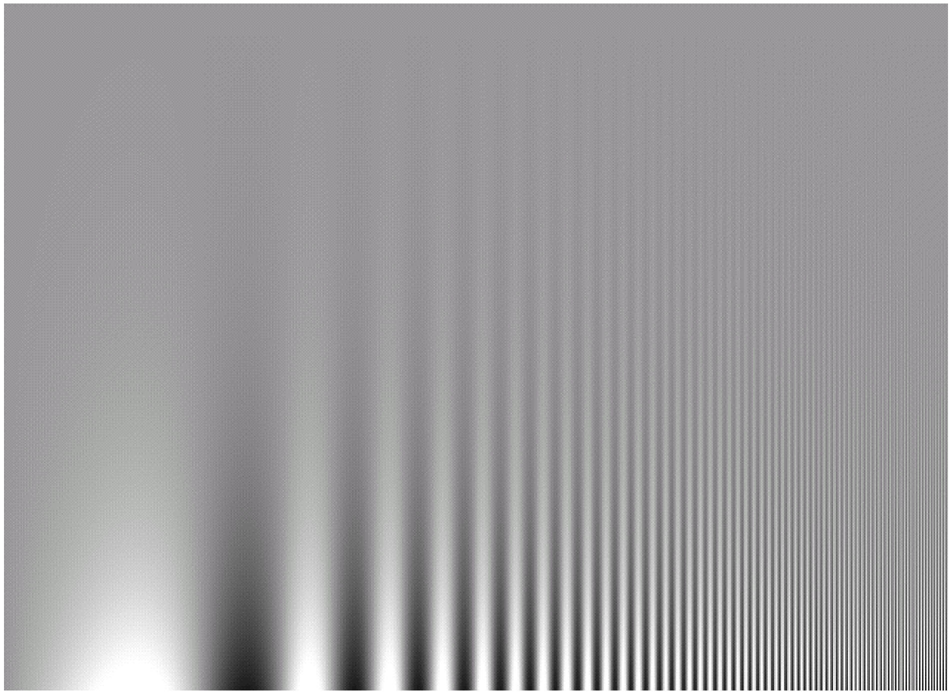
A famous contrast sensitivity test image shown was produced by Campbell and Robson in 1968 and illustrates the human sensitivity to contrast intuitively to any viewer. In the Campbell-Robson image, the luminance of pixels is modulated sinusoidally along the horizontal dimension. The frequency of modulation (spatial frequency) increases logarithmically, i.e., with exponential increase in frequency from left to right. The contrast also varies logarithmically from 100% to about 0.5% [or whatever your 8-bit gray scale display gives you] (bottom to top). As such, the luminance of peaks and troughs remains constant along a given horizontal path through the image. Therefore, if the detection of contrast is dictated solely by image contrast, the alternating bright and dark bars should appear to have equal height everywhere in the image. However, the bars appear taller in the middle of the image than at the sides. This inverted-U shaped envelope of visibility is your contrast sensitivity function.

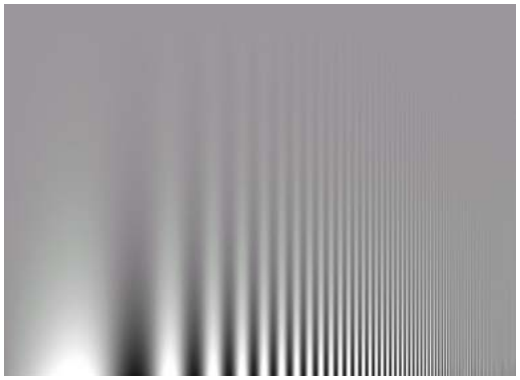
Campbell-Robson Contrast Sensitivity



Campbell-Robson Contrast Sensitivity

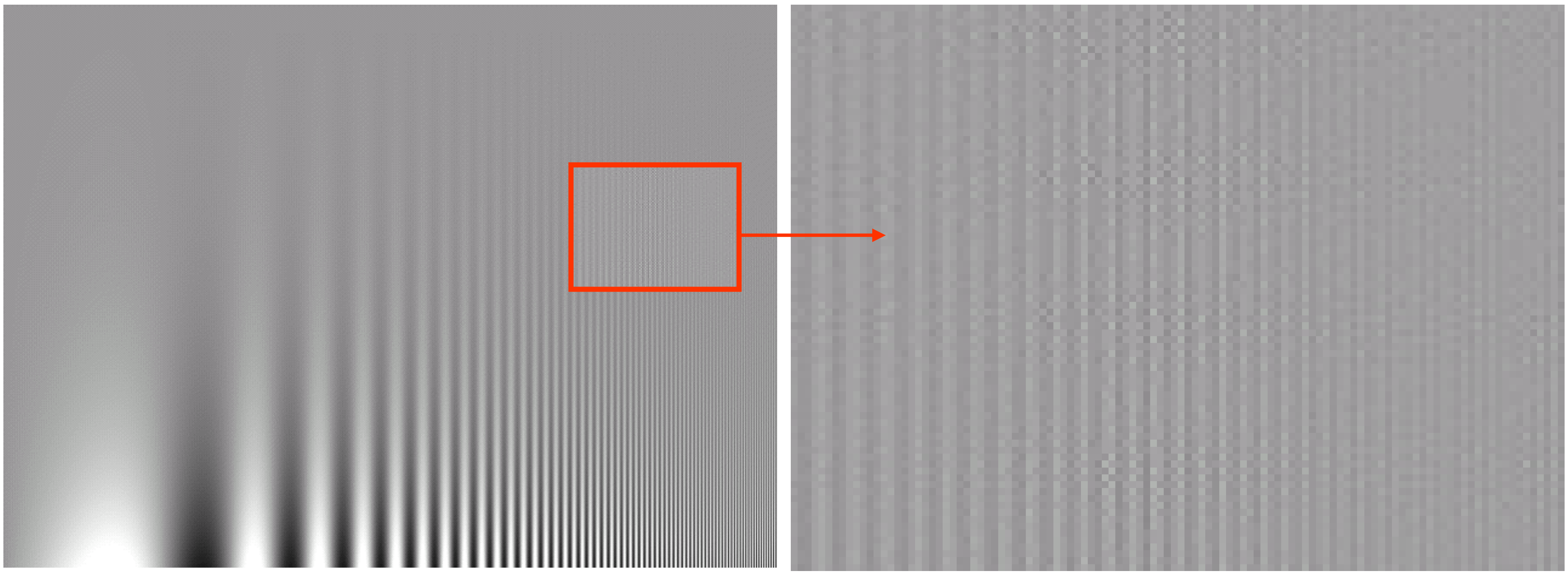
Like resolution, contrast sensitivity depends on viewing distance…





