Brief History of Imaging Technology

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Overview: Imaging began when an image from a pinhole lens in a Camera Obscura was traced onto paper, or fine fabric, in 1021 Iraq and 1550 Italy. Mechanical imaging migrated to chemical-based photography with the first successful sun-picture, made in 1826 France. Chemical imaging technology uses photons of light to chemically reduced silver ions to silver metal that creates a permanent image through a series of baths. Today's digital technology counts the number light photons falling directly onto a chip, where the image is focused through a lens, to produce an image directly from light with no intervening steps.

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Timeline of Imaging Events

Lens History; Pre-Photography; Film Camera; B&W Photography; Color Photography; Digital Photography; FAX Technology; Magnetic Media; Video Technology; Digital Printing Technology

3000 BC/BCE (5000BP)

- **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
- **Palm Leaf Manuscript first bound** (string through common hole) sometime about 1400-1499 BC
- **Isidore de Seville** publishes the relationship between codex, book & scroll in his Etymologiae between 499-400 BC
- Greek and Chinese scholars describe the basic principles of optics and camera, circa 300-400 BC
- **Aristotle writes of darkened room with small hole** in one wall, inverted image on opposite wall, 330-300 BC

- **Paper fragments are found in China** in materials dated to 179-41 BC

0 AD/CE (2000BP)

- **Greeks** discover rubbing fur on Amber cause attraction between the two (electron & static electricity) in about 1 [AD]
- **Paper invented in China in Han Dynasty court by Cai Lun** sometime around 105
- **Woodblock/woodcut** printing technology about 200
- **Paper technology** adopted in the Islamic world [Samarkand] after the Chinese defeated at Battle of Talas 751

1000

- **Reading Stone**, a glass sphere use to read by magnified letters was in recorded use around 1000 AD
- **Lens** is first described in the Book of Optics by Ibn el-Haitam an Iraqi Physicist published in 1021
- **Camera Obscura first** published in Book of Optics by Iraqi scientist, Ibn al-Haytham, used a pinhole in 1021
- **Paper technology** migrates Portugal/Spain in about 1071
- **Paper technology** into Italy sometime between 1300-1400
- **Paper technology** in Germany about 1400
- **Guttenberg Press** [**Johannes Gutenberg**] [also called letterpress] first used in Germany about 1439-1440

1500

- **Movable-type press** in use throughout Western Europe around 1500
- **Etching plate** and printing technology developed about 1500
- **Camera Obscura with a lens**, Girolamo Cardano replaced pinhole with biconvex lens in 1550s
- **Giovanni Battista della Porta** (1538-1615) published first account of Camera Obscura to aid drawing in 1558

1600

- **William Gilbert** conned *electric* from the Greek *electron* to identify force between materials rubbed together 1600
- **Telescope** - first written mention in Zeeland (Dutch) document, **Hans Lipperhey** claims a new device in 1608
- **Galileo** made his astrophysical studies using a early **telescope** in 1610
- **Antoine van Leeuwenhoek** Dutch amateur microscopist invented the water drop lens latter part of 17^{th} C
- **Newton** discovers that **white light** is composed of colors of light (**spectrum**) between 1664-66
- **Reflex-mirror** design in a camera obscura was first published in 1676

1700

- **Johann Heinrich Schulze** mixes chalk (white base), nitric acid and silver; notices **darkening on side of flask** exposed to sunlight; first photo-sensitive compound discovered, silver nitrate ($AgNO_3$) in 1724-27
- **Hall Achromat** curved-field lens, uses two glass types (crown & flint) to focus red and blue light in the same place, but because green-light focus point was shifted the resolution was soft, developed about 1770-75
- **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
- **Lithography technology** developed about 1796
- **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

- **Volta [Alessandro]** constructed the voltaic pile (**battery**) first device to produce a constant electric current 1800
- **Wollaston Landscape lens,** first properly designed lens but suffers curved-filed & chromatic aberrations in 1812
- **Lithography on stone** and metal plate (more modern) began in France about 1813
- **Camera for photography** used by **Niépce**, sliding wooden box camera, by Charles & Vincent Chevalier in 1812
- **Nicéphore Niépce** combines Camera Obscura with photosensitive paper; not fixed, thus not permanent, 1816

1825

- **Nicéphore Niépce** made the f**irst permanent image:** light-sensitive "bitumen of Judea" on a Pewter sheet 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
- **Michael Faraday** created the **electric dynamo** used to generate electricity in 1831
- **Chevalier Achromatic lens**, 2 elements cemented together, still found in point-n-shoot cameras, in 1835
- **Chromolithography** color printing developed around 1837
- **Daguerreotype,** Louis Daguerre, Ag-I negative on polished copper sheet, devl'pd w/ mercury vapor, 1835-39
- **Herschel**, John, FW., publishes work on a successful fixing agent, hyposulphites (Hypo) in 1939
- **Daguerre** licensed Chevalier lens for a wood-body camera designed for quarter-plate under his name in 1839-40
- **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
- **Niépce 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 POP paper 1850; Printing-Out-Paper technology 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 or 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
- **Telegraph Fax** - Alexander Bain is credited with inventing the 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

- **Telegraphic Fax sent,** Giovanni Caselli used the Pantelegraph to send first fax between Paris & 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
- **Silver-collodion paper**, POP by photographer, Ag- or U-NO_3 in collodion on sized paper introduced about 1864
- **Ernst Abbe** joins Carl Zeiss (Jena) as the main lens designer, known for microscope's Abbe Condenser, in 1866
- **Lord Kelvin patents** continuous stream ink drop (CJI) inkjet technology in 1867

1870

- **Silver-gelatin process** by RL Maddox: AgCl or AgI crystals in gelatin media (water solvent) on glass 1871
- **Ernst Abbe** at Carl Zeiss (Jena) develops **Abbe sine condition optics** improving optics significantly in 1873
- **Offset Lithography printing press technology developed** about 1875
- **First color print:** layers of subtractive cyan, magenta & yellow gel by Louis Arthur Ducos du Hauron in 1877
- **Rodenstock,** Munich Germany, considered superior LF lens maker with their digital (flat field) lenses in 1887
- **Dry Gelatin Plates,** over-the-counter glass plate negatives, thru 1930s, by pro-Photogs & press, in 1878
- **Lord Rayleigh** discovered the mechanism by which a stream of liquid breaks into droplets in 1878
- **Edison [Thomas Alva]** invented the electric light bulb in 1879

1880

- **Silver-gelatin papers** (Ag-Br) for photographic prints first created about 1880
- **Eastman** began sensitizing photographic paper using uncoated Germany and French papers in 1880
- **Eastman Permanent Bromide Paper** fast DOP paper, limited success because it was too fast for amateurs,1880
- **Platinum Print** (still salted paper print) was discovered by William Wills in 1873, reached market in 1881
- **Film** 1st created as silver-gelatin coated on cellulose nitrate film about 1884
- **Baryta layer** introduced to B&W prints, increases reflectiveness (Dmin) and expands tonal range, about 1885
- **Kodak** releases paper negatives on a roll (paper), processed by Kodak (1888) in 1885
- **Otto Schott** joins Abbe and Zeiss at Carl Zeiss, produces glass equal to Abbe's work, **Apochromatic** lens developed, corrected for all colors focusing in same plane and coma (all points focusing in same place) in 1886
- **POP** 1st **Printed-Out-Paper** which develops using light, matte gelatin emulsion on paper 1885; glossy in 1890
- **Kodak** (product name) for Eastman Kodak's factory-loaded camera w/ paper film consumers (thru 1889) in 1888
- **Film** 1st silver halide in gelatin on plastic film (early plastic) manufactured by Kodak in 1889

1890

- **Silver-gelatin prints** supplants albumen prints (first in 1850) sold pre-sensitized dry in a box around 1890
- **Paul Rudolph,** Carl Zeiss (Jens) develops **Anastigmat** lens w/2 asymmetrical groups, either side of iris, 1890
- **DOP, Developing-Out-Paper[s]** introduced, silver-gelatin (Ag-Br) papers developed in chemical bath, ca 1890-95
- **Aristo**, American Aristotype Co., is a Baryta coated, collodion emulsion Ag-Br POP that was very successful,1896
- **Velox**, one of the most popular printing papers by the Napara Chemical Co., introduced a slower DOP paper for use outside the darkroom, still 500x quicker than albumen (POP) but slower than the early DOP papers in 1897-8
- **Paul Rudolph** of Carl Zeiss (Jena) develops the very fast (f/3.5) **Planar** design, 6-element in 6-groups in 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
- **Kodak No1 Folding Pocket Camera** used 105 roll film (2¼ x 3¼) on nitrate base (thru 1915) for $10 in 1899
- **Kodak** buys Velox from Baklin for $750K because it's a 5-12 second (slower) gaslight DOP amateur paper in 1899
- **Self-Toning Matte** Baryta-coated gelatin emulsion Ag-Br DPOP papers [no commercial success, too fast] in 1899

