Brief History of Imaging Technology

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Digital imaging is the next step is the continual improvement of imaging with light; newer technology will follow. Lenses are currently the limiting factor in the advancement of the technology. Highend commercial digital sensors are sold that have finer detail than the capabilities of current lenses (high performance military lenses and spy systems are excluded). Digital sensors have one element for each piece of image information; chemical systems use several minute overlapping particles to create an image with finite detail, limited by noise.

History: The use of light to render an image began with the Camera Obscura around 1550. It used a simple one element lens focused on a wall, or a drawing board, so the image could be traced. Niépce used this basic technology in 1816 to form a silver image on paper; unfortunately, the image wasn't permanent because "fixing" (removing unexposed silver) had not yet been discovered. Later, Niépce (1826) made the first permanent photograph using photosensitive bitumen (tar) on a pewter sheet, while searching for photolithography.

Many early photographic images were produced as one of kind images: Daguerreotype (1839), Ambrotype 1855) and Ferrotype (1857); they remained common through the 1870-80's. Multiple positive copies from an image could be made using paper negatives, invented by Fox-Talbot in 1839, contact printed from the negative. The albumen print created by Blanquart-Evrard in 1850 http://albumen.stanford.edu/ made multiple prints from a negative (paper or glass) common. Albumen prints became the first commercial photographic process.

With the invention the Collodion Wet Plate process by Archer in 1851, multiple sharp positive images became common. By 1878, Kodak brought Gelatin Dry Plates into commercial production; they were sold photosensitive in a box and were faster (more sensitive) than collodion. Glass plates were considered superior to film through 1920-30s by studio photographers and newspaper/publishing technicians (now called prepress) because of controllability and dimensional stability. The last to switch, newspapers began replacing glass with Kodalith film in 1931.

Film (nitrate base) became a photographic image carrier beginning around 1889 as amateur roll film. Early amateur roll film cameras (1884) used paper negatives in a roll. Sheet film came into wide use around 1913 by professional photographers transitioning from glass plates for convenience during WWI news reporting.

The transition from cellulose nitrate film base to cellulose acetate film base started about 1908, when it was first used in amateur (small gauge) motion picture film. Many local laws required acetate base for amateur motion picture films. The final transition to acetate base was made between 1935-38 and 1948-51 depending on format. While cellulose acetate is not flammable, it can degrade faster than its cellulose nitrate precursor. This was not widely understood until recently at the 2007 AIC-PMG meeting. Fortunately, acetic acid (weak acid) from the deteriorating cellulose acetate does not destroy the gelatin layer the way nitric acid (strong acid) does when it evolves from degrading cellulose nitrate film base.

Despite its assured deterioration in 60-100 years, cellulose acetate film base is used on 90% of all film sold; film has inherent vice. Modern triacetate base (introduced in 1955) is far superior to earlier acetate formulations. Oddly, some historic nitrate based film is in better condition today than acetate base film made at a later time. Both types of film will continue to degrade outside cold storage, see the cold storage web reference below. Do not throw out (cull) degraded acetate film (vinegar smell). With effort, the gelatin pellicle (image layer) can be salvaged. Cellulose nitrate sheet film that has welded together into small bricks cannot be salvaged; the strong acid destroys the gelatin layer. Starting in the 1960's, Kodak offered some sheet film on a permanent polyester base, Estar; patent bought from DuPont. As of 2001, Kodak uses Estar base for all sheet film.

The first color imaging technology was invented by the noted physicist James Clerk Maxwell in 1861. Maxwell directed that three images be photographed using separate additive color filters (red, green and blue) resulting in three B&W transparencies that were projected with the same colors of light, recombining into a full color image on a screen. Significant experimentation on the delivery of the common color print was undertaken by many workers. Louis Arthur Ducos du Hauron developed a subtractive (cyan, magenta & yellow) color print using three layers of pigmented gelatin laid on a reflective surface yielding an early color print in 1877. This technology evolved into the very stable Tri Color Carbro print technologies; influenced the by the T. Manly (1905) Ozobrome color pigment print; sold in London as the Autotype after 1919; also referred to as a Fresson print (4 layers) after 1951 in France. Eventually the technology stream influenced the 1945 creation of the highly stable Kodak Dye Transfer printing process; unfortunately discontinued about 1991-4. Pigment colorants (subtractive CcMmYKk) are in common use by Epson, HP and Canon inkjet printers with even greater display and dark storage stability.

Early all-in-one color image "capture" technologies include (a) Autochrome, colored starch grains on glass, developed by the Lumiere brothers in 1907, (b) Dufaycolor meshed RGB lines on glass in 1908 and later (1934) on motion picture film; and (c) the Finlay Colour Process in 1908 that used a RGB additive checkerboard screen on film. Commercial color film technology came into use about 1931 with the 2-color (red and green) additive Kodachrome movie film process. Color image capture took a giant leap forward with the release of the Kodachrome 3-color subtractive reversal (positive) film process released on motion picture film in 1935; discontinued in 2009. Post-1937 Kodachrome transparency film (K-14) has high dye stability; 185 years (yellow) in dark storage; only two Kodachrome films are in use (2009) today. Early color dyes could be highly unstable, fading in as little as 6 to 10 years. Ektachrome transparency film (1941) was easier to process, but

the early versions E1, E2 & E3 were unstable. Kodak is now estimating 250 years (Wilhelm & Bower, 1993) of dye stability in dark storage for their post-1990 Ektachrome E6 films. Ektachrome films have a very short life of 1-4 hours when displayed in a slide projector. All color film is on acetate base. Cold storage is the only viable preservation method for color films, see http://videopreservation.stanford.edu/library/cold_storage_v15a.pdf.