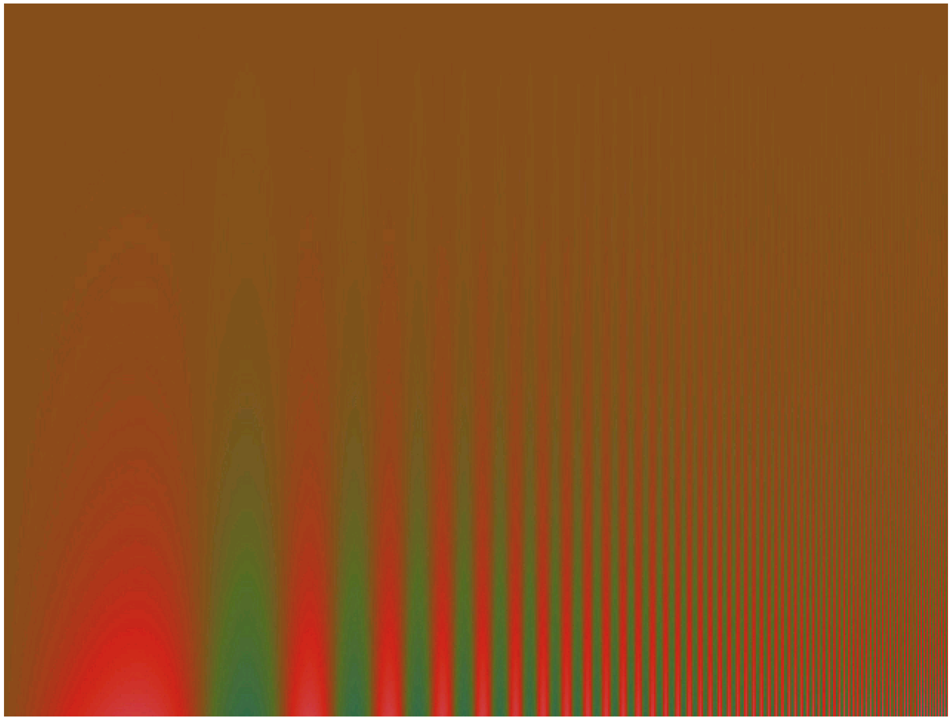
Campbell-Robson Contrast Sensitivity

Contrast sensitivity depends on the resolution of the reproduction…



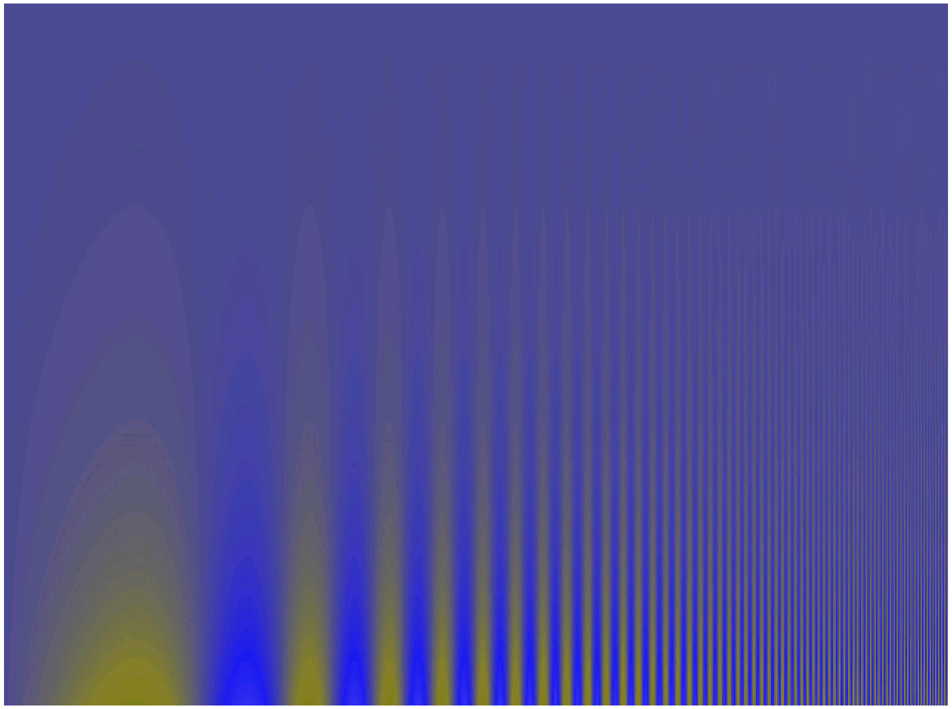
Campbell-Robson Contrast Sensitivity

Contrast sensitivity also depends on color mix…



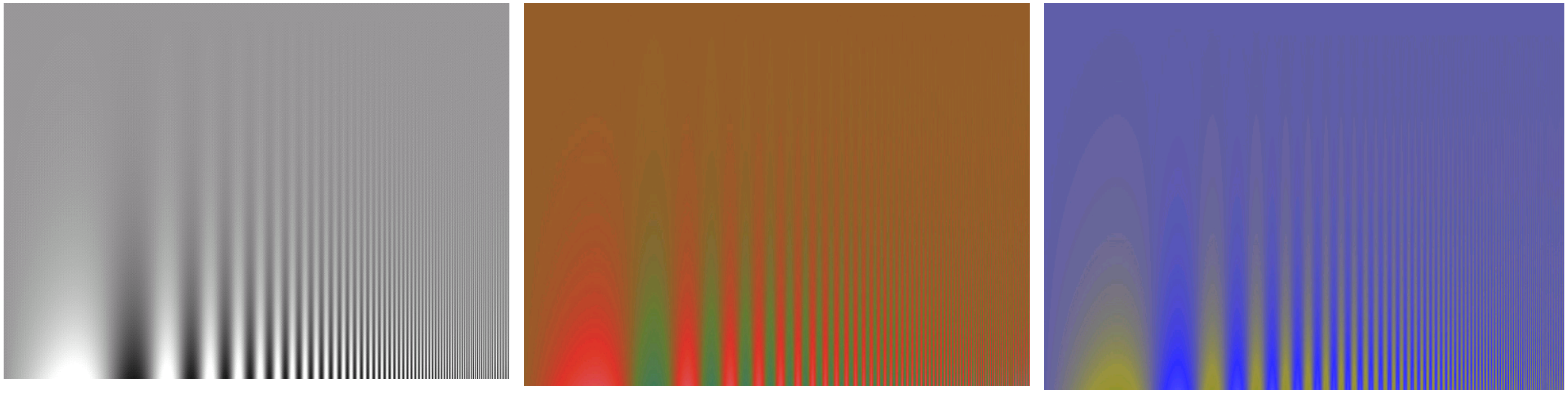
Campbell-Robson Contrast Sensitivity

Contrast sensitivity depends on color mix…

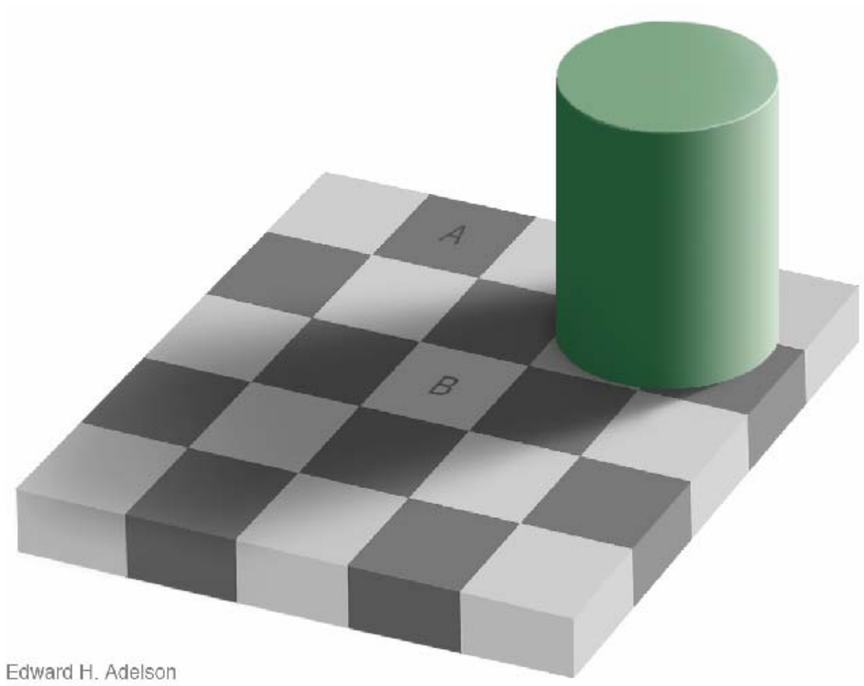


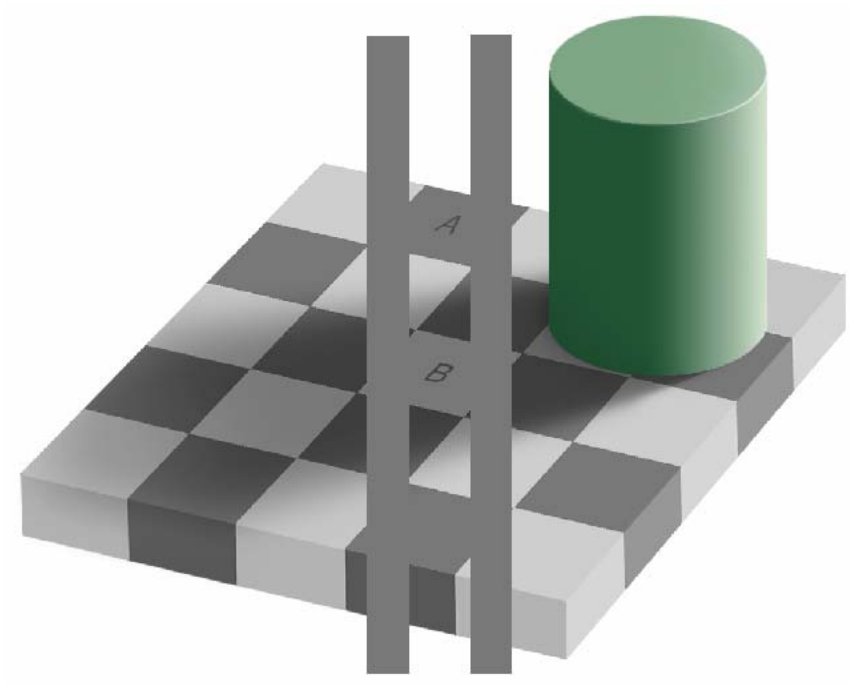
Campbell-Robson Contrast Sensitivity

Comparison of contrast sensitivity with different color mixes…



Adelson Checkershadow…





Resolution vs. Contrast

A common argument, coming primarily from TV and Cinema display makers, is that contrast is more important than resolution for a satisfying visual experience…

High Resolution
High Contrast

Low Resolution
High Contrast

High Resolution
Low Contrast

Pop Quiz #5

How many colors can we distinguish?

Philips Vidiwall: Interesting spec - 120 inches, 36,864 pixels, (256x144) and >200 billion colors!

How many colors can we distinguish?

"My answer is 12,500".

"Yes, that's roughly how many different colors the average eye can distinguish.

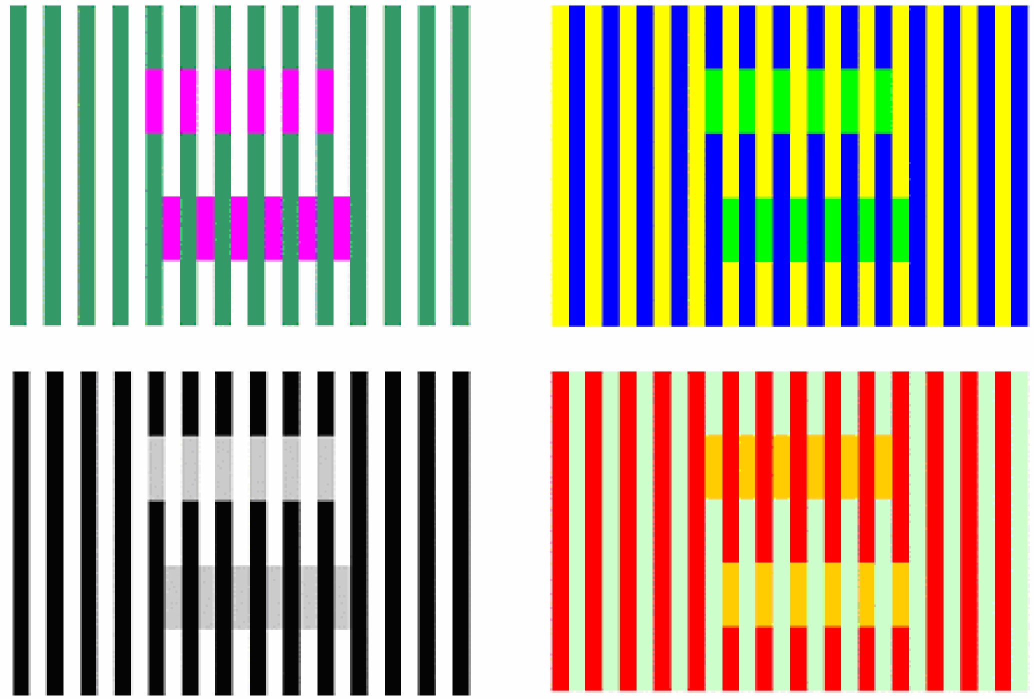
One actually does need 8 bits in order to match the eye's ability to discriminate color, but claiming 16M "colors" is not exactly truth in advertising".