1900

- **Kodak No 3 Folding Camera** used 118 roll film (3¼ x 4¼) on nitrate base (thru 1915) for $68 in 1900
- **The Brownie Camera** (thru 1924; No 3 to 1934) used 117 roll film (2¼ x 2¼) on nitrate base, for $1, in 1900
- **Carl Zeiss** (Jena) renames Anastigmat Series **I** thru V, **Protar**, no astigmatism or field curvature in 1900
- **No 2 Brownie Camera** (thru 1924) child 's box (**cultural icon**) used 120 nitrate roll film (2¼ x 2¼) for $2 in 1901
- **Otto Schott** of Zeiss Jena, develop rare earth glass (aka Jena glass) in 1901
- **Paul Rudolph** of Carl Zeiss develops **Tessar** high resolution & contrast lens; 4 elements in 3 groups in 1902
- **Carl Paul Goerz** (1886, Berlin) developed 1-group, 3-element compact Dagor Anastigmatic flat field lens, 1904
- **Ozobrome,** Thomas Manley invents Raydex proportional color pigments in gelatin layers on paper in 1905
- **Kodak No 4A Folding** w/Goerz Dagor lens ($110) 126 roll film (3¼ x 5½) nitrate base (thru 1916) in 1906
- **Kodak** begins to study in-house papermaking and encouraged others such as American Playing Card Co. in 1906
- **Vacuum Tube**, a continuously variable **electron valve** (variable gate) was patented by Lee De Forest in 1906
- **Graflex No1A,** Folmer & Schwing, USA, first MF (116 roll film) SLR w/ waist-level & focal-plane shutter in 1907
- **Kodak No 4 Pocket Folding**, very large body w/20 lens opt' ($83) 123 roll film (4x5) nitrate (thru 1915) 1907
- **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 in UK), alternating R, G & G images, released 1908
- **Cellulose Acetate factory** is opened by Kodak (used for film base) in Australia about 1908
- **Safety Base film** announced by Kodak, cellulose acetate safety film in various formulations beginning in 1909

1910

- **Aristo is reintroduced**, faster DOP papers become popular for enlargement in the [professional] darkroom in 1910s
- **Dye Imbibition** technology created by Fredric **I**ves (dye absorbing) Trichromatic Plate Pack (3 neg; 1 exp) 1911
- **Schneider** Kreuznach optics (German) opens, will make lenses for 35-mm format to large format, in 1912
- **Enlarger** [$95 or $2-3000 today] with electrical-based lighting system become common for professionals in 1913
- **Kodak Park Papermaking machine** is built in 1914, first used at Kodak Park for photo paper in 1915
- **Kodachrome (1) still** film 2-col additive, bleach & dye sub process, John Capstaff at Eastman, between 1914-16
- **Technicolor, Process 1**, 2-color (R & G) additive motion picture with 2 simultaneous images thru filters in 1916
- **Ansco's Cyko DOP** fast Baryta coated fast enlarging paper, "8x-faster than Soft Cyko," introduced in 1917
- **Tri-Color Carbro** subtractive color (CMY) pigmented gelatin layer print, Autotype, H.F. Farmer in 1919

1920

- **Kodachrome (1) MP** film (2-color additive, dbl-sided film) tested by Paragon Studios (Fort Lee, NJ) in 1922
- **Technicolor, Process 2**, 2- color additive, R & G positive images cemented together in exhibition positive, 1922
- **Radiofax - Richard Ranger** at RCA invents wireless fax, first transatlantic photo NYC to London in 1924
- **Leica I,** developed 1913, first 35-mm rangefinder camera with either 5-elm Elmax or 4-elm Elmar 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
- **Kodacolor (1) MP film,** Eastman lenticular additive color, 16 mm amateur gauge in 1928
- **Technicolor, Process 3**, 2- color additive (R & G) using dye-imbibition process (not cement film) in 1928
- **Magnetic Tape**, iron oxide powder on paper tape was invented by Fritz Pfleumer in 1928
- **Graflex Speed Graphic** f/4.5 B&L Tessar or Kodak Anastigmat , wire loop focus (thru 1939) 4x5 & 5x7sht, 1928
- **Rolleiflex** releases its double lens reflex (DTL) medium format (2¼ x 2¼) camera in 1929
- **Technicolor, Process 4**, full color using 3-strip camera, subtractive (CMY) dye-transfer final print, in 1924/29

1930

- **DOP surface texture variables** (Defender and Kodak brand ranges are wide) released between 1930-40
- **Dufaycolor motion picture film,** 3-color additive using mesh of RGB lines in 1931
- **Contax I** released by Zeiss Icon (east German) 35-mm SLR rangefinder camera with Zeiss f1.5 lens 1932
- **RCA demonstrates television system**, based on electron beam scanning (Farnsworth) technology in 1932
- **Xerographic image first made** in 1932
- **Ihagee Exakta,** (Kine-Exakta) 1st production 35-mm SLR, 127 roll film (1⅝x2½) w/changeable bayonet lens 1933
- **135-mm film** (35-mm format) acetate base film in familiar pre-loaded daylight-loading cassette by Kodak in 1934
- **Retina I** by Kodak (German-built) using their new daylight-load 35mm cartridge w/ integral Schneider Xenar 1934
- **Magnetic Tape Recorder** was first built by Joseph Begun (Germany) in 1934-35
- **Gevaluxe Velours by Gevaert** a very high-texture matte surface considered height of B&W matte papers in 1935
- **Kodachrome** (final - K14) 3-layered subtractive (CMY) reversal positive MP & still film (yel. fugitive til '37), 1935
- **Nikkor 50 mm** f/3.5 lens (50/3.5) was releases by Nikon, mounted on **Hanza Canon** (Canon rangefinder) in 1935
- **Vacuum deposition of lenses coating** - Zeiss, designated "T or T*" reducing internal reflections & flare, increases contrast & resolution, not available until 1940, then only in Sweden & Switzerland, til after WWII 1935
- **Agfacolor**, tripack subtractive (CMY) color reversal process in 1936
- **Argus A** 35-mm daylight-load cassette camera made for mass consumption ($12.95 - 500,000 sold) in 1936
- **Kodachrome dye stability increased** with the substitution of a 185-year stable yellow dye in 1937
- **Xerography** patented by Chester Carson in 1937

1940

- **Ilford Multigrade** DOP is released, variables facilitated by colored filters for hard & soft negs on same paper, 1940
- **HK7 Hasselblad** (Sweden) reconnaissance camera w/coated lenses, updating German design for Allies in 1941
- **Azochrome** silver dye bleach print created by Kodak from Eastman's Wash-Off process in 1940
- **First multi-layer color negative film**(s) developed in 1941
- **Kodacolor** (final - C22) first color print from a color negative film, red-tone emphasis, thru 1963, began in 1942
- **Kodak releases Kodacolor chromogenic print paper in 1942**
- **Kodak Dye-Transfer**, dye imbibition process, gelatin receiver layer accepts 1 of 3 (CMY) dyes, on paper 1945
- **Carl Zeiss (Jena)** assisted by US Army to move into West Germany (Stuttgart) was renamed Carl Zeiss 1946/7
- **Carl Zeiss (Jena) in** East Germany renamed Kombinat VEB Zeiss Jena, labeled Zeiss Jena in west, about 1946
- **Ektachrome** supplants Kodachrome color reversal film, 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
- **Graflex Pacemaker Speed Graphic** w/Kodak coated Ektar 101/4.5 (Crown Graphic -1pb) all Press used in 1947
- **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
- **Haloid Co trademarks Xerox** for Carlson's xerographic technology, (founded 1906 high speed DOP papers),1948
- **Vidicon,** analog electronic image acquisition tube, used in television cameras, was introduced 1949
- **Contax S** Carl Zeiss Dresden (east German) first pentaprism 35-mm SLR (prototyped before WWII) in 1948-9
- **Hasselblad 1600**, MF SLR, with focal plane shutter used a Kodak Ektar 80/2.8 lens in 1948/9-53