Film photography rose to a very high technological state before it was eclipsed by digital technology**.** Film and lenses were "strategic" WWII materials and critical tools in cold war espionage. Film remained cutting-edge technology through the 1980s; removing silver was the major driving force, e.g., Kodak T-grain. The principal drawback with film is image noise. Film grain is often assumed to be made of fundamental film particles, but it is not -- it is system noise. Fundamental film particles, either (a) silver particles (0.2 - 1 microns) or (b) color dye clouds (≈ 1 - 4 microns) are an order-of-magnitude smaller than film grain, whose size is roughly 6-20 microns. Image noise is the visual agglomeration of tens to hundreds of fundamental film elements seen through the thickness of layers, of chemical reactants. This chemical system noise creates a signal-to-noise ratio (SNR) of 10:1 for most films; relatively high. Film grain became perfectly acceptable and was largely ignored, until digital images became common. When digital imaging evolved into a mature technology, its inherently low SNR of 100:1 to 1000:1, and absence of film grain (because there is only one photo active element per site), made it the next technological step. On the other hand, small digital chips (found in phone-based cameras, point-n-shoot models and less expensive DSLRs) and the use of fast shutter speeds will yield very noisy digital images.

Some twenty years after its zenith, film is now historic technology, used by film aficionados and those slow to adopt digital for a variety of reasons. Film is being discontinued. Kodak still finds motion picture film manufacture profitable. However, when movie theaters move to digital display, the end of film will follow shortly. Economics will eventually force motion picture film manufactures to discontinue their relatively small runs of still film formats. When this occurs film will become rare.

Lenses reached a penultimate state just before WWII and topped out in the 1970s. Computer-aided-design continues to help improve zoom lens designs, which are inherently less sharp than prime lenses (fixed focal length). Most prime lens designs were developed over 80-100 years ago by the great German designers. Modern lenses possess small incremental improvements over those designs, because vacuum deposited coatings are the cutting-edge of lens development. In general, the street value of a lens is a rough indicator of its quality. The cost of specific lenses within a group, such as the 35, 50 or 85 mm primes, or the ubiquitous 24 to 70/85 mm zoom are examples; see <http://photodo.com/> and <http://www.dpreview.com/lensreviews/>.

The progression of light-based imaging begins with pseudo-lenses made of stone about 5000 BP and then…

List of Imaging Events

Color Code Key

Lens History; Pre-Photography; B&W Photography; Color Photography; Digital Photography; Magnetic Media; Video Technology

3000 BC

- **Polished stones** were used to magnify (early visual aid) and condense light, about 3000 BC, or earlier
- **Glass** was invented in the Bronze Age, and then perfected by the Egyptians 3000- 2500BC
- Greek and Chinese scholars describe **basic principals of optics** and camera, circa 300-400 BC
- **Aristotle** writes of a **darkened room with a small hole** (pin hole camera) in one wall [Camera Obscura, Latin: dark room] focusing an inverted image on the far wall 330-300 BC

1000 AD

- **Reading Stone**, a glass sphere use to read by magnified letters was in recorded use around 1000 AD
- **Ibn el-Haitam** Arabic Physicist described the **first lenses** and Camera Obscura around 1000 AD
- First **Camera Obscura** with a lens: when Girolamo Cardano (1501-1576) suggested replacing the hole with a biconvex lens to improve the image in 1550s
- **Giovanni Battista della Porta** (1538-1615) published what is believed to be the first account of the possibilities of Camera Obscura as an aid to drawing in 1558

1600

- First written mention of telescope, Zeeland (Dutch) document, **Hans Lipperhey** claims a new device in 1608
- **Galileo** made his astrophysical studies using a early **telescope** in 1610
- **Newton** discovers that **white light** is composed of colors of light (**spectrum**) between 1664-66
- **Johann Heinrich Schulze** mixes chalk (white base), nitric acid, and silver and notices **darkening on sides of flask** exposed to sunlight; first photo-sensitive compound discovered, silver nitrate ($AgNO_3$) in 1727
- **Benjamin Franklin's** kite flight in 1752 led to concept of **electricity**; paper on electricity was published 1756
- **Elizabeth Fulhame** published *Essay on Combustion*; silver salts to stain designs on cloth in 1794
- **Thomas Wedgwood** created **Sun Pictures**, cameraless shadowgrams 1790-1802-5; paper or leather with silver chloride-nitrate; un-fixed; darken with more than a candle; 1802 Royal Society pub by Sir Humphry Davy

1800

- Lithography on stone and metal plate began in France about 1813
- **Nicéphore Niépce** combines Camera Obscura with photosensitive paper; not fixed, thus not permanent, 1816
- **First permanent image** light-sensitive "bitumen of Judea" on Pewter sheet, Nicéphore Niépce in 1826
- **Joseph Jackson Lister** develops lenses with **reduced chromatic aberrations** by introducing concept of several lenses, each with a portion of the full magnification formerly required from one lens element, in 1830
- **Chevalier Achromatic lens**, 2 elements cemented together, still found in today's point-n-shoot cameras 1835
- **Daguerreotype** by Louis Daguerre, Ag-I negative on polished copper sheet, devl'pd w/ Mercury vapor in 1839
- **William Fox Talbot** publishes how to make **Photogenic Drawings**, AgCl/-NO_3 crystals in paper, fixed, 1839
- **Paper negatives** (waxed after processing) shown to scientists and hobbyist, see Fox Talbot above, in 1839