-- Dr. Norman Bardsley

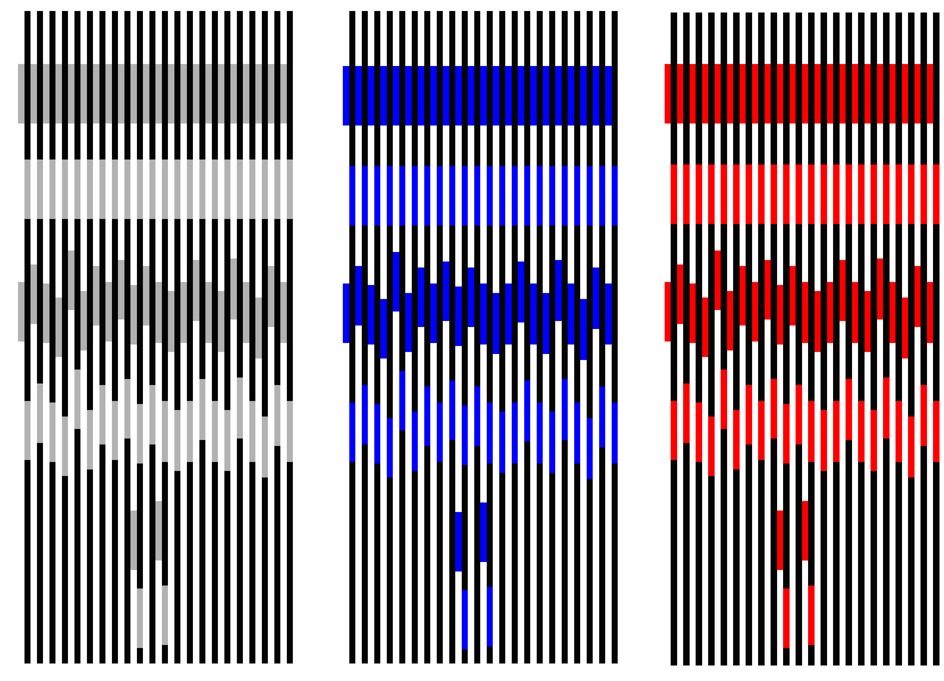
Consultant to the displays industry

Chrominance Contrast

The human visual system must not only detect light and color, but as an optical system, must be able to discern differences among objects, or an object and its background. Known as physiological contrast or contrast discrimination, the relationship between the apparent brightness of two objects that are seen either at the same time (simultaneous contrast) or sequentially (successive contrast) against a background, may or may not be the same.   Motion adds further confusion…



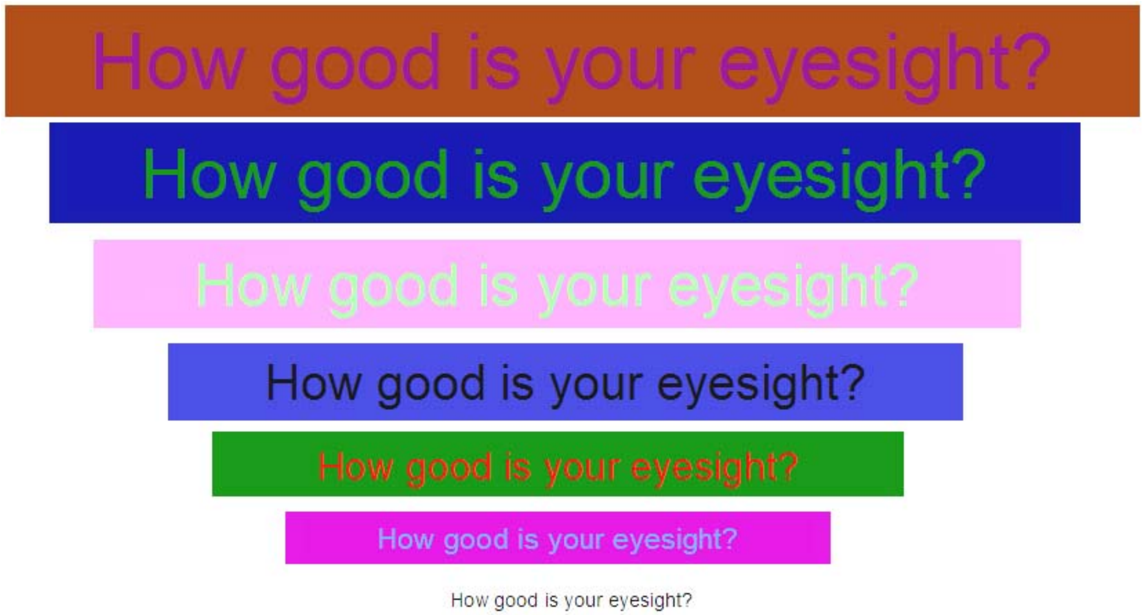
A trillion colors?



The Munker-White Illusion

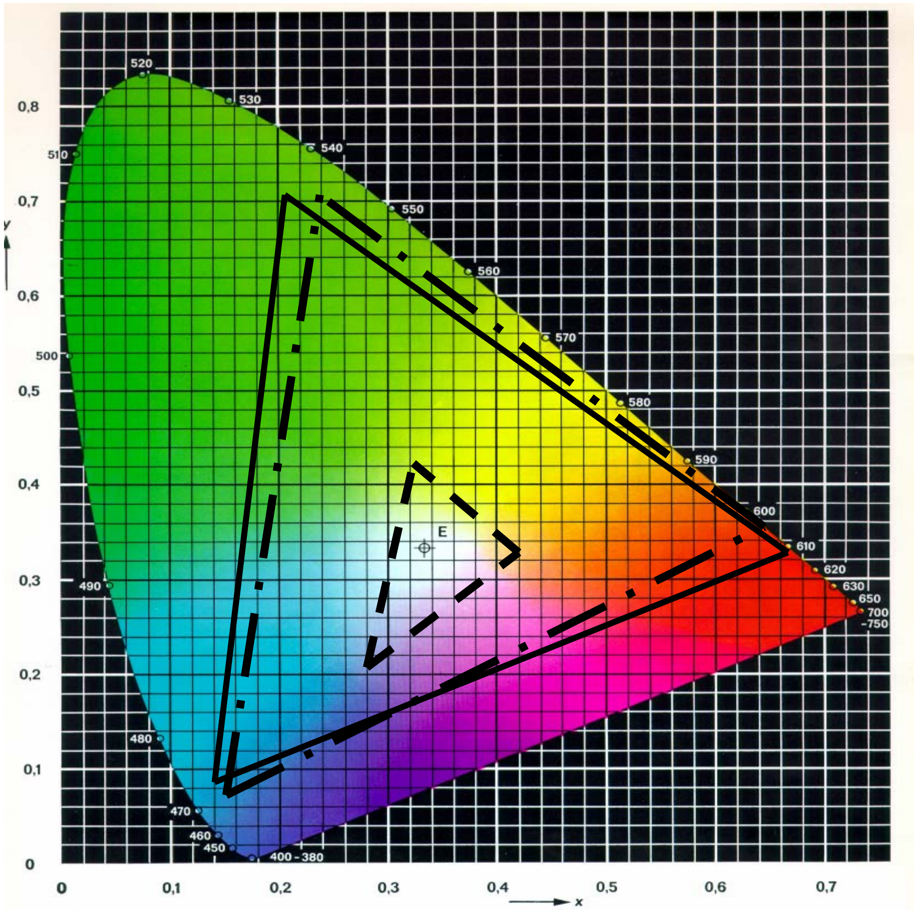
Chrominance Contrast

Chrominance contrast is very important in terms of text readability. Font size, in these examples is far less important to readability than the relative contrast relationships.



We need a different question!

For most applications, the color range (or gamut) is more important than the "number" of colors. It is shown here on the CIE (x,y) plot

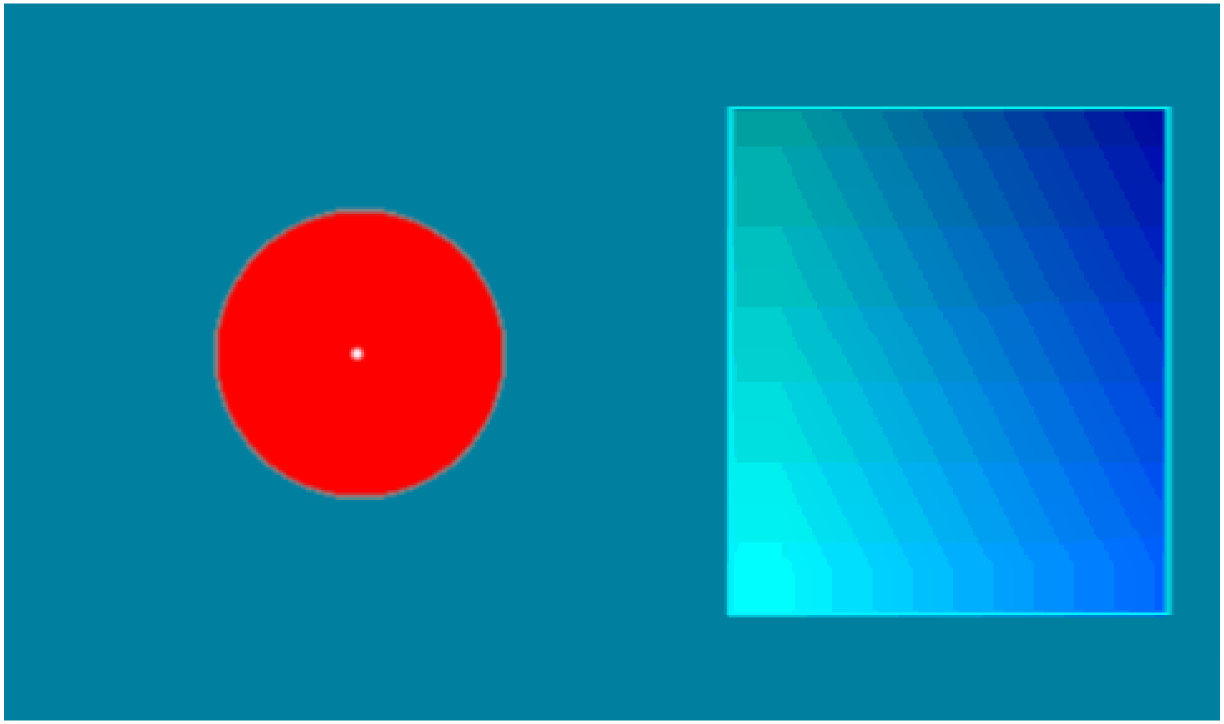


NTSC Standard

Typical PDP (good)