1950

- **Nikkor** lens quality found equal to Zeiss and Leica multi-coated equivalents in the early 1950s
- **Type-C** chromogenic paper is released by in the early 1950s
- **Eastman Color Negative & Positive MP films**, camera negative to positive w/o Technicolor process, in 1950
- **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
- **Siemens** introduced the first continuous inkjet **(CIJ)** commercial printer (strip chart recorder) in 1951
- **BBC VERA** (Vision Electronic Recording Apparatus) first VTR, ½" steel tape, 200 ips past static heads, 1952
- **Asahiflex I** (Asahi - Pentax) first Japanese 35-mm film SLR w/ waste-level finder using M37 lens mount in 1952
- **RCA tests video recording** (B&W & color) experimental ½" magnetic tape, 360 isp, 3/5 static heads in 1953
- **Contaflex** by Carl Zeiss (west Germany) release their SLR (single lens reflex, through lens viewing) in 1953
- **Yashimaflex** (Yashica in Japan) medium format (MF) twin-lens reflex (TLR) in 1953
- **Eduard Schueller** develops **Helical scan** rotating video head, slanted for increase track length, patent 1953
- **Hasselblad 1000F** releases SLR body, used the Zeiss Distagon 60/5.6 or the Tessar 80/2.8 in 1953-57
- **Leica M3** by Leitz (Ur-Leica 1913) advanced 35-mm rangefinder with interchangeable bayonet lenses in 1954
- **Hasselblad 1000F** got rave review from Modern Photography (shot 500 rolls of film & dropped it twice) in 1954
- **Ampex Video Tape Recorder,** 2" plastic tape past vertical-rotating Quad head, lead Charles Ginsburg, 1956
- **Hasselblad** releases its flagship 500C body, with modified leaf shutter, using a range of Zeiss lenses in 1957
- **Dye-sublimation** digital printing technology developed in 1957
- **Magnetic Storage** developed by IBM for main frame computers, 305 RAMAC, 50 24" disks holding 5 MB 1950/6
- **Contarex** (Cyclops) by Carl Zeiss (west) releases first SLR with integrated light meter in 1958
- **Integrated circuit** conceived by Jack Kilby (Texas Inst), within 6 mo. Fairchild's Robert Noyce perfected, 1958
- **Canonflex** by Canon first Japanese reflex SLR w/ prism and focal-plane shutter 1-month before Nikon F 1959
- **Nikon F** is released, a reflex SLR body with interchangeable lens internal metering (compact & affordable) 1959
- **Xerox 914** is released by Haloid/Xerox as the first charged-black-particle-transfer copier on plain paper in 1959

1960

- **Phototypesetting** printing technology developed in 1960s
- **Ansco & Agfa** aka IG Farben, last of German "assets" sold to American interests (GAF) after WWII between 1960-7
- **Multiple-coating developed** for lenses, lens development reach penultimate lens performance in the 1960s
- **Estar film** base is introduced by Kodak (polyester, aka Mylar) in Kodalith line, replaced cellulose tri-acetate, 1960
- **Kodachrome II** is introduced by Kodak, transparency film, K-14 processing; very color stable, in 1961
- **Haloid Co** (famous high-end DOP paper maker) changes name to Xerox in 1961
- **Hasselblad 500EL** (electric) started going into space with NASA, went to the moon on Apollo starting in 1962
- **Polacolor** first instant color process, dye diffusion (Dufaycolor) type, by Polaroid in 1963
- **Cibachrome** silver dye bleach process refined, positives prints from transparencies, Ilford, in 1963
- **Xerox 813** releases first desktop plain paper copier in 1963
- **Spotmatic** by **Pentax** a reflex SLR w/ focal-plane shutter, TTL metering and M42 screw lens mount in 1964
- **Yashica D** released with Yashinon lens, MF TLR based on the Rollie, $125 D popular w/ prosumer in 1966
- **IVC** (Sunnyvale, CA) introduced **1" tape** helical scan video tape recorder in 1967
- **Porta-Pak** video camera is introduced by Sony, ½" tape (DV-2400 Video Rover) first viable portable video, 1967
- **Sweet [R.G.]** works w/ continuous inkjet printing leading to commercial CIJ printers by A.B. Dick, VideoJet &Mead in 1968-9
- **CCD** imaging chip first viable light-to-digital chip, developed by Willard Boyle & George Smith at Bell Labs, 1969
- **Laser printing** technology developed around 1969
- **Xerox 9700 1st Laser Printer** was created by Gary Starkweather from a modified a Xerox copier in 1969

1970

- **High quality lenses become affordable**, and resolution reaches point of diminishing returns in 1970's
- **Digital video camera**, Bell Labs built their CCD technology into the world's first solid-state video camera in 1970
- **Luminos Bromide RD** rapid-dry resin-coated paper (polyethylene fails early do to TiO_2 attack) released in 1970
- **8" Floppy Disk** by IBM to improve the distribution of code patches & diag's in IBM System/370 Model 145, 1971
- **Intel 4004**, Faggin, Hoff, & Mazor, first commercial integrated circuited, 2250 transistors on one chip in 1971
- **SX-70** is released by Polaroid, color instant camera, opaque screen clears (1 min) after dyes develop, in 1972 **SX-70** is released by Polaroid, color instant camera, opaque screen clears (1 min) after dyes develop, in 1972
- **Kodacolor II**, Kodak begins C-41 color negative process, started with Kodacolor-X (1963-74), begin in 1972
- **Technicolor closes US plant** as dye-transfer process becomes too expensive for commercial films in 1972
- **Ochi's 8x8 pixel CCD** (64 pixels) digital imaging sensor, Bell Labs had given up commercialization, in 1972
- **Thermal printing** technology developed about 1972
- **100x100 CCD** developed by Fairchild Imaging, CCD201ADC, first pixel array (also 500-pixel linear array) in 1973
- **Portable HD,** IBM releases dual-spindle **30/30 Winchester**, sealed portable 60 MB, forerunner to all HDD 1973
- **Xerox 6500** the first color copier developed in 1973
- **Kodak Polycontrast Rapid RC** paper (resin coated) multigrade DOP paper released in 1974

1975

- **Flatbed scanner** invented by Ray Kurzweil for OCR (becomes Xerox Textbridge 1980) 1975
- **Altair 8800**, Mits Corporation introduced the first popular home computer, w/o operating system, in 1975
- **Prototype CCD Digital Camera** by Steve Sasson (Kodak) created used Fairchild B&W 100x100 chip in 1975
- **IBM** (possibly Steven Sears) invents the first (CIJ) inkjet printer, oversprays badly, drop size 15-400 microns, in 1976
- **IBM 3800** released their first laser printer on the market in 1976
- **CASI Photo System** still video TV camera, designed for commercial portraits with computer & printer in 1977
- **Canon (Ichiro Endo)** discovers the **thermal DOD** inkjet printer technology capable of drop sizes around 1 micron in 1977
- **Apple I** by Steve Wozniak & Steve Jobs 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 supersedes 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
- **Electronic image** 1st pub by National Geographic; Emory Kristof used electronic camera in minisub in 1979

- **HP** develops its thermal DOD inkjet technology [brings to market in 1984] developed in 1979

1980

- **ST 506 Harddrive** released by Seagate Technologies first **5-¼" HDD** for desktops, 5 MB, $1000 in 1980
- **IBM PC** was conceived in Boca Raton, Florida in early 1980, IBM introduced PC Model 5150 in 1981
- **Sony Mavica** B&W 0.79 MP, first viable color digital imager, based on video still technology (570x490) in 1981
- **T-grain technology** created by Kodak introduce in silver particles for Kodacolor films (before processing) in 1982
- **Pentax Nexa** a B&W analog video still camera prototype, images stored on floppy disk, in 1983
- **HDTV standard** developed by International Telecommunication Union's (ITU-R) working party (IWP11/6) in 1983
- **Versatec ECP-42** [Xerox] first electrostatic color printer (200 ppi, 24-wide) seeds of graphic arts industry, in 1983
- **MegaVision** introduces a 1000-line digital still camera, uses analog Vidicon to create 1000x1024 still in 1984
- **Canon RC-701,** 0.4 MP Pro color still video camera with analog transmitter (news) used at 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
- **Pentacam VSC-3000** used Sony 3-CCD video camera w/Nikon F4S SLR body (768x494) in 1984
- **HP Thinkjet CMYK ink-set** released first thermal drop-on-demand (DOD) inkjet printers in1984