- **Talbotype (Calotype)** by William Fox Talbot**;** AgCl/-$N0_3$ fixed paper neg. w/contact printing, a pos print 1841
- **Salted Paper prints** (generic name for the Talbot's process) silver salts in paper fibers, fixed, 1841
- **Petzval Achromatic Portrait lens**, first "specifically designed photographic lens" created in 1841
- **Carl Zeiss** opens his workshop in Jana, Germany to make eyeglasses and microscopes for University 1846
- **Niepce de St Victor** and **Louis-Désiré Blanquart-Evrard** experiment with albumen on glass plates 1847

1850

- **Color Daguerreotypes**, first Hillotype (1851) and then Heilochrome (1853), short life in 1850s
- **Albumen Print** invented by **Louis-Désiré Blanquart-Evrard** sensitized egg albumen coated on paper 1850; **Printing-Out-Paper** technology (POP) where a print is developed by exposure to sun, then fixed and dried; could be further chemically developed for darker image; for many details see http://albumen.stanford.edu
- **Crayon Portraits** by itinerate artists, thin POP under-image, chalk/charcoal design layer, 1850's thru 1900's
- **Collodion Wet Plates**, Frederick Scott Archer, silver-collodion (-Br, -Cl & -I) in ether solvent on glass, 1851
- Alexander Bain is credited with inventing **Telegraphic Fax** technology (dots & dashes), patented in 1853
- **Ambrotype** invented by James Ambrose Cutting: an underexposed collodion glass plate negative with a black (cloth) background, combined to produce a visual interpretation that appears as a positive image, 1854
- **Tintype** (Ferrotype) by Hamilton Smith, underexposed neg. on black metal plate, makes positive image 1857

1860

- Giovanni Caselli using the **Pantelegraph,** sent the first telegraphic fax between Paris and Lyon in 1860
- **First additive color process**: 3 exposures thru 3 filters comb'd into color image, James Clerk Maxwell 1861
- **Electro-magnetic radiation** is described by James Clerk Maxwell, radio waves uncovered, in 1864

1870

- **Silver-gelatin process** by RL Maddox: AgCl or AgI crystals in gelatin media (water solvent) on glass 1871
- **Ernst Abbe** joins Zeiss (Jena), develops **Abbe sine condition optics**, improving optics significantly in 1873
- **First color print:** layers of subtractive cyan, magenta & yellow gel by Louis Arthur Ducos du Hauron in 1877
- **Dry Gelatin Plates,** over-the-counter glass plate negatives, thru 1930s, by pro-Photogs & press, in 1878

1880

- Building on silver-collodion media pre-1880; **silver-gelatin emulsion papers** first created about 1880
- Eastman Kodak began (see 2005) sensitizing photographic paper using Germany and French papers in 1880
- **Platinum Print** (still salted paper print) was discovered by William Wills in 1873, reached market in 1881
- **Baryta layer** introduced to prints, increases reflectiveness (Dmin) and expands tonal range, about 1885
- **Otto Schott** joins Abbe and Zeiss, produces glass equal to Abbe's work, **Apochromatic lens,** 1886
- Manufactured **Printed-Out-Paper** POP (devl'pd w/light) gelatin emulsion (AgBr) available 1885 (glossy 1890)
- Kodak paper roll negative: sold in Kodak cameras only, processed by Kodak, in 1888
- Silver-gelatin emulsion coated on cellulose nitrate film created around 1884; **film first manufactured** in 1889

1890

- **Silver-gelatin print** supplants albumen prints (first in 1850), sold pre-sensitized dry in a box around 1890
- Carl Zeiss Foundation develops **Protar** camera lens with no astigmatism or field curvature in 1890-94
- Silver-gelatin (-Br) papers intro., **Developing-Out-Paper** (DOP) developed in chemical bath, about 1890-95
- **Paul Rudolph** of Zeiss Jena, develops **Planar** lens with 2 symmetrical groups; the most copied style 1896
- Gabriel Lippmann developed an indirect color process based on Bragg diffraction, **Lippmann Process**, 1891
- **CRT** demonstrated by Karl Ferdinand Braun; cathode-ray tube w/fluorescent screen & electron beam in 1897
- **Wire Recorder** for sound was developed by Valdemar Poulsen**,** the Telegraphone, in 1898

1900

- **Otto Schott** of Zeiss Jena, develop **rare earth glass** (Jena glass) in 1901
- **Paul Rudolph** of Zeiss Jena, develops **Tessar** high resolution & contrast lens; 4 elements in 3 groups 1902
- Thomas Manley invents Raydex (**Ozobrome**) proportional color pigments in gelatin layers on paper in 1905
- Kodak begins to study in-house papermaking, and encouraged others such as Am. Playing Card Co., in 1906
- **Vacuum Tube**, a continuously variable **electron valve** (variable gate) was patented by Lee De Forest in 1906
- **Autochrome,** tri-colored starch grains coated on glass was invented by Lumiere brothers, France 1907
- **Dufaycolor** invented by Louis Dufay, mesh of RGB lines on glass, later on motion picture film, in 1908
- **Finlay Colour Process** developed by Clare L Finlay, mosaic of RGB squares on glass plate in 1908
- **Kinemacolor** first color MP process by GA Smith (1906 UK), alternating R, G & G images, released 1908
- Kodak opens **cellulose acetate factory** (used for film base) in Australia about 1908
- Kodak announces cellulose acetate **Safety Film base** (various formulations through time) in 1909