Typical reflective LCD (not so good)

The color Cyan…



Stare at the white dot in the center of the red circle. The longer the better (two minutes and you'll get a much stronger effect). Not long after starting, you'll begin to see a thin rim of light around the edge. But don't stop staring yet! Once the two minutes are up, then slowly move your head backwards – you will see a color that is not seen on typical display screens…

Motion and Emotion

We usually see motion blurred…

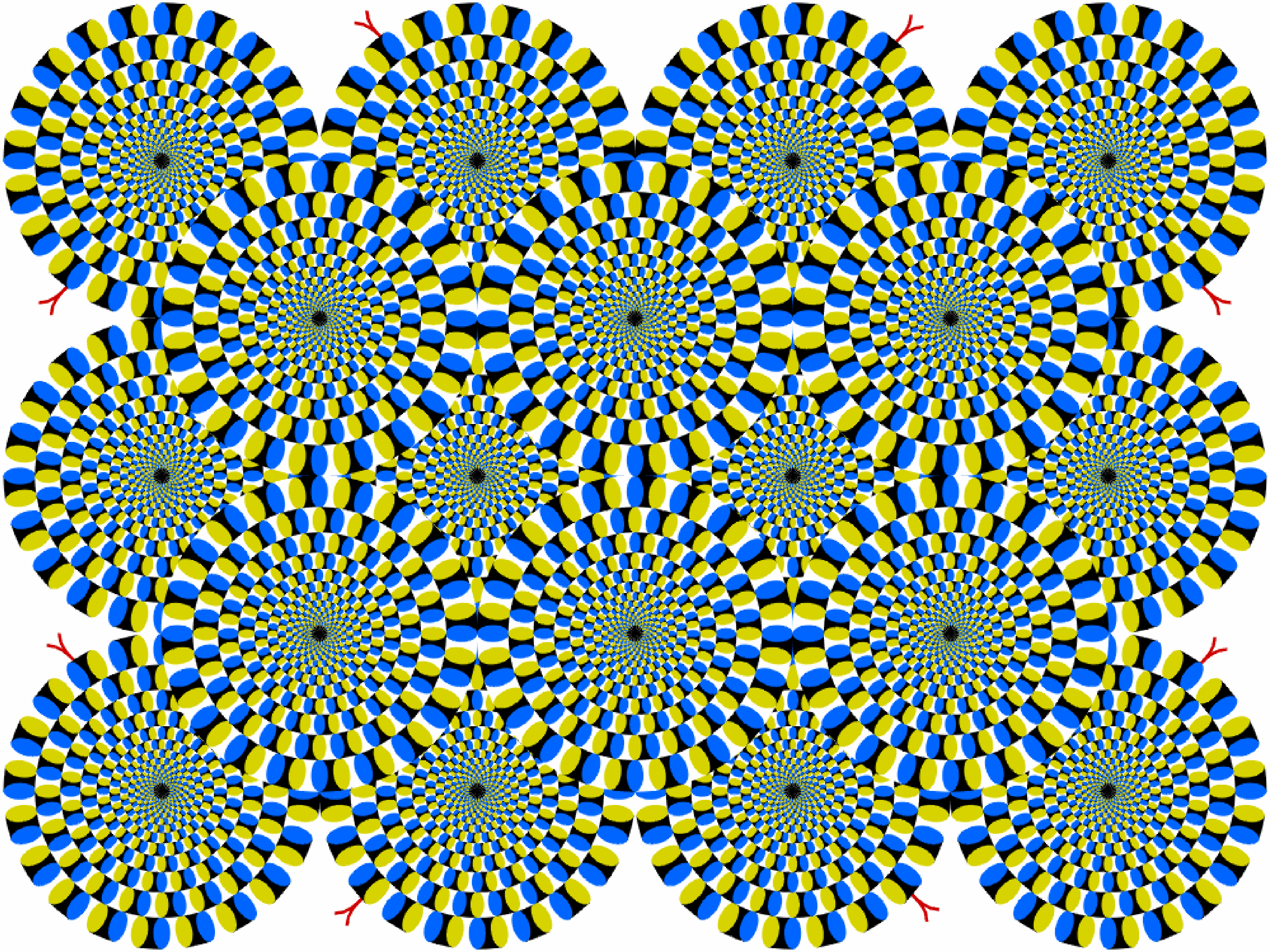
We can sometimes move our eyes/head so that background blurs…

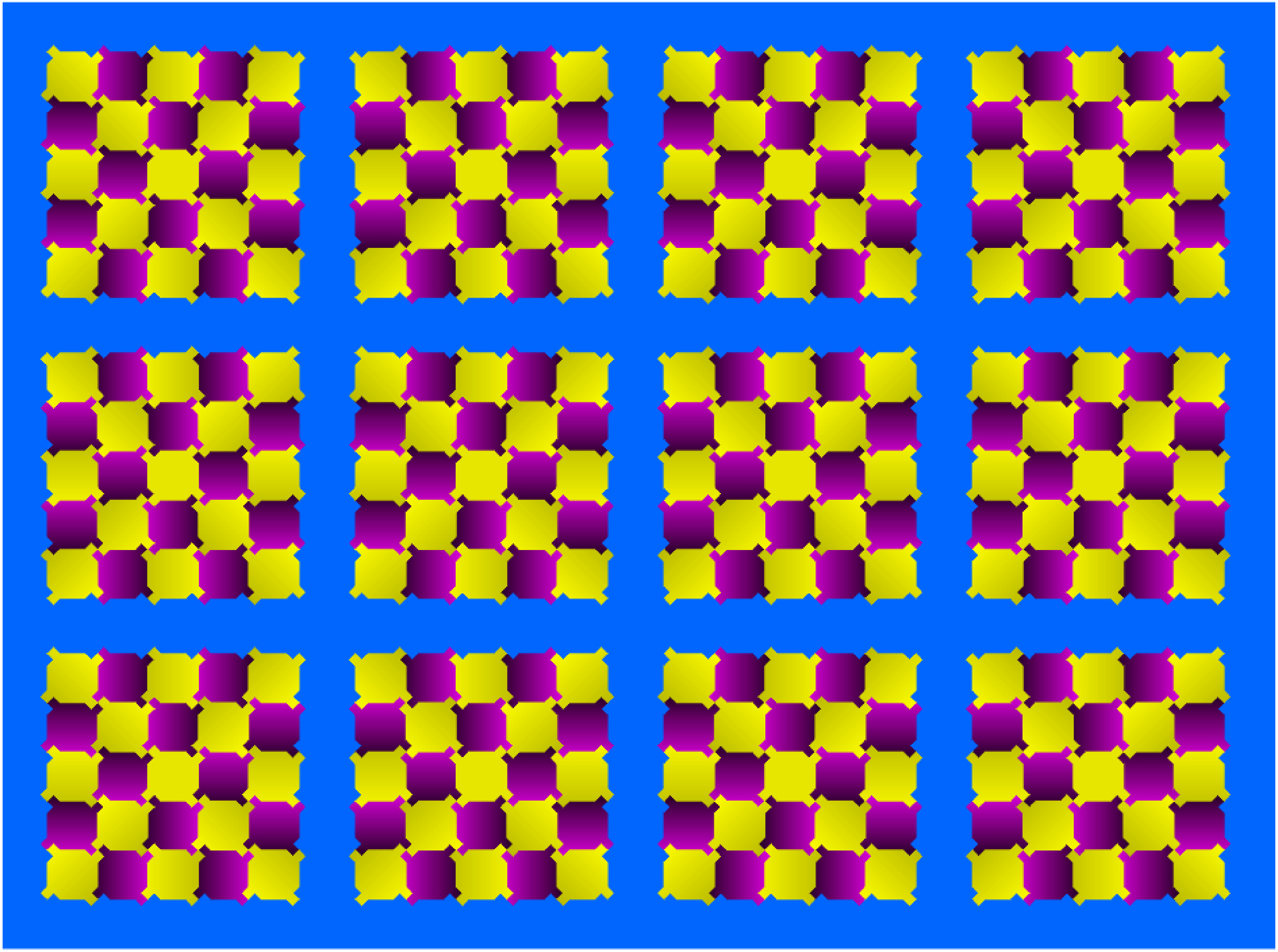
Need to distinguish between motion artifacts and natural blur…

Blur and Video…

In video applications, we typically try to capture images that blur the background, intentionally slowing or stopping the motion. (In some sports broadcasts, as much as 50% of the broadcast is slow-motion, instant replay).