1985

- **Canon BubbleJet BJ-80 with** CMYK ink-set early thermal drop-on-demand (DOD) inkjet printers in1985
- **Amiga 1000** first mini-computer by Commodore w/superior graphics/sound for video, 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
- **1.4 MP CCD array** sensor developed by Kodak in 1986; first megapixel camera **Videk** (1320x1335) 1.4 MP,1987
- **IRIS Model 3024** inkjet printer (IRIS Graphics), using 1-micrometer glass jets, was develop &introduced 1987
- **HP releases PaintJet**, its color inkjet technology in 1987
- **Digital Image first published** by USA Today, first video-still image (digital color) on front page in 1987
- **Associated Press** starts 5-yr-conversion program from film to digital photo transmission saves 90% time, 1987
- **HP DeskJet** [first mass-market inkjet] was debuted in 1988
- **Electro-Optical Camera** by Kodak, US Gov covert, w/Exabyte tape storage tethered to a Canon F1 body in 1988
- **Canon RC-760** hi-band video still, news photographers, USA Today, 0.6 MP SLR $5.5K 2" video floppy in 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
- **Color Studio 1.0** released by Letraset for Mac platform, first professional image manipulation software in 1989
- **Kodak D-5000**, CCD-prototype for all digital SLRs, use KAF-1300, 1.3 MP w/PCMCIA, K-mount lenses in 1989

1990

- **Ektachrome E6** claims 250-year dark fading stability for CMY dyes in 1990
- **IRIS Model 3047** is introduced, on thick paper using fugitive inks is used by Nash Editions for artworks in 1990
- **IRIS Graphics** acquired by Scitex (Israel) in 1990
- **Polymer Plate** technology [water washed relief plate] for Letterpress printing developed in the 1990s
- **Photoshop 1.0** Mac only, John & Thomas Knoll wrote and licensed to Adobe (1988); v1 in 1990
- **HP DeskJet & DeskWriter,** CMYK ink-set inkjet printers are released by HP in 1991
- **Mike Collette** invents **digital scanback** (3750 x 6000) on seeing Kodak's 6K trilinear CCD, 12-bit ADC, in 1991
- **Leaf DCB-1** "The Brick" first MF mono back, 4.2 MP (Fairchild 2048 x 2048 chip), uses 3-color wheel, in 1991
- **Kodak DSC DC3** prototype for DCS 100, uses F3 body, SCSI, NTSC, 8-bit B&W/color, 600 files,$20-25k, 1991
- **Kodak DSC 100** first Pro DSLR, F3 body w/ very large external HDD, 1024x1280, 1.3 MP, $30K, 987 sold, 1991
- **Giclée coined by Jack Duganne** at Nash Editions for inkjet prints intended as artworks made on IRIS printer, 1991
- **Kodak DCS 200** uses Nikon N8808 film body, has internal HDD, 1012x1524, 1.53 MP, $30K, 3240 sold, in 1992
- **PhotoCD** introduces by Kodak, optical storage media; heavy compression and YCbCr color space, in 1992
- **MegaVision T2** released, a 3-shot (R,G &B) back using color filter wheel for Sinar 4x5, 4MP (2048x2048) in 1992
- **Leaf Volare** (MF) introduced by Scitex (Israel) 3-shot back ($25K), Phillips 24x36 mm, 2048 x 3096, 6 MP, 1992
- **Sound Vision CMOS-PRO** produces first CMOS image (960x800, 1.8 MP) by Bob Caspe (Leaf) in 1992
- **Epson develops the MJ-500 (Stylus 800)** micro piezoelectric inkjet printer in 1993
- **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
- **ICC [International Color Consortium]** co-founded, Apple & Linotype-Hell AG, cross-platform color profiles 1993
- **ColorSync 1.0** by **Apple** developed color management integrated into OS by **Robin Myers** & others in 1993
- **Dye Transfer** (still) process is discontinued by Kodak (sole supplier), some materials found afterwards, in 1994
- **Epson releases Stylus Color P869A** the first high-resolution (720-ppi) color printer in 1994
- **Apple QUICKTAKE 100** 1st consumer digital camera below $1000 VGA-based (480x640) with help of Kodak in 1994
- **DC40** 1st Kodak fixed lens versions of VGA-based (DC50 = 504 x 756 pixels, 24-bit) consumer (≈$1000) in 1994
- **DC50** 1st Kodak zoom-lens versions of VGA-based (DC50 = 504 x 756 pixels, 24-bit) consumer (≈$1000) in 1994
- **AP NC2000** by **Kodak & AP** specifically for news photographers, 700 exposures on disk ($15K) 550 sold, 1994
- **CompactFlash** (CF) (transfer chip in card) and **SmartMedia** image memory cards introduced in 1994
- **Steve Johnson** tests 6000 x 7520 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, 1524 x 1012, $11K, 1994
- **Epson MJ-700V2C**, first photo-quality 720 dpi desktop color inkjet printer in 1994
- **Photoshop 3.0** for Mac, Win, IRIX & Solaris, added Layers, no 16-bit yet, 1994
- **Durst Lambda 130** is released by Durst, 3-color laser printer onto chromogenic papers in 1994

1995

- **LightJet 2000** 3-color laser-to-chromogenic technology developed by Cymbolic Sciences (sold to Océ) at PMA,1995
- **HDTV standard**, worldwide agreement, ITU-R BT.709-2, 16:9, 1080i/p (maximum) & sRGB color 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
- **Nikon Coolpix 100** stored 19 images (480x512) on a PCMCIA card ($1000) slipped into laptop for download in 1996
- **Nikon E2N** first Nikon DSLR, F4 innards, purpose-built body w/interchangeable lens, PCMCIA, 1.3 MP in 1996/7
- **QuickTake 200** Apple's VGA-based digital camera with video feed ($600) built by Fuji (**FujiFilm DS-7**) in 1997
- **Sony Mavica MVC-FD5** w/47mm/f2 lens used 3.5" floppy disk for 55 - 480x560 VGA ($600) real-estate agents 1997
- **Sony Mavica MVC-FD7** w/40-400/f1.8 zoom lens, 3.5" floppy disk for 55 - 480x560 ($800) real-estate agents 1997
- **Technicolor reintroduce dye-transfer process**, used in film restoration such as Wizard of Oz (etc.) in 1997
- **BetterLight** releases **Model 6000** Mike Collette develops second-generation scanback (6000x8000) in 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
- **HDTV on air** CBS went on air in NYC with WCBS-HD (4/6/97) top of Empire State Building, 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 [major improvement]** Color Management, basic 16-bit operations & History Pallet added1998
- **Chromira developed by ZBE,** 3-color laser light to chromogenic is released at 300-ppi resolution & 36-bits in 1998
- **Multispectral ink technology** (CcMmYyKkR[O]GB sets & variations) was published by Tzeng & Burns in 1999

2000

- **SpectraShop 1.0** color measurement & analysis software created by **Robin Myers** (co-inventor ColorSync) 2000
- **IRIS printer**, owned by Scitex, is acquired by Creo Products in 2000
- **ICM** [Image Color Management] added to Windows 2000 and XP with Adobe porting to ColorSync 2.0 in 2000
- **Estar base news,** Kodak moves to Estar (polyester/Mylar) for all sheet film (roll film still on acetate) in 2000-1
- **Kodak KLI-10200** tri-linear color CCD array released w/ 10,200 7um-pixels over 3"- beyond lens resolution 2001
- **Polaroid** enters Bankruptcy 2001; sold to BankOne 2002; as of 2006, surviving entity only distributing asset
- **Technicolor ends dye-transfer process**, sold to Thompson in 2002
- **RA-4 color print processing technology invented by Kodak,** R, G & B imaging technology is released in 2002
- **Canon 1Ds** (2704x4064, 11 MP) first DSLR recognized with resolution superior to 35 mm film in 2003
- **Kodak KLI-14403** tri-linear color CCD array released w/ 14,404 5um-pixels over 3"- beyond lens resolution 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 in June 2005