1910

- Fredric Ives develops major **dye imbibition** (absorbing) Trichromatic Plate Pack (3 neg in 1 exp) in 1911
- Kodak builds papermaking machine at Kodak Park in 1914; first photographic paper from Kodak Park in 1915
- **Technicolor, Process 1**, two color (R & G) additive motion picture with 2 simultaneous B&W reels in 1916
- **Tri-Color Carbro** subtractive color (CMY) pigmented gelatin layer print, Autotype, H.F. Farmer in 1919

1920

- **Technicolor Full Color, Process 4,** using 3-strip camera, subtractive (CMY) dye-transfer final print in 1924
- Richard Ranger (RCA) invents analog wireless fax, **Radiofax**; first transatlantic photo, NYC to London in 1924
- **Leitz** releases **Leica I,** 35-mm rangefinder camera w/ 5-element Elmax or Elmar (4-elmts, 3-gps) lens, in 1925
- **Mechanical Television** is demonstrated by JL Baird (technological dead-end) in 1926
- **Philo Farnsworth,** has "hayfield revelation" on electron beam scanning in 1921; Farnsworth transmits first television moving image and patents invention in 1927
- **RCA demonstrates workable television system**, based on electron beam scanning technology in 1932
- Eastman **Kodacolor motion picture film** (not final incarnation) lenticular additive color, 16mm amateur, 1928
- **Magnetic Tape**, iron oxide powder on paper tape was invented by Fritz Pfleumer in 1928

1930

- **Kodachrome** 2-color additive positive (reversal) color motion picture film tried by Fox Film Co in 1931
- **Dufaycolor motion picture film,** 3-color additive using mesh of RGB lines in 1931
- Zeiss Icon AG releases **Contax I,** 35 mm camera with Zeiss f1.5 lens (Dr. Bertel's, 7-element) in 1932
- **Magnetic Tape Recorder** was first built by Joseph Begun (Germany) in 1934-35
- **Kodachrome** (K-14) 3-layered subtractive positive film, stable w/no unused couplers after processing, 1935
- Nikon releases **Nikkor 50 mm** lens, mounted on **Hanza Canon** (Canon rangefinder) in 1935
- Zeiss develops **vacuum deposition coatings on lenses**, reducing internal reflections and flare, increasing contrast and resolution in 1935, not available until 1940, then only in Sweden & Switzerland until after WWII
- **Agfacolor**, tripack subtractive color reversal process in 1936
- Kodachrome has low dye stability from inception (1935) through 1937, improved with 185-yr yellow in 1937

1940

- Kodak **Azochrome** silver dye bleach print created from Eastman Wash-Off process in 1940
- First multi-layer **color negative film**(s) developed in 1941
- First color print from a color negative film, **Kodacolor**, C-22, red-tone emphasis, thru 1963, began in 1942
- **Kodak Dye Transfer**, dye imbibition process, gelatin receiver layer accepts 1 of 3 (CMY) dyes, on paper 1945
- Kodachrome color reversal film is supplanted by **Ektachrome**, easier processing, blue-tone emphasis in 1946
- Ektachrome **E1, E2 & E3** released, had poor cyan and yellow dye stability (E3 through 1976), E1 & E2 in 1946
- William Shockley (+others) invent **transistor**, go, no-go **electron gate,** replaces electron valve (tube), 1947
- **Edwin Land** develop Polaroid **Model 95**, first instant image camera system, B&W only, in 1948
- **Bob Herr** (3M) proposed **idea of recording pictures & sound**, tape at 15 ips past rapidly-rotating head,1948
- **Vidicon,** analog electronic image acquisition tube, used in television cameras, was introduced 1949
- Carl Zeiss Dresden (east Germany) release **first SLR** (prototyped before WWII in Jena) in 1949

1950

- Nikkor lens quality found equal to Zeiss and Leica multi-coated equivalents in the early 1950s
- **Wetzel** (3M) demonstrates **first B&W video recording**, fixed-head at 7.77 ips for 15 min (7000 ft) in 1950
- **John Mullin**, Bing Crosby Enterprises**, experimental VTR**, blurred,¼" tape, static heads at 360 ips in 1951
- **BBC VERA** (Vision Electronic Recording Apparatus) first VTR, ½" steel tape, 200 ips past static heads, 1952
- **RCA tests video recording** (B&W & color) experimental ½" magnetic tape, 360 isp, 3/5 static heads in 1953
- Carl Zeiss (west Germany) release their SLR (single lens reflex, through lens viewing) **Contaflex** in 1953
- **Eduard Schueller** develops **Helical scan** rotating video head, slanted for increase track length, patent 1953
- **Ampex Video Tape Recorder,** 2" plastic tape past vertical-rotating Quad head, lead Charles Ginsburg, 1956
- IBM develops **magnetic storage** for main frame computers, 305 RAMAC, 50 24" disks holding 5 MB, 1950-56
- Carl Zeiss (west) releases **Contarex** (Cyclops), first SLR with integrated light meter, in 1958
- Jack Kilby of Texas Inst. conceived of **integrated circuit**; in 6 mo Fairchild's Robert Noyce perfected, 1958
- Nikon releases the **Nikon F** SLR body with internal metering (more compact and affordable) in 1959