The argument that motion video doesn't need high resolutions is weakened by the level of slow-motion used…





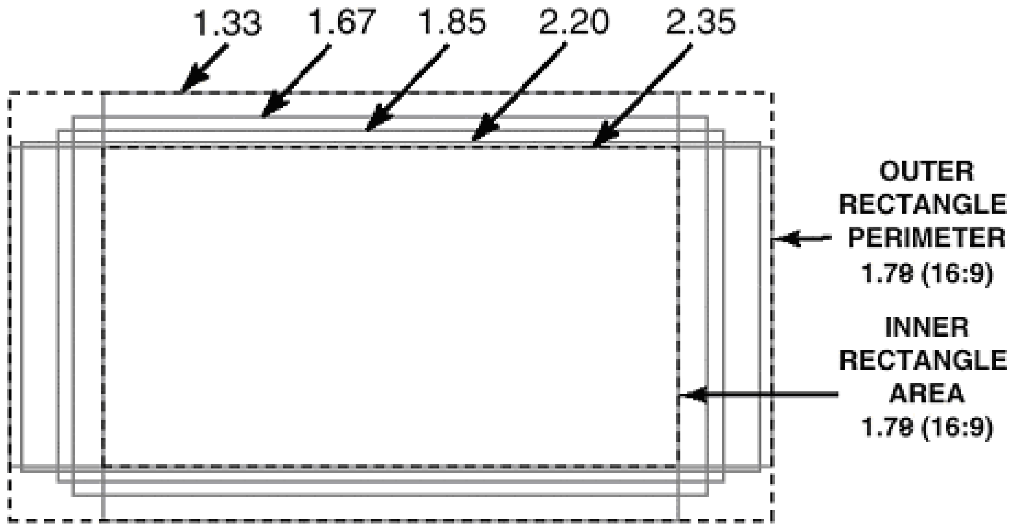
Pop Quiz #6

How did we end up with a 16:9 aspect ratio?

Why 16:9?

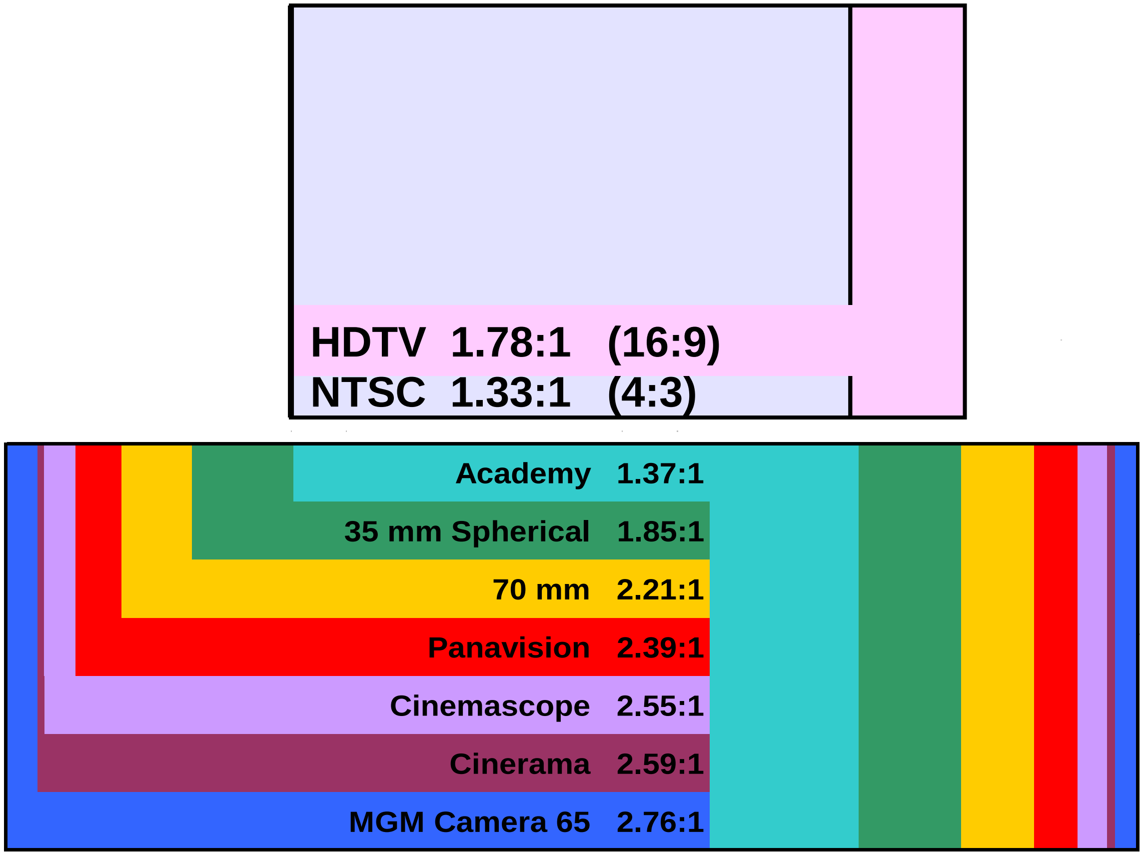
Kerns Power's Solution

The most prevalent aspect ratios filmmakers and TV producers deal with today are: 1.33 (the Academy standard aspect ratio), 1.67 (the European widescreen aspect ratio), 1.85 (the American widescreen aspect ratio), 2.20 (Panavision), and 2.35 (Cinemascope).



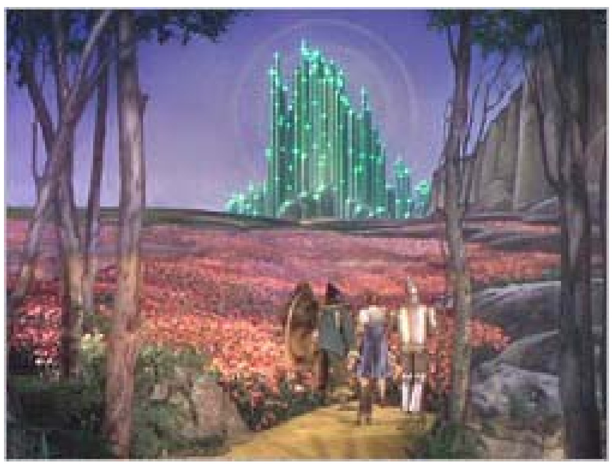
It's important to remember that the 16:9 aspect ratio was not derived based on human factors studies, but as a compromise that enabled all film cameras to continue being used without an adjustment to content.

Cinematographic Aspect Ratios



In other words, if you buy a 16:9 TV screen, the native movie format cannot be viewed without the letter-box effect.

Aspect Ratio Conflict: Example



Before the 1950s, most films were created at a 4:3 aspect ratio (Academy Standard). Almost every classic film made before 1953, appeared in the 4:3 aspect ratio.

In other words, if films such as *Gone With the Wind, The Wizard of Oz,* and *It's a Wonderful Life* are broadcast over the air in high definition, or viewed by way of DVD, although the images will be high definition, they will not be in a wide aspect ratio.

Wide screen TVs will show these classic films in a 4:3 aspect ratio – with a window-boxing effect.

Aspect Ratio Conflict: Example

With letterboxing, some vertical picture resolution is sacrificed, but the director's original widescreen composition is preserved.

But, letterboxing is different dependent on the film title shown:

- **Miramax's *The English Patient* (1996) in Academy Flat (1.85:1).**
- **Fox's *The Thin Red Line* (1998) in Anamorphic Scope (2.35:1).**

Pop Quiz #7

What is the optimal aspect ratio for the human visual system?

The Golden Ratio?

Is there an optimal aspect ratio for the human visual system?

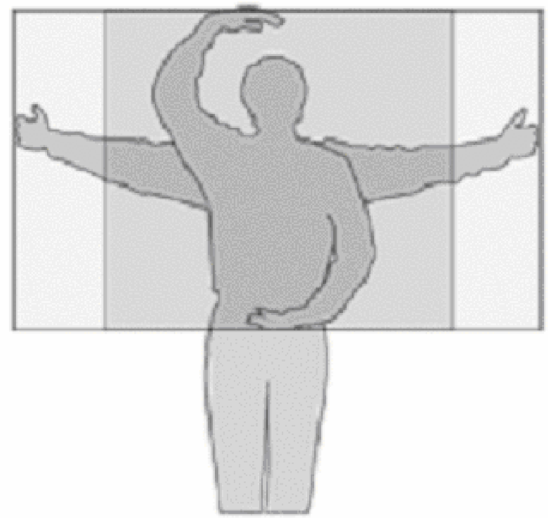
In simplest terms, the Golden Ratio is occurs when point C divides the line in such a way that the ratio of AC to CB is equal to the ratio of AB to AC. Algebra shows that the ratio of AC to CB is equal to the irrational number 1.61803…(precisely half the sum of 1 and the square root of 5).

"The Golden Ratio" = "Phi" = "The Divine Proportion"

The Golden Ratio

Salvador Dali's *Sacrament of the Last Supper*

HDTV Industry Icon



"The Golden Ratio has been used in many great works of art to achieve what we might term "visual effectiveness". One of the properties contributing to such effectiveness is proportion – the size relationships of parts to one another and to the whole. The history of art shows that in the long search for an elusive canon of "perfect" proportion, on that would somehow automatically confer aesthetically pleasing qualities on all works of art, the Golden Ratio has proven to be the most enduring".

-- Mario Livio

The Golden Ratio

Well, if indeed, the Golden Ratio is somehow aesthetically pleasing, it should come as no surprise that there have been numerous psychological experiments to identify if indeed there is an aesthetically pleasing proportion. The German physicist and psychologist Gustav Fechner conducted pioneering experiments in this field in the 1860s. Fechner's experiment was simple: ten rectangles varying in their length-to-width ratios were placed in front of a subject, who was asked to select the most pleasing one. The results showed that 76% of all choices centered on the three rectangles having ratios of 1.75, 1.62, and 1.50, with a peak at the "Golden Rectangle" (with ratio 1.62). Fechner went further and measured the dimensions of thousands of rectangular-shaped objects (windows, picture frames in the museums, books in the library), and claimed to have found the average ratio to be almost identical to the Golden Ratio. Many psychologists have repeated similar experiments since then, and obtained similar results. In particular, British psychologist Chris McManus concluded in 1980 that: "There is moderately good evidence for the phenomenon which Fechner championed."

Optimal Viewing Distance

Factors that influence the Optimal Viewing Distance:

Viewer: Visual acuity, age, cultural preferences, gender, etc., all impact the "optimal" viewing distance: it's different from viewer to viewer.

Content: TVs can be used for text-based Internet browsing, gaming, news programming, photo imagers, or fast-action motion pictures. These different uses will have differing optimal viewing distances.

Horizontal Viewing Angle: In TV environments, not all viewers face the device straight-on, which can significantly impact the optimal viewing distance, depending on display technology.

Vertical Viewing Angle: Particularly with the advent of wall-mounted flat panel displays, TVs can be situated at different heights, impacting the optimal viewing distance.