2005

- **IRIS printers**, manufacturer owned by Creo, is bought by Kodak in 2005
- **Nash Editions donated IRIS 3047** to SI NMAH, begins using Epson 9600 and Pigmented K3 inks in 2005
- **Epson Stylus R2400 inkjet,** optimized for B&W printing using 3-gray inks CcMmYKkM[atte]K in 2005
- **Fujifilm Crystal Archive Type II** paper released for digital chromogenic RA-4 printers in 2005
- **Kodak** announce discontinuation of B&W printing papers in 2006
- **IRIS printers**, owned by Creo, is bought by Kodak in 2005
- **HP Color LaserJet 1018** was introduced in 2006
- **Multispectral ink technology,** CcMmYyKkR[O]GB & variations, was introduced by Epson HP and Canon, 2006-7
- **31 & 39 MP in H3D-body by Hasselblad** medium format using 27x49 MP sensor at 16-bits, $18K & $25K in 2006-7
- **BetterLight** releases **10K scanback** (10200 x 13600) 416 MP, USB, 14-bit ADC, beyond lens capability, 2007
- **39 MP full array CCD**, Kodak (37x49 mm; 5412x7216; Bayer pattern; 6.8-um pixel) [size of 6K scanback] 2007
- **Biogon 25/2.8 lens** w/mount for Leica M mount, Zeiss claims 400lp/mm in center at f/4, diffraction limit, in 2007
- **Kodak discontinues** 6K, 10K and 14K tri-linear CCD arrays used in scanbacks and hi-end flatbeds in 2007-8
- **Epson Stylus R1900 inkjet** uses CMYyKkR[ed]&O[range] w/ gloss optimizer to create a wider color gamut in 2008
- **Sony 24.81 MP CMOS** 12-bit A-D on chip 6104x4064 active 5.95-um pixels (24x36 mm) 43.3 mm diagonal, 2008
- **Polaroid** (not original Corp) announces discontinuance of instant films (production will end by 2009) in 2008
- **Instant B&W photography has ended** was agreed to by photographers around the world [listservs] June 2008
- **Sony Alpha A900** DSLR, 24.6 MP (6048 x 4032) full frame CMOS for less than $3000, Sept. 2008
- **Canon EOS 5D MKII** lowers price of their 21 MP (5616 x 3744) full frame CMOS,5D MKII, $2700 late-2008
- **ColorSage** is releases by BetterLight**,** first spectral based (380-780nm, 4 nm steps) color workflow tool in 2008
- **Nikon DX3** dSLR full-sized (24 x 36 mm; 6048 x 4032;) 24.5 M at $7100 in late 2008
- **DALSA 33 MP CMOS** (36 x 48 mm; 4992H x 6668V) Bayer pattern in 2008
- **DALSA 48 MP CMOS sensor** (36x48 mm) in late 2008
- **Kodak discontinues** producing Kodachrome after 74 years of production in June 2009, stock gone Fall 2009
- **Kodak Discontinues** EverSmart & Select (5600 ppi) scanners; now: iQSmart, 7.2 -10K ppi, XY-stitch 2009
- **Polaroid** process is being revived by a Dutch-Austrian team in a closed Dutch Polaroid plant, in 2009
- **Sony Alpha A850** DSLR, 24.6 MP (6048 x 4032) full frame CMOS for less than $2000, in late 2009
- **22 to 24.6 MP DSLRs by Nikon, Canon & Sony** w/ full-sized (36x24) CMOS become affordable ($2-3K) in 2009
- **50 & 60 MP in H4D-body by Hasselblad** medium format using 27x49 MP sensor at 16-bits, $27K & $42K in 2009

- **64 GB memory card** ($700) allows the storage of 4-5000 RAW image files in late 2009

2010

- **Océ** making wide-format paper, discontinued LightJet and ink-sets is sold to Canon in 2010
- **Pentax 655D** is released a 40MP 44x22 mm CCD medium format camera (larger pixels w/ less noise) $10K, in 2010
- **Mike Collette** (Dicomed and BetterLight) announces the end of scanning back manufacture at BetterLight, 2011
- **Sigma SD1 Merrill** is released after EQ/Tsunami w/ its Foveon 15x3 = 46 MP, APS-C at 24x16 mm CMOS in 2011
- **Kodak sells Image Sensor Division** to a private equity firm - Platinum Equity, in 2011
- **Sony SLT-A65** is released by Sony for under $1K utilizing its 24.3 MP APS-C (23.5x15.6) CMOS in 2011
- **Kodak discontinues digital cameras,** after early success w/ DCS 4, 5, 6 & 700 series & DCS pro 14n, in 2011
- **Nikon D800** is releases a dSLR with a 36.3 MP full frame (36x24 mm) CMOS, for $3K, in 2012
- **Kodak files for reorganization under Chapter 11 bankruptcy** in early 2012
- **Kodak discontinues Ektachrome Color Reversal** 35-mm slide film (motion picture EKT remains) March 2012

History of Modern Imaging Technology begins with Niépce using the Camera Obscura technology [from a much earlier era] in 1816 to form a silver chloride (AgCl) image on paper; unfortunately, the image wasn't permanent because "fixing" (removing unexposed silver) had not yet been discovered (see Herschel in 1839). Sometime around 1824-26, Niépce made the first permanent photograph [Heliograph] using photo-sensitive bitumen (tar) in oil of lavender on a pewter sheet, while searching for photolithography. The photosensitive tar was hardened by light over 8 hours; the unexposed material was washed away with an aliphatic solvent [oil of Lavender] leaving a crude image on a shiny metal plate. Rejected by the French Royal Society, he deposited it with his colleague Francis Bauer in England in 1827. By 1829 Niépce was working with Daguerre on the Physautotype process using oil of lavender; Niépce died in 1833, unrecognized. The Daguerreotype was invented in 1838/9 France. Daguerreotypes are related to Physautotypes, they also use a shiny metal (silver-coated copper plate) as a light-reflective surface. The silver surface is sensitized using iodine vapor (AgI) just before exposure, then developed-out using mercury vapor and fixed using salt (NaCl) creating a [white] negative image on a bright metal background. Britain became the technological battleground for Daguerre and Fox-Talbot who had developed his paper-based competing technology in 1839 as well.

Herschel [John F.W.] publishes the first viable fixing agent (hyposulphites, "Hypo") for silver salts in 1839; see Wood's 2008 article http: //www.midley.co.uk/midley_pdfs/herschel_14mar1839_wood.pdf. Shortly thereafter in 1839, William Fox-Talbot published his article on the "Photogenic Drawing". He reported on a stable chemical image formed using silver salts on paper, after fixing: generically called a salted-paper print/negative. The history of silver-image-on-paper goes back to Schulze in 1724/7 when he discovers the first photo-sensitive compound, silver nitrate ($AgNO_3$), on the side of a flask exposed to sunlight. Niépce was making silver images on paper as early as 1816; however, without fixing they were unstable to light.

One-of-a-kind photographic images prevailed through the 1840s, when multiple identical images became common using either a salted paper print or an albumen print. Photography remained esoteric and hand-made until the commercial (dry) glass plate negative was introduced about 1878; although [waxed] salted paper negatives were available. The Daguerreotype (1839), Ambrotype (1855) and Ferrotype (1857) remained common through the 1880's. Multiple positive copies from an image could be made using salted paper negatives that were contact printed -- as a Talbotype (1841) or using albumenized paper (1850). The **albumen print** created by Blanquart-Evrard in 1850 http://albumen.conservation-us.org/ made multiple prints from a negative very common. Albumen prints became the first commercial photographic process; they were sold dry in a box. Albumenized paper can still be purchased from the Chicago Albumen Works, now in eastern Massachusetts.

Multiple "Sharp" Prints: With the invention the Collodion Wet Plate process in 1851, the first glass plate negative, made multiple sharp positive images common when printed on albumen paper. By 1878, Kodak brought Gelatin Dry Plates into commercial production; they were sold photosensitive and dry in a box and were faster (more sensitive) than dry collodion, but not faster than handmade wet collodion plates. Glass plates were considered superior to film through 1920-30s by studio photographers and newspaper/publishing technicians (now called prepress) because of their controllability and dimensional stability [and flat]. The last to switch were newspaper printers (not news gathers) who began replacing glass with Kodalith film (thicker and more dimensionally-stable film), in 1931.

Film became a photographic image carrier beginning around 1889 as amateur roll film, a gelatin layer with silver salts on cellulose nitrate base (modern plastic of the era). However the earliest amateur roll film cameras (1884/5) used paper negatives in a roll. Sheet film came into wide use around 1913 by photographers transitioning from glass plates for convenience during WWI news reporting. 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 (1945-91) espionage. Film remained an unchallenged technology through the 1990s. Removing silver to lower manufacturing costs was the major driving technological force at the end, e.g., Kodak T-grain (flat silver particle with greater surface area) was the last major innovation. The principal drawback with film is image noise, often called film grain. Film grain is often assumed to be fundamental film particles, but it's not, film grain is system noise. Fundamental film particles, either (a) silver particles (0.2 - 1 microns) or (b) color dye clouds (≈ 1 to 3 microns) are an order-of-magnitude smaller than film grain, whose size is roughly 10-20 microns.

Film grain is the human visual-system's agglomeration of tens to hundreds of fundamental film elements seen through the thickness of the layers. This system noise creates a signal-to-noise ratio (SNR) of 10:1 for most films. 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 500:1 to 1000:1 made it the next technological step. On the other hand, the use of (a) small digital chips (found in phone-based cameras, point-n-shoot models and less expensive dSLRs with smaller chips) and the use of (b) high ISO (600-3200) film speeds can yield very noisy digital images. These images still have the advantages of portability and web-usefulness, however nasty, they appear.