1960

- Lens designs with more **advanced coatings** reach point of penultimate performance in the 1960s
- Kodak introduces **Estar** film base (polyester, aka Mylar) in Kodalith line, replaced cellulose tri-acetate in 1960
- Kodak introduces **Kodachrome II** transparency film, still K-14 processing; very color stable, in 1961
- **Polacolor** first instant color process, dye diffusion (Dufaycolor) type, by Polaroid in 1963
- Silver dye bleach process refined, positives prints from transparencies, Ilford, **Cibachrome**, 1963
- IVC (Sunnyvale, CA) introduced **1" tape** helical scan video tape recorder in 1967
- Sony introduces ½" tape and DV-2400 Video Rover **Porta-Pak**, first viable portable video device in 1967
- First viable light-to-digital **CCD imaging chip**, developed by Willard Boyle & George Smith at Bell Labs, 1969

1970

- Excellent lens designs become cheaper, resolution reaches point of diminishing returns in 1970's
- Bell Labs built their CCD technology into the world's first **solid-state video camera** in 1970
- **Intel 4004**, Faggin, Hoff, & Mazor, first commercial integrated circuited, 2250 transistors on one chip in 1971
- Polaroid release the **SX-70,** color instant camera, opaque screen clears (1 min) after dyes develop, in 1972
- Kodak begins C-41 color negative process with **Kodacolor II**, started with Kodacolor-X (1963-74), begin 1972
- Ochi's **8x8 pixel CCD** (64 pixels) digital imaging sensor, Bell Labs had given up commercialization, in 1972
- Fairchild Imaging markets CCD201ADC, first **100x100 CCD** pixel array (also 500 pixel linear array) in 1973
- IBM releases dual-spindle **30/30 Winchester** (# 3340) sealed portable 60 MB, forerunner to all HDD in 1973

1975

- Ray Kurzweil invents CCD **flatbed scanner** for OCR (becomes Xerox Textbridge 1980) 1975
- Mits Corporation introduced the first popular home computer, **Altair 8800**, $400, no operating system in 1975
- Steve Sasson (Kodak) created huge **Prototype CCD Digital Camera** used Fairchild B&W 100x100 chip 1975
- **CASI Photo System** still video TV camera, designed for commercial portraits with computer & printer in 1977
- Steve Jobs & Steve Wozniak, **Apple I** based on MOStek 6502 chip, Homebrew Computer Club, $666, in 1977
- **Apple II** in full case w/color monitor (Apple I had wood case) by Apple Computer, sold for $1298 in June 1977
- Ektachrome **E4** with better color dye stability supercedes others in 1977
- **Schneider** begins selling multi-coated (flare suppression) lenses, 1977, completes upgrade of full line 1978
- **Fujinon** begins multi-coated (Electron Beam Coating) lenses, prior they were all single coated, 1977-80

1980

- Seagate Technologies releases **ST506,** first **5-¼" HDD** for desktop computers 5 MB, $1000 in 1980
- **IBM PC** was conceived in Boca Raton, Florida in early 1980, IBM introduced PC Model 5150 in 1981
- First viable color digital imager **Sony Mavica** B&W 0.79 MP(video still 570x490 pixels) in 1981
- Kodak first introduce **T-grain technology** in silver particles for Kodacolor films (before processing) in 1982
- Pentax demonstrates **Nexa**, B&W analog video still camera prototype, image stored on floppy disk, in 1983

- International Telecommunication Union's (ITU-R) working party (IWP11/6) to **develop HDTV standard**, 1983
- **MegaVision** introduces a 1000-line digital still camera, uses analog Vidicon to create 1000x1024 still in 1984
- **Canon RC-701,** 0.40 MP Pro color still video camera with analog transmitter (news) LA Olympics in 1984
- Apple **Macintosh** Computer (128 K) 9" B&W screen, 8 MHz processor, 128K RAM (4 MB via 3rd party) 1984
- **JVC GR-C1** first camcorder (camera & VTR) 1/3-size mini-VHS cassette, plays in VCR with adapter in 1984
- Focal Point still **Pentacam VSC-3000** Sony 3-CCD video camera w/Nikon F4S SLR body (768x494) in 1984

1985

- Commodore **Amiga A1000** first mini-computer w/superior graphics & sound, GUI, 12-bit color, 32-bit, 1985
- **Polaroid** defeats Kodak in the instant camera patent claims while digital is being developed in 1986
- **Newtek Digi-view**, Amiga platform, first computer capture device, 0.6 MP 12-bit, B&W w/RGB wheel in 1986
- Kodak develops **1.4 MP CCD** sensor array 1986; first megapixel camera **Videk** (1320x1335)1.4 MP in 1987
- USA Today publishes first video still image (digital color) on front page in 1987
- Associated Press announces (5-yr) conversion program, digital photo transmission saving 90% time, in 1987
- **Canon RC-760** news camera (used by USA Today) 0.6 MP SLR $5.5K (aimed at news photographers) 1987
- Canon RC-250 **XAPSHOT**, 0.20 MP video still consumer level ($499 1/10th cost of above) hook to Mac, 1988
- **Nikon QV-1000C** B&W video still camera, first DSLR, F-mount (news photographers) 0.38 MP, $20K, 1988
- **JPEG & MPEG file formats** developed, using DCT compression technology, 1988
- SONY **ProMavica MVC-5000** 2-chip video still, first transmit instant color images over phone (news), 1989
- Letraset released **Color Studio 1.0** for Mac platform, first professional image manipulation software in 1989