Resolution: Pixel density is important to viewing distance so long as the viewer can identify pixellation. High resolutions enable the viewer to be closer to the screen.

Calculating the Optimal Viewing Distance

Based on Screen Height

According to the HDTV Insider, the optimum distance for watching HDTV (16:9) is 3.2 times the screen's height. For a standard-definition TV (4:3), the optimum is 7.2 times the screen's height. Because wide aspect ratios are better suited for the human visual system, the optimal panel size is much larger. For example, according to this analysis, a 20"' LCD TV at a 16:9 aspect ratio will fit in a room with a viewing distance of less than 3 feet, while a 20" LCD TV at a 4:3 aspect ratio requires almost 5 feet.

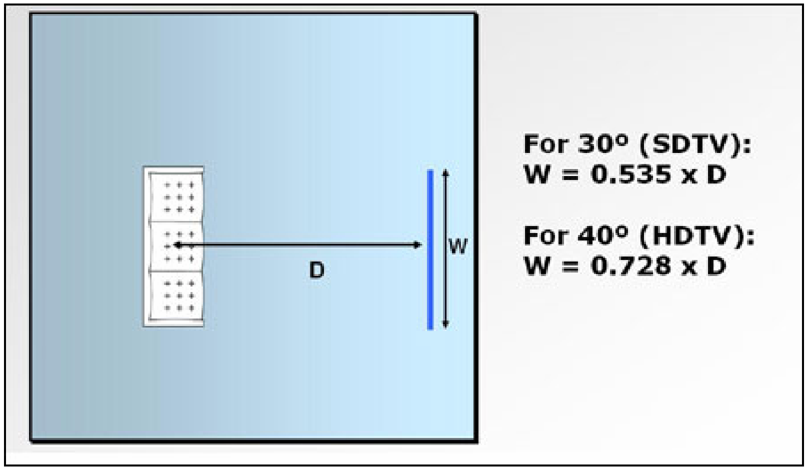
LCD TV Diagonal	16:9 Optimal Viewing Distance	4:3 Optimal Viewing Distance
10.0 inches	15.7 inches	29.4 inches
12.0 inches	18.8 inches	35.2 inches
13.0 inches	20.4 inches	38.2 inches
15.0 inches	23.5 inches	44.1 inches
18.0 inches	28.2 inches	52.9 inches
20.0 inches	31.4 inches	58.7 inches
24.0 inches	37.7 inches	70.5 inches
28.0 inches	43.9 inches	82.2 inches
3.0 feet	56.5 inches	105.7 inches
4.0 feet	6.3 feet	11.7 feet
5.0 feet	7.8 feet	14.7 feet
6.0 feet	9.4 feet	17.6 feet
	1.57 multiplier	2.94 multiplier

Calculating the Optimal Viewing Distance

Based on Screen Width

Another calculator similarly identifies viewing distance based on screen size and viewing angle, suggesting that widescreen is best at 40 degrees, while 4:3 screens are best viewed at 30 degrees.

But this calculator suggests a multiplier of 1.87 for SDTV and 1.37 for widescreen TV, which is much different than the HDTV insider calculator.



1.87 multiplier

1.37 multiplier

The first calculator uses screen height; the second calculator uses screen width. BUT… both of these calculation forget that it's not the height or width of the screen that is most important, but rather the size and shape of the image.

Optimal Field of View

Human vision experts differ in their opinions about our "field of view". Certainly we can recognize movement in our peripheral vision that is at something approaching 180 degrees. Note: our up-down peripheral vision is much weaker than our left-right peripheral vision. Regardless of peripheral vision, our active resolvable viewing area is considerably smaller.

Our left-right resolvable vision is typically accepted to be about 40 degrees.

Our up-down resolvable vision is somewhat less, at about 25 degrees.

Interestingly, this results in an approximate aspect ratio of 1.6 – the Golden Ratio!

As noted, cinema is typically shown at a much wider aspect ratio. Note, however, that the left-right edges of the cinema screen are primarily used for fast motion – which our peripheral vision can detect without resolving. As such, something similar to the 2.35 Cinerama aspect ratio is considered by many to be ideal for most movie-goers.

Utilization of the TV Screen

While there are many possible usages for a TV screen, (and more coming with the inevitable digital convergence), we will consider three primary uses – HDTV (16:9 input), SDTV (4:3 input), and Widescreen DVD (~2.35:1 input). Whether the user has a 4:3 TV or a 16:9 TV, all three of these uses are likely to be needed. For each usage, a different portion of the total screen area is utilized.

Screen Utilization		
	16:9 screen	**4:3 screen**
16:9 input	100.0%	75.0%
4:3 input	75.0%	100.0%
2.35:1 input	75.7%	56.7%

Optimal Field of View

We can roughly calculate the optimal viewing cone for different aspect ratios of image inputs as follows:

Optimal Viewing Cone		
	16:9 screen	**4:3 screen**
16:9 input	30.83°	30.83°
4:3 input	23.35°	23.35°
2.35:1 input	40.00°	40.00°

Note that regardless of the screen shape, the optimal field of view is the same. What's important is not screen width or screen height, but what portion of the screen is being used.

Calculating the Optimal Viewing Distance

Based on Optimal Viewing Cone for Different TV Uses

As such, we can calculate an optimal viewing distance multiplier for different aspect ratios based on screen usage:

Optimal Viewing Distance Multiplier		
	16:9 screen	**4:3 screen**
16:9 input	1.58x	1.45x
4:3 input	2.11x	1.93x
2.35:1 input	1.20x	1.10x

Again, note that these multipliers are based on "immersive" experiences, not the sort of TV viewing most people are accustomed to in their living room.

Comparison of Calculators

It's reasonable to assume that over time a 16:9 screen will be primarily used for 16:9 inputs and a 4:3 screen will be primarily used for 4:3 inputs. Given this assumption, it's interesting to compare the three viewing distance calculators reviewed:

Comparison of Viewing Distance Calculators		
	16:9 screen	**4:3 screen**
Based on screen height	1.57x	2.94x
Based on screen width	1.37x	1.87x
Based on screen content	1.58x	1.93x

Viewing Distance and Resolution

- If you have a 40-inch TV, depending on which calculator you choose, the optimal viewing distance can be as little as 55 inches.
- At 1280x720 pixels, a 40-inch TV translates to only 37ppi, which is quite visible to the human eye at 55 inches
- At 1920x1080 pixels, a 40-inch TV translates to 55ppi, which is still quite noticeable…

Finding the Peacock…

"The problem with television is that the people must sit and keep their eyes glued on a screen; the average American family hasn't time for it...for this reason, if for no other, television will never be a serious competitor (to radio)."

-- New York Times, commentary after television introduced at the World's Fair in 1939

Image courtesy of The David Sarnoff Library

"The initial sets didn't work very well. The color was inaccurate, the picture was low quality, plus there was very little color programming available".

-- Alex Magoun, Director The David Sarnoff Library

Color TV broadcasting was introduced in 1951. The first national broadcast (21 stations) was at the Tournament of Roses Parade on January 1, 1954.

"In the broad daylight and sunshine, it was necessary to draw the shades and cut out all glare if the colors on the TV screen were not to be washed out… Since it is necessary to sit much farther away than from a black and white set, one wonders how big a color tube will be practical. Finding a happy compromise between picture size and viewing distance could be tricky for the engineer and the viewer, particularly if the latter must start rearranging furniture again".

1954 Admiral Color Television

-- New York Times, Monday, January 4, 1954

TV Technology Battles

- **CRT vs. FPD**
- **LCD vs. PDP vs. RP**
- **720p vs. 1080i vs. 1080p**
- **OLEDs and what might be coming…**
- **My choice…** **"Snap, Crackle, and Popular Culture"**

Standards Battles

- HD-DVD vs. Blu-ray
- DVB-H vs. FLO Forum
- HDMI vs. DisplayPort

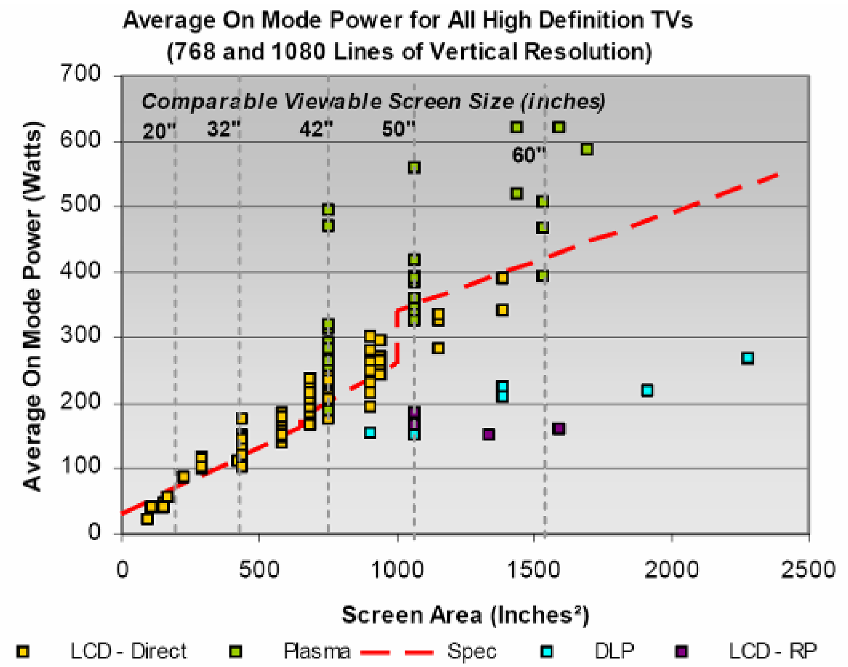
Future of TV…

- The Death of Commercial TV
- CE/PC Convergence
- Green TV
- 3D
- Curved displays
- Wider aspect ratios
- Resolution

CE/PC Convergence

- IPTV
- Interactive HD-DVD/Blu-ray
- Downloadable entertainment
- Interactive gaming
- Home telepresence
- Gesture recognition; Wii-like interaction