Film is now historic technology, some twenty-two years after its zenith. It is still used by film aficionados, the motion picture industry and those slow to adopt digital for a variety of reasons. Film is being discontinued. Kodak still finds the manufacture of motion picture film profitable; although it filed Chapter 11 bankruptcy in early 2012. The most popular still color films, Kodachrome and Ektachrome, were recently discontinued. When movie theaters move to digital display, the end of film will follow shortly. Economics will ultimately force film manufactures to discontinue their relatively small runs of still-film formats (used in P-n-S, older SLR and view cameras), in comparison to motion picture film, when motion picture film is discontinued. When this occurs film will become very rare, unless its manufacture is sold or transferred to China.

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, because 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 (see time line below). While cellulose acetate is not flammable, it can degrade faster than its [cellulose] nitrate precursor. This was not widely understood until recently: the 2007 AIC-PMG bi-annual meeting.

Acetic acid vs. nitric acid evolving from historic film base: Fortunately, **acetic acid**, the weak acid the escapes from deteriorating cellulose acetate does not destroy the thin gelatin layer on the film that carries the image layer [has either silver particles or dye clouds]. However, **nitric acid,** the strong acid that evolves from degrading cellulose nitrate film base damages, softens and then utterly destroys [liquefies] the proteins in gelatin.

Despite its assured deterioration in 60-100 years, cellulose acetate film base is used for 90% of all film sold today. Thus, film has inherent vice; it is born with a clock ticking down to failure. Modern triacetate base (1955) is far superior to earlier acetate formulations, so modern film is considered more stable than earlier versions. Acetate base fails by yellowing, curling, shrinking and channeling; the smell of deterioration is vinegar, hence the name Vinegar Syndrome. While heavily channeled and warped acetate base film looks very bad, don't throw it out (cull) degraded acetate film. With effort, the gelatin pellicle (image layer) can be salvaged and scanned. Cellulose nitrate film fails through yellowing, darkening, shrinking, curling physical deterioration of the film, and then, deterioration of the gelatin image layer by the very strong acid deterioration by-product. Nitrate deterioration has been thought to be a more serious problem for many reasons. However, some historic nitrate based film is in better condition today than acetate base film made at a later time. A local collection of 1906 nitrate roll film negatives is still in very good condition a hundred years later. The main problem with the film is that it can s welded together into small bricks, which cannot be salvaged. The strong acid that evolves from the film base, as it deteriorates, liquefies the gelatin image layer creating a brown-ooze material that sticks sheets of film together. Once the gelatin is damaged, the image is lost. This is different for acetate base film, where the gelatin layer remains intact because the deterioration by-product is a weak acid. The gelatin-based image can be salvaged even though the base is highly distorted. Both types of film will continue to degrade outside cold storage; cold storage is the only way to halt deterioration.

Estar base: Starting in the 1960s, Kodak offered some sheet film on a permanent polyester base: Estar (patent bought from DuPont). As of 2001, Kodak uses Estar for all sheet film, but continued using triacetate base for roll film.

Color Imaging Technology: The first color imaging technology was invented by the noted physicist James Clerk Maxwell in 1861. Maxwell used three images photographed using separate additive color filters (red, green and blue). The resulting three B&W transparencies were projected with the same colors of light, recombining into a full color image on a screen. Significant experimentation was conducted for producing the common color print, 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 (1877) color print. 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 this technology stream influenced the 1945 creation of the highly stable Kodak Dye Transfer printing process; unfortunately discontinued about 1994. Pigments are also being used today in permanent inkjet prints. Pigment colorants are in **common use** by Epson, HP and Canon inkjet printers (subtractive CcMmYKk inksets) with very high display and dark storage stability. Some inkjet technologies are unstable to very unstable.

Fading Studies of Digital Printing Technology: Check both WIR (Henry Wilhelm) http://wilhelm-research.com/ and Aardenburg Imaging (Mark McCormick-Goodhart) http:/www. aardenburg-imaging.com/index.html for fading studies on inkjet and photographic prints.

Early color technologies used color-separated B&W negatives that were printed onto film that had the image silver bleached-out and replaced with dyes in a multiple-stage process, such as the 2-color Kodachrome (1914/16) process (not the same Kodachrome released in 1935). Early "all-in-one" color image "capture" technologies that included color dyes in the original were (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. Color image capture took a giant leap forward with the release of the Kodachrome 3-color-subtractive reversal film (positive image) on still and motion picture film in 1935 (discontinued in 2009). Post-1937 Koda-chrome transparency film (K-14) has very high dye stability, with 185 years (yellow) in dark storage. Early color dyes (pre-1938) could be highly unstable, dark 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 notoriously unstable. Kodak is now estimating 250 years (Wilhelm & Bower, 1993) of dye stability in dark storage for their post-1990 Ektachrome E6 films. On the other hand, 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://vitaleart conservation. com/PDF/ cold_storage_v17j.pdf.

Lens history in photography begins about 1816. Early lenses evolved from eyeglasses and telescopes and thus tend to have 1 or 2 elements, with limited ability to focus all colors of light in the same field, softening the resolution of the lens significantly, while also focused in a curved image-plane or field, rather than the flat field of glass plates or digital chips. Focusing in a curved field was desirable for film, but is a critical fault in digital imaging. The noted Chevalier Achromatic lens (1835) used two cemented glass elements made from different glass formulations, to focus blue and red light in the same plane, with green light focused slightly out-of-plane, producing a slight soft-focus image in a curved plane-of-focus. The innovation was to focus the all colors of light the same field or the image plane, be it flat or curved. Daguerre officially adopted the Chevalier lens in 1839; it still gets heavy use in modern systems due to its compactness and simplicity. In the historic era, the design probably delivered about 15-20-lp/mm. Opticians were the first makers of lenses; their designs focus light in a curved field replicating the back of the eye. Very modern lenses [for digital applications] focus in a flat field.

Kingslake (noted lens historian) said: "…it is hard to understand why the development of a good camera lens was such a slow process…, …between 1840 and 1890." By 1841, Petzval designed his 4-element achromatic portrait lens, which became a photographic standard used through middle of the 20th century; it's thought to be capable of 20-30 lp/mm. The Petzval Portrait lens had a long shape due to a large air gap, and thus couldn't be used in amateur cameras that favored the compact Chevalier and Dagor designs. The Petzval lens pushed the use of different glass formulations to further, to improve light handling, but still only for two colors in the field. Otto Schott joined Ernst Abbe and Carl Zeiss (in Zeiss workshop founded 1846) http://www.smecc.org/ziess.htm to produce glass capable of implementing the workshops Apochromatic (famous APO lens) flat-field lens designs that corrected both spherical (shape for 3-colors) and chromatic aberrations (in-filed focus for 2 colors) in 1886; resolutions of 40-50-lp/mm are thought possible. By 1896, the Zeiss workshop developed the Protar and Planar lens designs, which only came into wide use after lens coating was developed 40 years later. Light scattering at the many air-to-glass surfaces (6-elements in 4-groups) was the issue in those formulations. The compact, 3-elements in 1 group, Dagor Anastigmatic (3 colors in the same field) flat-field lens was produced by Goerz (Berlin) in 1904 and it is still being used today in modern Point-n-Shoot & mobile (cell phone) cameras. The design was a significant advance, correcting spherical aberration, coma and astigmatism. It is thought to be capable of 40-60-lp/mm; a 1917 Goerz lens was MFT-tested in 2003 showing a very respectable 55-lp/mm.

20thC [last century] Lens Designs: Also at the turn-of-the-century, 1902, the Tessar design was the next significant advancement in lens development, the 4-element in 3-groups design (Carl Zeiss, at Jena) created higher contrast and thus greater resolution; 40-60-lp/mm is thought possible. The German designers continued to refine lens glass formulations and introduced coatings through WWII, raising lens quality to a very high level -- although the Allies did not share in the coating developments. Single lens coatings were introduced in 1935 Germany. The 1941 Hasselblad HK7 reconnaissance camera (made in Sweden who had access to Zeiss T-coatings) was commissioned by the Allies http://www.hasselblad.com/about-hasselblad/history/a-man-with- small-hands.aspx and was fabled to be better than the captured German equivalent. Film and lenses were strategic war materials facilitating reconnaissance and espionage. These advancements didn't reach the consumer until after the war. Used large-format lenses, which were excellent optics for the era, now pale when compared to their modern multi-coated [digital application] cousins.