1990

- Ektachrome **E6** claims 250-year dark fading stability for CMY dyes in 1990
- **Photoshop 1.0** Mac only, John & Thomas Knoll wrote and licensed to Adobe (1988); v1 in 1990
- **Mike Collette** invents the **digital scanback** on seeing **Kodak's 6K trilinear CCD array**, 12-bit ADC, in 1991
- **Leaf DCB-1** first MF mono back, 4.2 MP (Fairchild 2048x2048 chip), uses 3-color wheel, aka "The Brick" 1991
- **Kodak DSC 100** first Pro DSLR, F3 body with very large external HDD, 1024x1280, 1.3 MP, $30K in 1991
- **Kodak DCS 200** uses Nikon N8808 film body, has internal HDD, 1012x1524, 1.53 MP, $30K in 1992
- Kodak introduces **PhotoCD** optical storage media; heavy compression and YCbCr color space, in 1992
- **MegaVision** develops the **T2 3-shot back** using a color filter wheel for a Sinar 4x5, 4MP (2048x2048) in 1992
- Scitex introduces **Leaf Volare**, MF, 3-shot back ($25K), uses Phillips 24x36, 2048x3096, 6 MP CCD in 1992
- **Sound Vision CMOS-PRO** produces first CMOS image (960x800, 1.8 MP) by Bob Caspe (Leaf) in 1992
- **Canon EOS prototype** DSLR, unlike final EOS design but SLR, 1.3 MP in 1993
- **Nikon D1 prototype** F (looks like later model E) uses unique body design but SLR (480x1088) 0.56M in 1993
- Kodak **discontinues Dye Transfer** materials (sole supplier) in 1994
- Apple introduces **ColorSync 1.0**, developed in house by Robin Myers and others, released in OS in 1993
- **CompactFlash** (CF) (transfer chip in card) and **SmartMedia** image memory cards introduced in 1994
- **Steve Johnson** tests 6000x7520 scanback; licensed to **Dicomed** by Mike Collette; "the day film died" 1/15/94
- **KODAK DCS 420** Nikon N90X body, aka Nikon D3 first w/storage cards, SCSI port, 1524x1012, $11K, 1994
- Epson MJ-700V2C, 720 dpi **desktop color inkjet printer**, first "photo quality" printer in 1994
- **Photoshop 3.0** for Mac, Win, IRIX & Solaris, added Layers, no 16-bit yet, 1994

1995

- Worldwide agreement on **HDTV standard** ITU-R BT.709-2, 16:9, 1080i/p (maximum), sRGB space in 1995
- **Canon/Kodak EOS DCS 3**, Canon EOS-1N body, 1.3 MP CCD (1012x1268) in 1995
- **Canon/Kodak EOS DCS 1**, Canon EOS-1N body, 6 MP CCD (2036x3060) 12-bit ADC in 1995
- **Kodak DCS 460,** Nikon N90S body, 6 MP (2036 x 3060), 18MB file size, 12 bit ADC, $28K, 1995
- **Dicomed Bigshot 4000** first one-shot larger than 35mm (4096x4096 Fairchild CCD) 17 MP $35-55K, 1996
- **Kodak DC-120** first 1 MP (960x1280) digital SLR to break the $1000 barrier in 1996
- **Thinker.org** released by FAMSF with in-depth online accessibility to collection, 83,000 entries now, in 1996
- Mike Collette develops second-generation, **BetterLight** releases **Model 6000** scanback (6000x 8000) 1997
- **BetterLight** releases **Model 8000** scanback (8000x10660) 256 MP, 14-bit ADC, SCSI interface in 1997
- **Phillips** develops a huge, 63 MP B&W full-array CCD (7000x9000) for use in IR space telescopes in 1997
- CBS went on the air with WCBS-HD (4/6/97) top of the Empire State Building, **HDTV,** 16:9, 1080i, in 1998
- **HDTV sets** (digital) went on sale the USA, 16:9 aspect ratio, 720 (H) x 1280 (W), 720p (<1 MP) in 1998
- **Kodak DCS-560** (Canon EOS D6000) EOS 1N body, 6MP (2008x3040) 12-bit ADC, $30K, 1998
- **Foveon** CCD chip with "depth-based color sensitivity" (no Bayer Pattern on pixels) RGB digital sensor, 1998
- **Photoshop 5.0** added Color Management, some 16-bit operations and History Pallet, 1998

2000

- Kodak moves to use **Estar base (polyester, Mylar) for all sheet film**, roll film still on acetate base, in 2000-1
- **Polaroid** enters Bankruptcy 2001; sold to BankOne 2002; as of 2006, surviving entity only distributing assets
- **Canon 1Ds** (2704x4064, 11 MP) first DSLR recognized with resolution superior to 35 mm film in 2003
- **Kodak announces discontinuation** of **slide projectors**, parts available thru by 2008, in 2004
- **Kodak discontinues Eastman Ektachrome Color Reversal** motion picture film thru-out 2004
- **Kodak discontinues** producing B&W photographic paper, after 125 years of production, June 2005