Green TV



Latest Energy Star TV Specification

- **LCD TV Association initiated a Green TV logo program**
- **Energy Star will have power consumption ratings for TVs just as for home appliances starting in Q4'08.**
- **Energy Star program is technology neutral and the Energy Star certification requirements will get tougher over time.**
- **Concerns about both energy consumption and e-waste…**

3DTV

While we see numerous examples of 3D technologies on 2D surfaces all around us, actually showing a convincing 3D image on a display device is not a simple task. Key areas to watch:

- **3D Cinema**
- **3DTV**
- **3D Gaming**

Current boom in Hollywood…

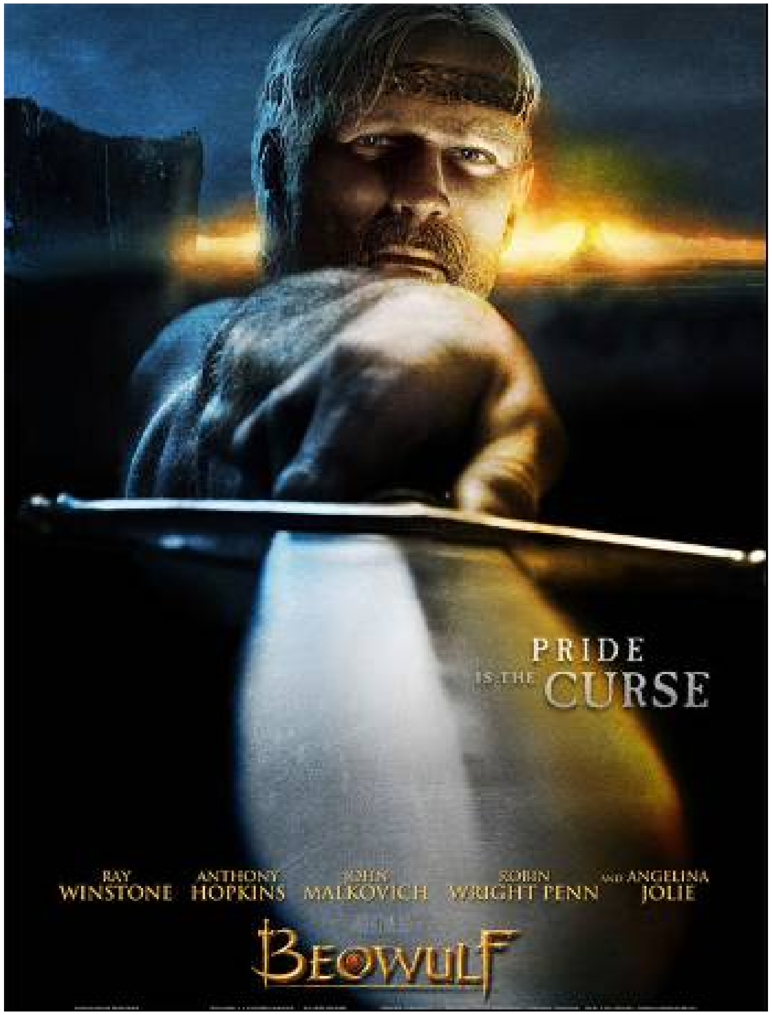
Major 3D film announcements…

- **US-3D**
- **Beowulf** (Robert Zemeckis)
- **Avatar** (James Cameron)
- **Battle Angel** (James Cameron)
- **Star Wars 3D** (6 re-mastered films by George Lucas)
- **Journey to the Center of the Earth** (New Line)
- **Monsters vs. Aliens** (DreamWorks)
- **Shrek IV** (DreamWorks)
- **Journey 3D** (Walden Media)
- **Tintin** (3 films by Peter Jackson and Steven Spielberg)
- **20+ other announced…**

Not just horror films, roller-coaster rides, and science specials… but major producers from major studios…

Beowulf – 1000+ screens in 3D

November 16, 2007
--opened in 3 different 3D formats



Veritas et Visus

Different ways of seeing 3D cinema

IMAX 3D

- Special cameras
- Special projectors
- Special screens
- Limited # of screens
- Passive or active glasses

REALD

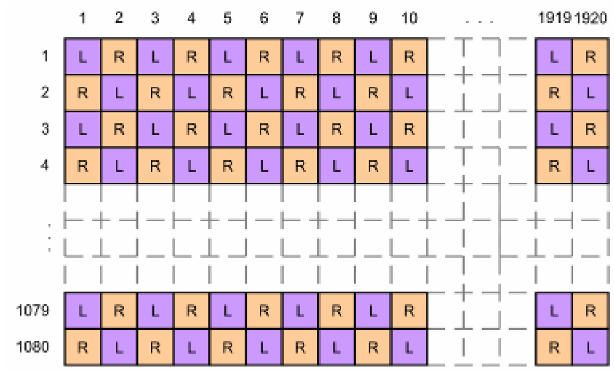
- Numerous 3D cameras
- Digital projection (DLP with Z-screen modulator)
- Passive glasses
- Special screens
- Growing # of screens (~1000 to date)

DOLBY 3D DIGITAL CINEMA

- Numerous 3D cameras
- Digital projection (DLP with Z-screen modulator)
- Active glasses
- Standard screens
- Lots of screens

Transition to the living room?

European initiative to develop 3DTV – led out of Turkey



TI's left/right eye checkerboard for 3D DLP

Samsung 3D-enabled DLP TV

- TI's DLP projection is enabling 3D Cinema; and may similarly popularize 3D in the home
- All Samsung rear-projection DLP systems today are 3D-enabled
- Mitsubishi's high-end DLP systems are all 3D-enabled
- If 3D takes off in the box office, DLP systems in the home could see a resurgence…

Gaming

Gaming may lead homes to 3D

- **Immersive.** **Games tend to be immersive experiences. Users are eager to improve the immersive experience. Success of Wii is indicative of this willingness, with motion sensing creating a sort of third dimensional experience.**
- **Movies:** **Game development oftentimes mirrors Hollywood release strategies.**
- **Software.** **Most games are already rendered in 3D.**
- **Hardware:** **Gamers have demonstrated a willingness to spend more to lead the market to better graphics and display solutions.**

Wider Aspect Ratios

Alienware: 2880 x 900 pixels

Wider Aspect Ratios

Scalable Displays: 40 x 8 feet

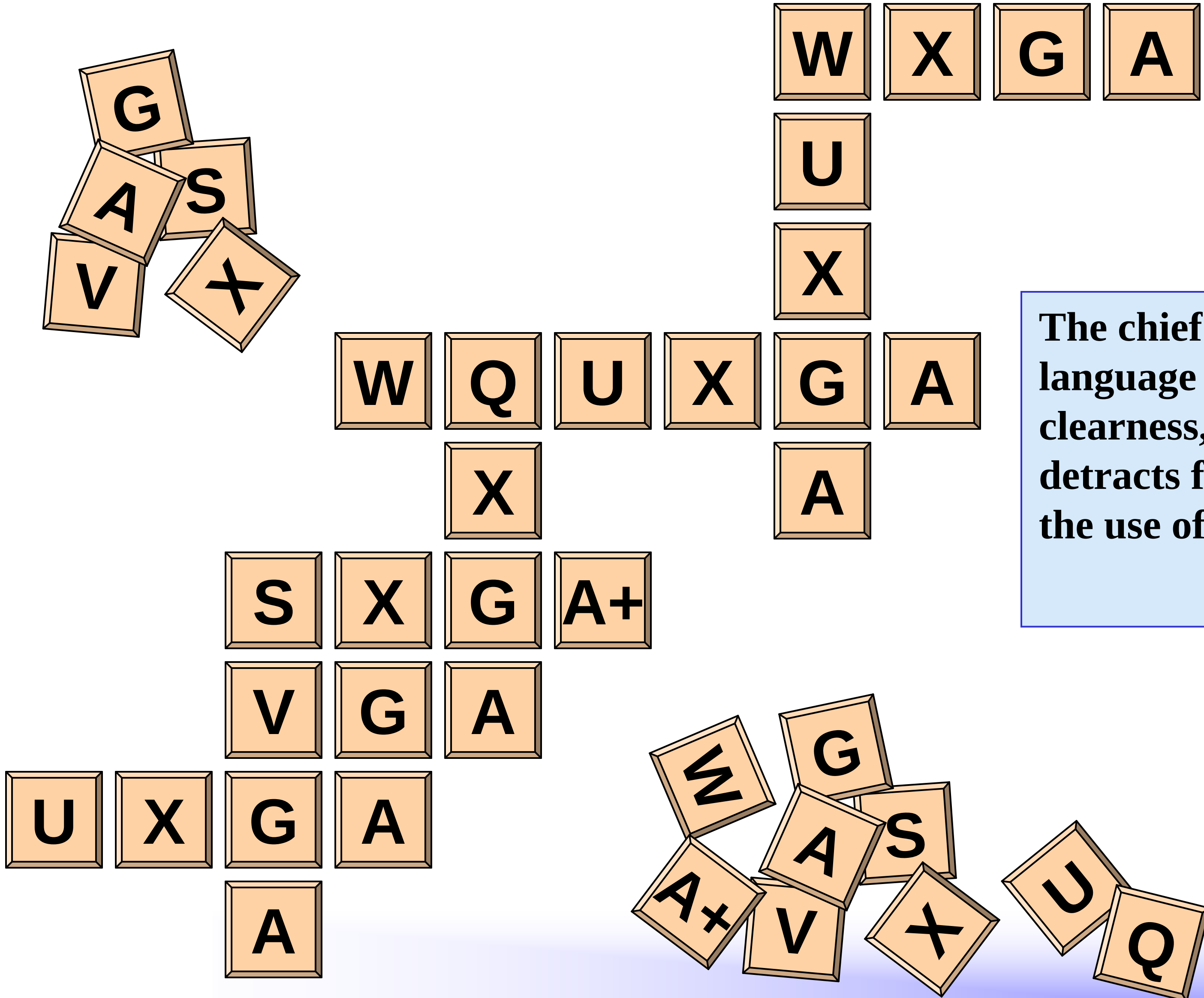
Pop Quiz #8

What does

"WQUXGA"

stand for?