Lenses reached a high state of development just prior to WWII with the development of lens coatings, then reached their and penultimate state during 1960s-80s with advanced multiple lens coatings (such as alternating silica and magnesium fluoride) http://en.wikipedia.org/wiki/Anti-reflective_coating. Small format lens makers were early adopters of multi-coatings, while it took through the 1980s for the large format lens makers to implement multi-coatings. The current lens advancements are due to computer design, exotic glass formulations and modern manufacturing techniques.

Computer-aided-design continues to help improve zoom lens designs, which are inherently less sharp (15-25% less) than prime lenses (fixed focal length). Most prime lens designs were developed over 80-110 years ago by the great German designers. Modern prime lenses have advanced in small increments, over those 100-year old designs. The current development cycle emphasizes glass composition (last seen during the late 19^{th}c) and the economical manufacture of exotically-shaped lens elements (computer aided design), using modern precision molding and hybrid processes, rather than the more expensive grinding process, a three centuries old technology.

Street Price is a Rough Indicator of Lens Resolving Power: The cost of a specific lens, within a group, such as the [groups of] either 35mm lenses, 50mm lenses or 85 mm prime lenses, or the ubiquitous 24/28mm-to-70/85mm zoom lens tend to denote its resolution capabilities; see http://photodo.com/ & http://www .dpreview .com/ lensreviews/. For details on lens design and history see http://en. wikipedia.org/wiki/List_of_lens_designs and the excellent book: "*A History of the Photographic Lens*," by Rudolf Kingslake (1989, 345pp).

Camera History: The function of a camera is to hold the lens exactly perpendicular to the film axis. Box cameras do this very well. Folding cameras have the unrecoverable fault of "lens alignment variability," with no way to check alignment when the camera is moved or re-opened. View cameras, used for large format and studio photography, must also be aligned each time either the lens or film standards are moved or even bumped; this is done using the Zig-Align tool. The BetterLight ViewFinder software also has a focus tool that makes "ground-glass" focusing an issue of the past. There is a great deal of camera design and history information online, Google "camera history" or see: http://en.wikipedia.org/wiki/History_of_the_single-lens_reflex_camera, http://www.midley.co.uk/index.htm, http://www.digitaljournalist.org/issue0602/dunleavy.html, http://en.wikipedia .org/wiki/History_of_the_camera, http://www.graflex.org/speed-graphic/graphic-models.html, http://www.box cameras.com/camcolhome.html #Cameras: 1880-1899 , http://www.digicamhistory.com/1970s.html http://www.nwmangum.com/Kodak/FilmHist .html, http://www.kodak.com/global/en/consumer/products/techInfo/aa13/aa13.shtml, http://www.camerapedia.org/wiki/Kodak ; http://www.ndsu.nodak.edu/instruct/rcollins /242photojournalism/historyofphotography.html and http://www.nikonweb.com/files/DCS_Story.pdf.

Digital imaging began in 1969 when the CCD was invented by Willard Boyle and George Smith at Bell Labs <http://www.nobelprize.org/nobel_prizes/physics/laureates/2009/smith_lecture.pdf**>**. An oscilloscope display was the first [8-bit] imager used by the 50-pixel Boyle & Smith CCD. This CCD was the next step is the continual improvement of imaging with light. Where electronic imaging counts the number light photons falling directly onto a chip [CCD or CMOS] focused through a lens, to produce an image directly from light with no intervening [chemical] steps.

The first commercial digital cameras were introduced about 1981-84 (Sony Mavica 0.79 MP B&W & Canon RC-701 color 0.40 MP), they were generally used by news photographers. By 1987-88, the leading edge of news photographers (USA Today and AP) began using digital images transmitted over telephone lines. Ten years later, 85% of press photographers said digital imaging technology was indispensable. The banner year for digital was 1991 when high-resolution cameras were introduced for: (a) news gathering (1.3 MP Kodak DSC DC3 w/F3 body); (b) studio photography for catalog production with the Leaf 2k 3-shot "Brick" and (c) product photography using the Dicomed 6K scanback (later became BetterLight Model 6000 for view cameras). Twenty years later, prices continue to decrease as quality and capacity increase. In the future, imaging will migrate to newer technology that is unknown today.

Lenses are the limiting factor in the current stage of advancement within imaging technology. High-end commercial digital sensors are sold that have finer detail than the capabilities of current lenses (high performance military lenses and spy systems are excluded). The best over-the-counter lenses are few and far between, Chris Perez has measured http://www.hevanet.com/cperez/MF_testing.html only one medium format lens, out of 30+, with a center resolution of 120-lp/mm at f11. Some of Canon's best prime lenses have been measured by Lars Kjellberg http://www.photodo.com/browse-lenses, to deliver 90-lp/mm (center) at f8 for the 200-mm f1.8 EF USM (the highest rated lens on ht photodo.com website); the 96-lp/mm at f8 for the center of a 135-mm EF f2 USM; and the 96-lp/mm at f8 for the center of a 50-mm Macro EFf1.4 USM. Thus, some of the best lenses available can only perform at about 100-lp/mm. These lenses will support sensors capable of 5080-ppi with 5-um pixels size.

Digital vs. Film – Basics: Digital sensors have one picture element for each piece of image information; chemical systems use several minute overlapping particles (silver or dye clouds) to create an image with finite detail limited by system noise. Digital systems have an order-of-magnitude less (10x less) image noise, when used as recommended. The final advantage is that press and commercial photographers can store hundreds of images on a memory device, while film is limited to 36-per-roll, or, one sheet film negative at a time.

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

The digital image technological path began with the transistor invented in 1947; the integrated circuit (IC chip) was developed in 1958; this lead to Boyle & Smith developing the charged coupled device (CCD) at Bell Labs in 1969, where the digital image 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, in line. A chip's exposure time could be varied 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, dSLR, with interchangeable lenses and storage on 2"-floppy-disks.

Digital was found to be the equivalent of film in the early 1990s. 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 a 3-color wheel in 1992 as a digital back for a view camera. **Stephen Johnson** (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-pixel 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 R, G & B 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; Bayer pattern) was acknowledged capable of producing digital images equivalent to 35-mm film.

Bayer Pattern Enables the Array Chip yet Degrades Image Quality: Most dSLR cameras use a **Bayer Pattern** of color dyes (BG-GR) over their full array of pixels, producing image data with diminished resolution because it spreads the RGB-data over 4-pixels. Scanback cameras and flatbed scanners have unique RGB data for each image pixel; this is a superior technology compared to arrays with a color-filter pattern.

Foveon [technology] was licensed to Sigma [camera & lens manufacturer] produced a 3-layer 4.7 MP (called 15 MP) dSLR camera (SD14/15, $1000, 2006) that shows equivalent image resolution to Canon dSLRs with 12-15-18 MP images made using Bayer pattern sensor. Sigma has made some fairly poor quality third-party lenses, but the camera clearly out performs the best of the Bayer pattern competition; this is best determined by examining comparable images made with the cameras on dpreview. They released the Sigma SD1 ($6900-8000) in 2010, its a 3-layer, 15.4 MP (they claim 46 MP) Foveon sensor camera, with individual R, G & B pixels stacked on each other producing a full set of RGB values for each individual pixel, similar to a flatbed scanner or a scanback (BetterLight). This could be a candidate for the “second best camera” after the BetterLight 8K scanback (85/254 MP at $18K) which will be discontinued when their supply of 8K Kodak tri-linear array chips are exhausted.

Digital vs. Film the Argument Continues: Digital imaging is now capable of recording spatial and color information at low noise, well beyond the limits of even most lenses. However, not all digital imaging meets this standard. Digital technology offers imaging with no intervening technologies to distort the color information such as film dyes, dye couplers or processing. In addition, there is no deterioration of the film base and dyes over time. Any 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 [normally] high contrast differences (small detail) always found in premium digital systems where noise is about 500:1. Neither observation is universally accepted; passionate arguments are ongoing.

Remastering a Film Collection: Easy online access to a collection of images can show its value to funders, and thus, drive the preservation process via 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. The issue of capture resolution: weather to capture at low resolution for on-line access or high-resolution for migration into the digital domain, is best addressed on a case-by-case basis. Cold storage will halt dye and film base deterioration; this allows for the development of remastering project funding at the pace common to grant-funded projects (slow).

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 of the high-end flatbed scanners and scanbacks. Image capture, using automated functions, can easily compromise digital images permanently. Although the “automated “functions that make digital imaging easier for the inexperienced, remove control from the experienced operator and can alter the fundamental image data captured by the sensor (CCD) 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 “automated” functions.