2005

- **BetterLight** releases **10K scanback** (10200x13600) 416 MP, USB, 14-bit ADC, beyond lens capability, 2007
- Kodak releases **39 MP full array CCD** (5412x7216; Bayer pattern) almost the size of small scanback 2007
- **Kodak discontinues** 6K, 10K and 14K trilinear CCD arrays, used in scanbacks and hi-end flatbeds 2007-8
- **Polaroid** (not original Corp) announces discontinuance of instant films (production will end by 2009) in 2008
- Photographers around the world, via listservs, agree that **instant B&W photography has ended** June 2008
- Sony introduced **Alpha A900** DSLR, 24.6 MP (6048 x 4032) full frame CMOS for less than $3000, Sept. 2008

- Canon responds: lowers price of **EOS 5D MKII** DSLR, 21 MP (5616x3744) full frame CMOS, $2700, late-2008
- **BetterLight** releases **ColorSage,** first spectral based (380-780nm, 4 nm steps) color workflow tool in 2008
- **Kodak discontinues** producing Kodachrome after 74 years of production in June 2009, stock gone Fall 2009

Electronic imaging probably began with the Radiofax, a fax device used for the first intercontinental radio transmission of a continuously variable analog B&W image (of Calvin Collage) in 1924. Television technology as we know it was developed by Philo T. Farnsworth, starting with his 1921 "hay field revelation" on scanning with a beam of electrons. By 1927, Farnsworth had transmitted the first 60-line TV image and patented the system; there were competitors: RCA and Baird. Television is a continuously variable analog signal that shows motion by presenting a continuous stream of still images, 30 per second (NTSC). After 1950-6, video could be saved by recording on magnetic tape, prior to that it was recorded off-screen onto film (kinescope); see http://videopreservation.stanford.edu/museum/index.html. Video became portable with ½" EIAJ reel-to-reel; the 1970 Sony AV-3400 Portapack VTR is a "most-produced" example http://www.labguysworld.com/Sony_AV-3400.htm. Video is often called a time-based media because it records events on liner tape through time.

Some of the earliest electronic imaging used stills from a video stream; the CASI Photo System (1977) is an example; see http://www.digicamhistory.com/1970s.html. Still frame video capture proved unwieldy and a photographic dead-end. MegaVision (1983) made many significant contributions to the transition from analog to digital imaging. The first was a processor (1024 XM) which converted analog video signals into digital images. In 1984 they introduced a 1000-line analog video (vidicon) capture camera that was later upgraded to 2000-line Tessera system (1986) designed for catalog work. Some workers entered the digital domain in 1992 using the Kodak PhotoCD, where film originals were migrated to the digital format by Kodak, harkening back to the first Kodak cameras (1884) where the slogan was "You press the button - we do the rest."

The transistor was invented in 1947; the integrated circuit (IC chip) was developed in 1958; this lead to Boyle and Smith (1969) developing the charged coupled device (CCD) at Bell Labs -- digital imaging was born. The CCD quantized light focused directly on a pixel array, not on the face of an analog imaging tube (vidicon). The CCD counts photons of light that fall on picture elements (pixels) creating a serial numeric electron count from each pixel. The chip's exposure time could be varied (trading for higher noise) making it parallel to film. The analog stream of electron counts is converted into machine code by the analog to digital converter (ADC). The first known CCD digital still camera was made by Steve Sasson in 1975, at Kodak. The Sony Mavica (magnetic video camera) was the first commercial CCD camera, born digital image, SLR with interchangeable lenses and storage on 2" floppy disks.

Between 1973 and 1994 the quality of CCD output, level of noise and pixel density improved to a point where digital was found to be equivalent to film. MegaVision introduced a fully digital 3-shot system (T2), using a 2024 x 2024 monochrome Fairchild CCD with 3-color wheel in 1992 as a digital back for a view camera. Stephen Johnson (photographer in Pacifica, CA) pronounced film dead in early 1994 after testing the BetterLight Model 6000 scanback prototype developed by Mike Collette. The BetterLight used a Kodak 6K trilinear array with three 6000-long rows of red, green and blue (RGB) pixels that scan across the back of a view camera creating a very high megapixel image. Each pixel has unique RGB color values created at the bit-depth of the ADC (14-bit). In 2003, the Canon 1Ds DSLR, 11 MP (2704 x 4064; 12-bit ADC) was acknowledged capable of producing digital images equivalent to 35 mm film. DSLR cameras use a Bayer Pattern of color dyes (BG-GR) over their full array of pixels producing color data with diminished (4:1) color information. Scanback cameras and flatbed scanners have unique RGB data for each image pixel, this is a superior technology.

Digital imaging is now capable (1994-2008) of recording spatial and color information at low noise, well beyond the limits of film and even lenses. Digital technology offers imaging with no intervening technologies to distort the color information such as film dyes, dye couplers or processing, and all with no film base or color dye deterioration over time. In addition, the photographer can edit and output at the highest level of competence; this capability was once only reserved for color service bureaus.

Many photographers who favor film assert that the smooth tonal gradations of midtones found in many early to mid-twentieth century images is one of the enduring qualities of film. With the continued use of digital equipment by ever increasing numbers of artists and technicians, it is now suggested that this property is due to internal lens flare found in earlier uncoated or single-coating lenses. On the other hand, some say that noise in film (typically 10:1) is so high that it blends the high contrast differences (small detail) always found in premium digital systems where noise is about 500:1. That is, the noise in film produces the smooth transition found in the in the midtones of film images. Nether observation is universally accepted; passionate argument is ongoing.