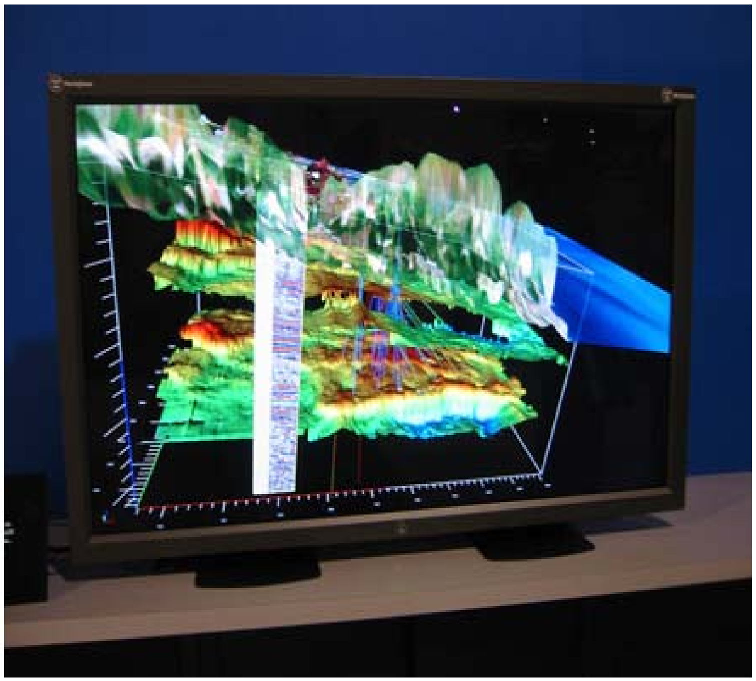
DTA – "Death To Acronyms"



The chief virtue that language can have is clearness, and nothing detracts from it so much as the use of unfamiliar words.

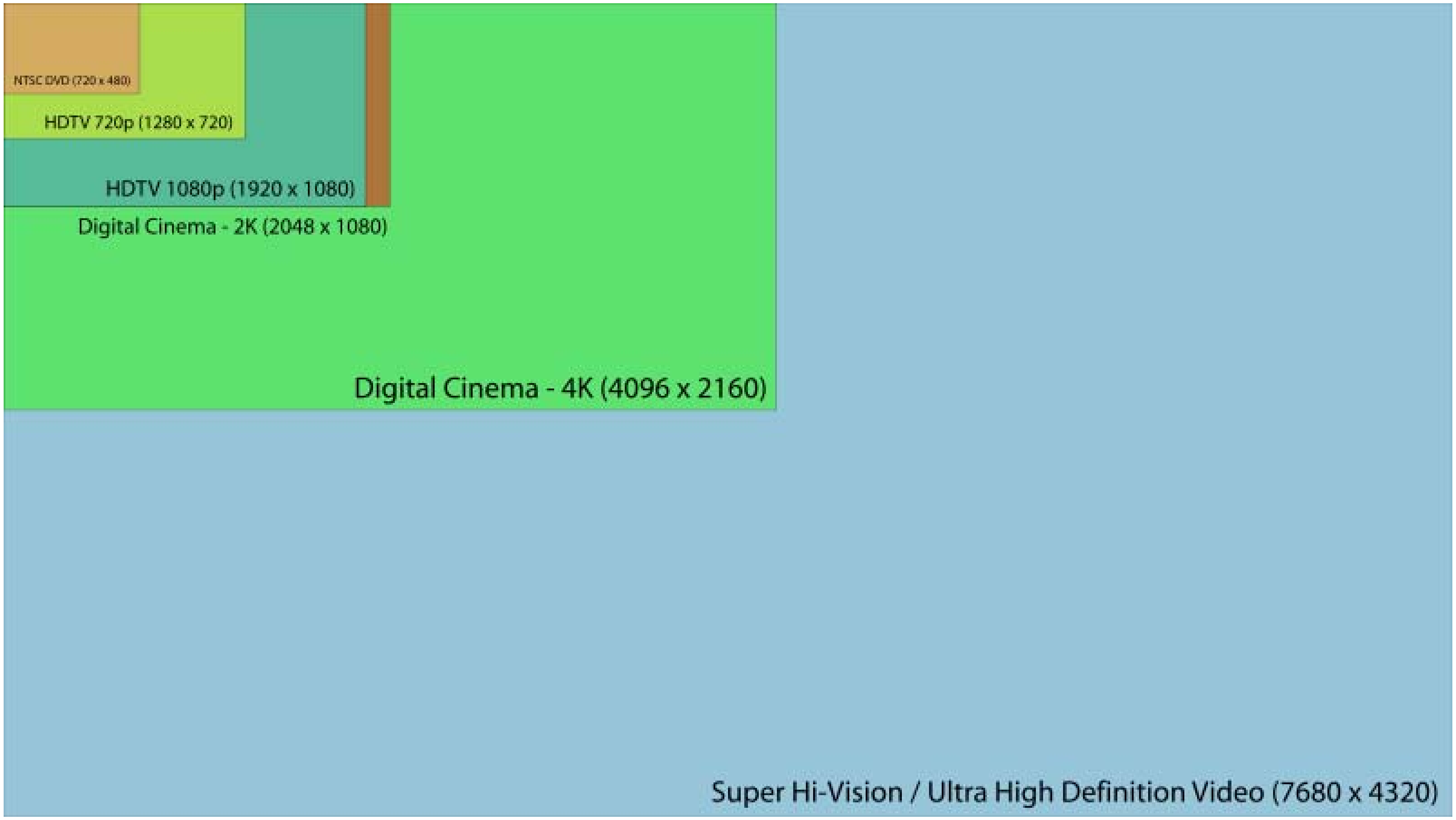
-- Hippocrates

And now QFHD…



Westinghouse 56-inch at 3840x2160; Sharp 62-inch at 4096x2048

HDTV is just beginning!



The Gigapxl Project…

http://www.gigapxl.org

…Image Quality

Crop from original 1.09 gigapixel image

140-megapixel camera

50-megapixel camera

22-megapixel camera

11-megapixel camera

6-megapixel camera

3-megapixel camera

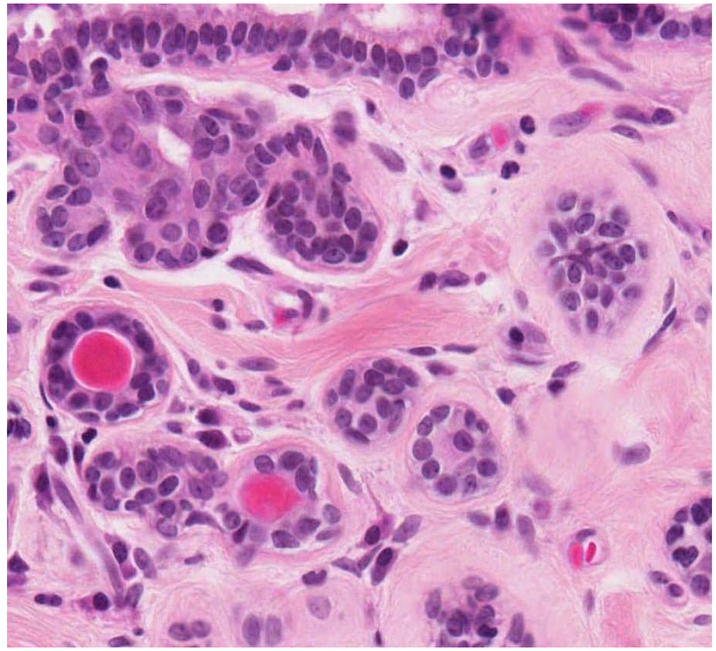
Images from the Gigapxl Project

The Last Supper at 16-gigapixels…

Jesus' right eye…

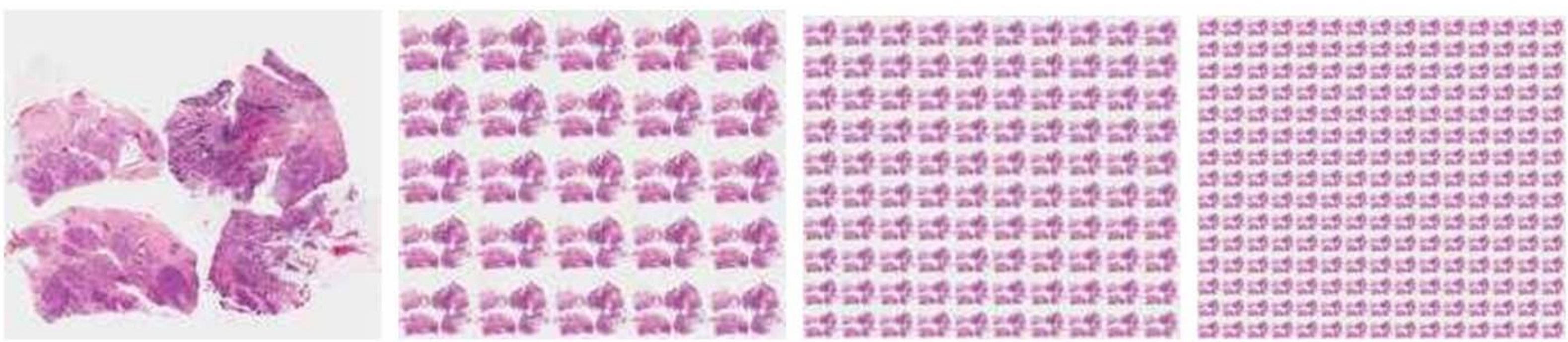
http://www.haltadefinizione.com

The world's first terapixel image…



- **The file size is 143.5GB**
- **More than 1 million notebook PCs (at 1280x800 pixels) would be required to view the image at its native resolution**

http://bigtiff.org/terapixel.htm



Original image
73,042 x 62,633 pixels

25 x original
365,210 x 313,165 pixels

100 x original
730,420 x 626,330 pixels

225 x original
1,095,630 x 939,495 pixels

Earth from Cassini-Huygens…

930 million miles…

http://ciclops.org