Add a well-known photographic target into each frame of images used for documentation or remastering. The photographic target market has exploded. It began with the GretagMacbeth, now called x-Rite, Classic Mini ColorChecker, 24-patches with 6 gray, was $60, its but discontinued; the x-Rite Passport (3-in-1, includes mini-CC) for $100 with free camera DNG-profile software; QPcard’s 203 Book is a less expensive “Passport” in a cardboard wallet ($50) with free camera profile software; SpyderCheckr is also a “Passport” type device at 4-times the size for $140; AIC’s PhD [PhotoDocumentation] target, 3 sizes: ,small $75, medium $100 & large $150; and Stouffers calibrated B&W 12- or 37-step reflective scanner targets for $25 to $35. B&W transparency targets are used for scanning negatives or transparencies, they include the Kodak No1A (transparent B&W 11-step wedge) available again in a 14-step configuration or the Stouffer B&W transmission step wedges http://www.stouffer.net/ TransPage.htm sold in a wide range of step-counts and step-widths, from $25 to $75. Robin Myers has measured many of the modern (and older too) targets in his Spectral Library http://www.rmimaging.com/spectral_library /library_index.html.

Storage of Digital Files: 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 the preservation format for documents with both text & digital images.

Digital images can be stored indefinitely without deterioration, however, they can be lost swiftly through the 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 5-7-10 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 (no phthalocyanine dye) is still not available and thus DVD+/-R is not considered reliable.

Compression of an image file diminishes the potential of the numerical image data by throwing data away to save space or improve download speed. If the original image data is not as important as the space it occupies, or, the speed of download or speed of movement within a network, compression could be used. Compression should not be the default option; use only when it is necessary. Some compression formats may not be available in the future.

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) and 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 from equating the old JPEG name with the new JPEG2000 format. Free J2K plug-ins for Adobe Photoshop found online; Adobe CS4 Photoshop Extended includes support for JPEG2000.

Curators, archivist, preservation providers and users are rethinking 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. And, they are indistinguishable from the original. Digital files are continually migrated to larger (newer) storage media that are as perfect as the original. Migration of digital files is perpetual. Digital files cannot be tucked away and forgotten in benign storage environments (CD-R), as was done in the past with physical artifacts. Digital collections must be actively managed, as are, computers and networks. The good news is that most digital collections don't require the physical space or energy that is needed to keep physical artifacts stable over decades and centuries. After physical artifacts are migrated to digital, the physical artifacts still need to be stored in an archival manner. The use of cold storage is compact; with a good imagebase and location records, images can be retrieved when required.

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.

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

New technology introduced by digital imaging has allowed very accurate measurement of color in materials and artworks. This color measurement capability has also made it possible to make very color accurate digital images that can be used to document fading and the small changes found in paper and photography conservation treatments.

Use the publication "***The AIC Guide to Digital Photography and Conservation Documentation***" *by* Jeffrey Warda (editor), Franziska Frey, Dawn Heller, Dan Kushel, Timothy Vitale and Gawain Weaver. 2011. 223 pp with 150+ ill., found at Amazon.com ($80) to create color images that have the best possible color accuracy. Using ICC/ICM/DNG input and an output profiles is required, as is, a calibrated and profiled monitor. Most digital cameras (including the BetterLight scanback, most medium-format systems and even some flatbed scanners) output in the RAW/DNG format that use a digital file development module (or stand-alone software) such as Adobe Camera Raw in Photoshop & Adobe Lightroom, Apple Aperture, Bibble and DxO Optics Pro, along with DNG profiles to open and develop digital images. ICC profiles are used for the output of the image, such as inkjet printers and monitors. Most current general profiling packages (such as i1Profiler, free with i1Pro/Pro2, don't produce camera profiles, but still make monitor and printer profiles. Camera profiles (today) are generally made by "color target with software" systems such as XRite Passport ($100), QpCard 203 ($50) and Datacolor SpyderCheckr ($110); the software is generally free with the package of targets.

[**NOTE:** ICC is the generic color management protocol, generally used in Apple systems, defined by a color consortium with extensive standards; ICM is the version used for Windows OS; as of today, there is no color management on iPhone, iPad or other mobile OS formats. ICC created in 1993/4 is the Internal Color Consortium at http://color.org/index.xalter. ICM was created in 1997 is the Image Color Management protocol <http://en.wikipedia.org/wiki/Color_management>

DNG is the Digital NeGative image format <> related to the RAW format; DNG profile are different from ICC/ICM profiles and cannot be used interchangeably as they can.]

Measuring color has become very easy and economical in the digital age. In the past one used (a) the Munsell color patch books ($1-2K) and a good eye or (b) a spectrophotometer costing between $6K (Minolta portable) to $30K (benchtop scientific instrument with variable in/out angles and spectral include/exclude for measurements of high texture samples). Munsell Color http://munsellstore .com/ publishes 1600-patch books of standard color patches ($945 ea. matte or gloss, not both together). The glossy swatch book samples rest in pockets so they can be pulled out and laid on an artifact for color matching. One reports the color patch number from before and after fading; use the same light source for all visual measurements; operator skill varies; software for conversion to Lab and XYZ can be purchased for under $20. Bruce Lindbloom has an excellent online CIE Color Calculator http://www.brucelindbloom.com/ and valuable information on Lab and XYZ (foundation space) color. X-Rite has a visual color test online, FM100 Hue Test, http://www.xrite.com/ custom_page.aspx Page ID=77&Lang=en.

Definitive color measurement method [for under $1K] is to measure the color using a handheld spectrophotometer [**X-Rite i1-Pro** attached to a computer via USB] and report the data as either (a) RGB numbers within a specific Color Space such as <Adobe RGB 1998> or <sRGB>, or, as (b) Lab color numbers (L*a*b*), a color space with an internal standard so it's values are color space independent. The X-Rite i1-Pro is a 45°/0° handheld spectrophoto-meter ($995) with an internal incandescent, 2850°K, light source [smooth and featureless spectra, but a little heavy on the red end of the visible spectrum] corrected in the i1-Pro firmware.

XRite i1Pro2, the brand new (4/13/2012 for $1600-1900) <http://www.luminous-landscape.com/reviews/accessories/eye_one _pro_ii.shtml> spectrophotometer has a new lighting system with a UV-LED (along with the tungsten source) to produce analysis lighting with a larger UV component capable of measuring OBA (optical brightening agents) found in many inkjet papers, using the M0, M1 & M2 conditions for making profiles which are more accurate. However, since humans can't see UV light, but machines can, the most accurate protocol is yet to be determined. ICC has yet to define a technology to emulate human vision. As simple as that sounds, the basic work done in 1931 for the tristimulus [CIE] **XYZ** protocol.

SpectraShop v4 ($95) created and distributed by Robin Myers http://www .rmimaging.com/ is used to make color measurements and to calculate and demonstrate the difference between other [spectral] color measurements or with known standard spectra from the RMI Spectral Library. Most spectrophotometers are supported; with limited indirect support for the ColorMunki. The entry level version of the software is free, including the online Spectral Library [of real materials and color standards]. There are other software tools (see CT&A on the BabelColor website) for making and analyzing spot measurement, but without a library of spectra for comparison.

X-Rite ColorMunki is a $450 spectrophotometer with an internal LED light source [truncated visual-light spectrum with wide spikes]. The ColorMunki Photo ColorPicker (spot measurement software) can be used to make spot measurements in Lab [color space] or sRGB (no way to change the internal color space). ColorMunki measurements can be exported in the "comma delimited columns" format, which can be opened in MS Excel or Apple Numbers; this format can also be imported into SpectraShop and BabelColor CT&A, for comparison to other i1-Pro measured spot colors, or, the color standards found in the RMI Spectral Library. X-rite is not yet distributing a ColorMunki SDK, so third-party code-writers cannot add the device to their color measurement and analysis applications.

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[13,900 words – it just keeps getting longer]

Tim Vitale

Paper & Photography Conservator
Digital Facsimiles & Digital Image Restoration
Oriental Screens & Scrolls in the Western Manner
Video & Audio Cassette Remastering to Digital
Remastering Still Film to Digital [degraded too]
Archive & Collection Surveys
Video & Film Surveys
Preservation & Imaging Consulting

510-594-8277
Fax 510-891-1602
tjvitale@ix.netcom.com

Vitale Art Conservation
2407 Telegraph Avenue #312
Oakland, CA 94612

See: http://vitaleartconservation.com
Albumen Photography Website in 2000 http://albumen.conservation-us.org
VideoPreservation Website in 2007 http://videopreservation.conservation-us.org