Image Collection Remastering: Easy online access to a collection of images can show its value to funders, and thus, drive the preservation process (Preservation and Access). Remastering analog images into the digital domain preserves the image because images can be captured without color or resolution loss, well above the spatial information bandwidth, contained in the film. In addition, there is no deterioration of the digital artifact (image file) once the file (and two backups) are held in the digital domain on HDDs. After digitization, color-shifted film can be color corrected by a skilled operator using tools in Photoshop, at any time. The issue of capture resolution, weather to use low resolution for access, or high-resolution for migration, is best addressed on a case-by-case basis. Cold storage will halt dye and film base deterioration, allowing for the development of remastering project funding later.

The ability to digitize film is not going away anytime soon although Kodak has discontinued several of its trilinear CCD arrays, such as those used in some high-end flatbed scanners and scanbacks. Image capture using

automated functions can easily compromise digital images permanently. Although the automated functions make digital imaging easier for the inexperienced, they remove control from the experienced operator and can alter the fundamental image data captured by the sensor (CCD or CMOS) and analog-to-digital converter (ADC) before the file is even written to memory within the capture device. Even with a neutral gray target (4-8 steps) in the frame, full tonal range information can be compromised before the file is saved when using automatic functions.

Digital images need a file format that holds the digital image data securely and permanently. Archival storage of image information should be done using the TIFF format, made within well-known imaging software such as those in the Adobe and Apple families. RAW and DNG are both viable born-digital formats; DNG is preferred because it does not use sidecar files for metadata storage. PDF/A is a preservation format of document files with both text and digital images.

Use of a well-known color target such as the X-Rite ColorChecker or the Stouffer B&W transparent step wedge is recommended in each image frame. Although digital images can be stored indefinitely without deterioration, they can be swiftly lost through negligence (lack of backup). A digital file can be permanently "lost" if it is stored without regard for basic computer technology (backup) or by using inappropriate storage media, i.e., CD-R/RW or DVD±R/RW. The recommended digital storage medium is the hard drive (HDD). They are usually viable for 5-7 years. Although a HDD can fail, it is usually backed-up on another HDD or stored in an "internally redundant" RAID array (mode 1 or 6; mode 5 is no longer recommended). Multiple HDDs (three) appear to be more viable than RAID arrays at this time. Network backup on a RAID array can be one or two legs in an acceptable backup protocol, but relying on a RAID array using mode 5 has proven problematic for some users. Optical media (CD-R/RW, DVD±R/RW) will fail between 3-25 years; optical disk readers probably won't be available in 15-20 yrs. CD-R with gold reflective layer and phthalocyanine dye layer, recorded at slow speed (8X), can be reliable up to 25 years. A DVD±R with both archival attributes is not available and thus are not considered reliable.

Compression of an image file diminishes the potential of the numerical image data by throwing pieces away to save space or to improve download speed. If the original image data (web or thumbnail) is not as important as the space it occupies or the speed of download or movement within a network, compression could be used. Compression should not be the default option. Use compression only when it is necessary. Low-use compression formats may not be available in the future. Digital point-n-shoot cameras only make JPEG images.

Lossy compression (throwing original data away) is more effective for reducing file size and increasing download speed. Lossless compression, as found in the "best color" mode of JPEG2000 wavelet compression technology (J2K-C-LL) is superior to any level of the lossy JPEG (Discreet Cosign Transform) compression technology. Some forms the JPEG2000 format can be truly lossless. Archival use of JPEG2000 format is still in its tentative state; it may become common; opinions are evolving. Institutions such as the Library of Congress and the National Archives http://www.digitalpreservation.gov/formats/content/still.shtml have massive amounts of valuable historic materials that are being digitized and backed-up (twice, one off-site), they are driving the exploration of JPEG2000. As of May 2009, a University of Conn questionnaire revealed a continuing resistance to the JPEG2000 format; much of it through equating the old JPEG name with the transcendent new tool.

Curators, archivist, preservation providers and users must rethink their concept of storage. Storage protocols have been based on preserving physical artifacts. In the digital domain, however, perfect examples of the original (file) are always possible, indistinguishable from the original. Digital files are continually migrated to larger (newer) storage media as perfect as the original. Migration is perpetual. Digital files cannot be tucked away and forgotten in benign storage environments (CD-R) as in the past. Digital collections must be actively managed as are computers and networks. The good news is that most collections don't require the physical space or energy needed to keep physical artifacts stable over decades and centuries. Maintaining the physical original is still important. With good records (imagebase), cold storage of historic originals is very compact.

The digital workflow has put all imaging processes into the hands of one operator. In contrast, the film workflow utilized at least three skilled crafts to bring a color image from studio, to processing and then printing, often leaving the creator out of the final stage. The differences between digital and film-based workflows are revolutionizing how images are captured, stored, viewed and accessed.

The transition to digital is still in process, specifications and details for IT protocols change often. Creditable professionals can, and do, disagree. When in doubt, question the more opinionated views.

Tim Vitale
Paper, Photographs &
Electronic Media Conservator
Film Migration (still) to Digital Format
Digital Imaging & Artwork Facsimiles
Preservation & Imaging Consulting
Preservation Associates
1500 Park Avenue
Suite 132
Emeryville, CA 94608
510-594-8277 Off
510-594-8799 Fax

Mail to: tjvitale@ix.netcom.com
Albumen website (2001) <http://albumen.stanford.edu/>
VideoPreservation Website (2007) <http://videopreservation.stanford.edu>