Photogrammetry

Historical Evolution of Photogrammetry

Historical Evolution of Photogrammetry

The developments in photogrammetry, from around 1850, have followed four development cycles.
Each of these periods extended about fifty years. These cycles include:

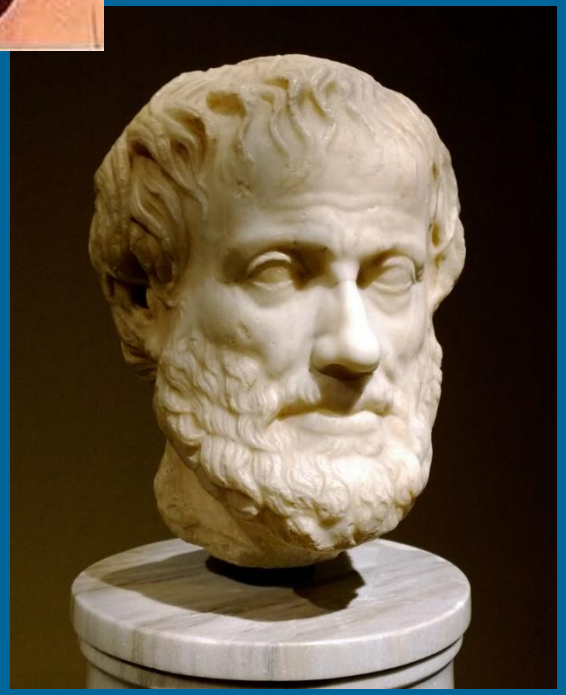
(a) Plane table photogrammetry, from about 1850 to 1900,

(b) Analog photogrammetry, from about 1900 to 1960,

(c) Analytical photogrammetry, from about 1960 to 2010,

(d) Digital photogrammetry, which just began to be a presence in the photogrammetric industry.

Early developements

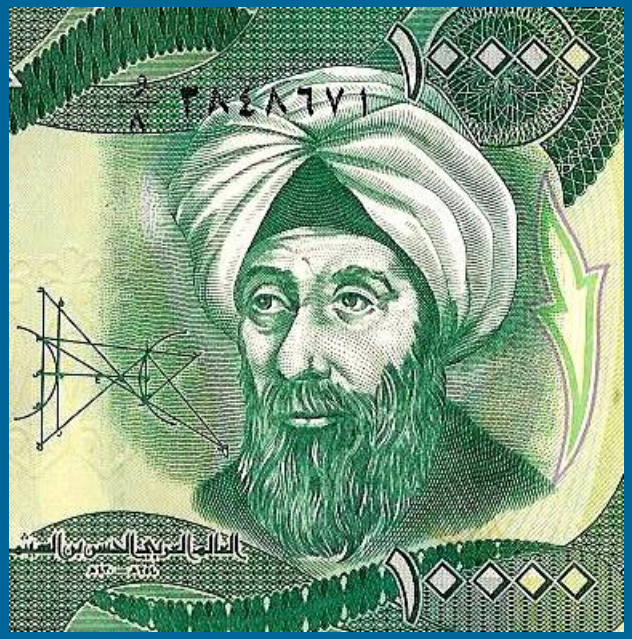


There were a number of discoveries long before the first photographs were made. First there was the Chinese philosopher Mo Ti and Greek Mathematicians Aristotle and Euclid who described the idea of a pinhole camera that projected light and image.

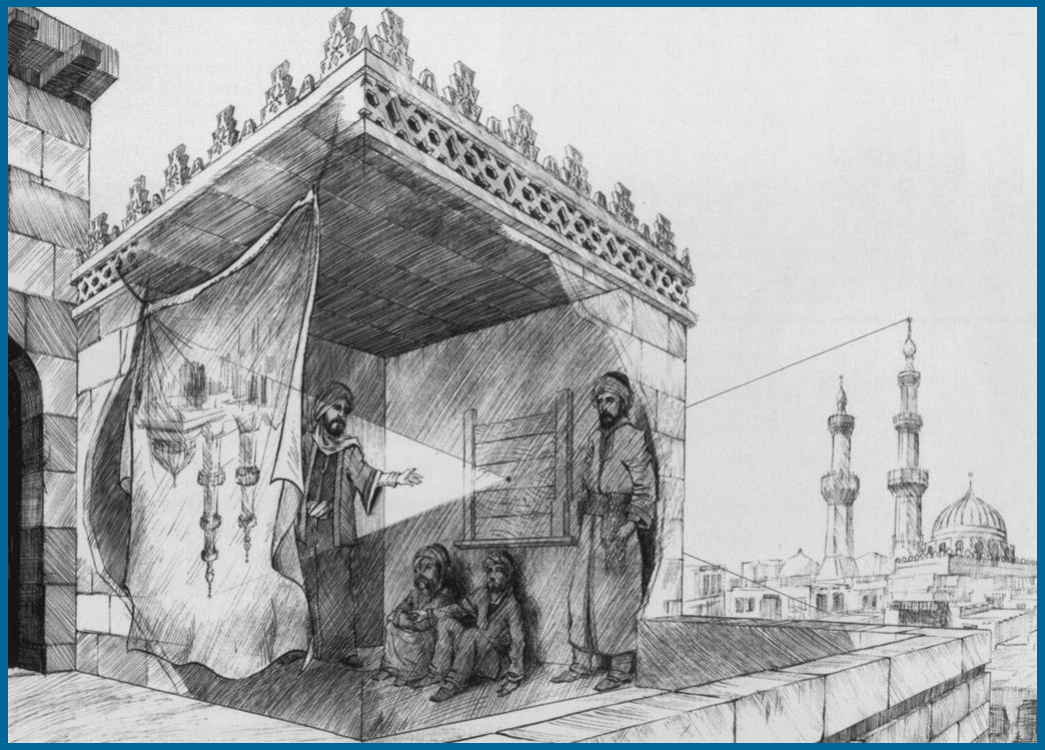
Aristotle makes practical use of the principles of a pinhole camera by observing the sun during a partial solar eclispse by using gaps between leaves of tree and holes in a sieve.

In the 6th Century, this device was later used in experiments and finally coined the “camera obscura” in 1604 by Johannes Kepler.

Early developements

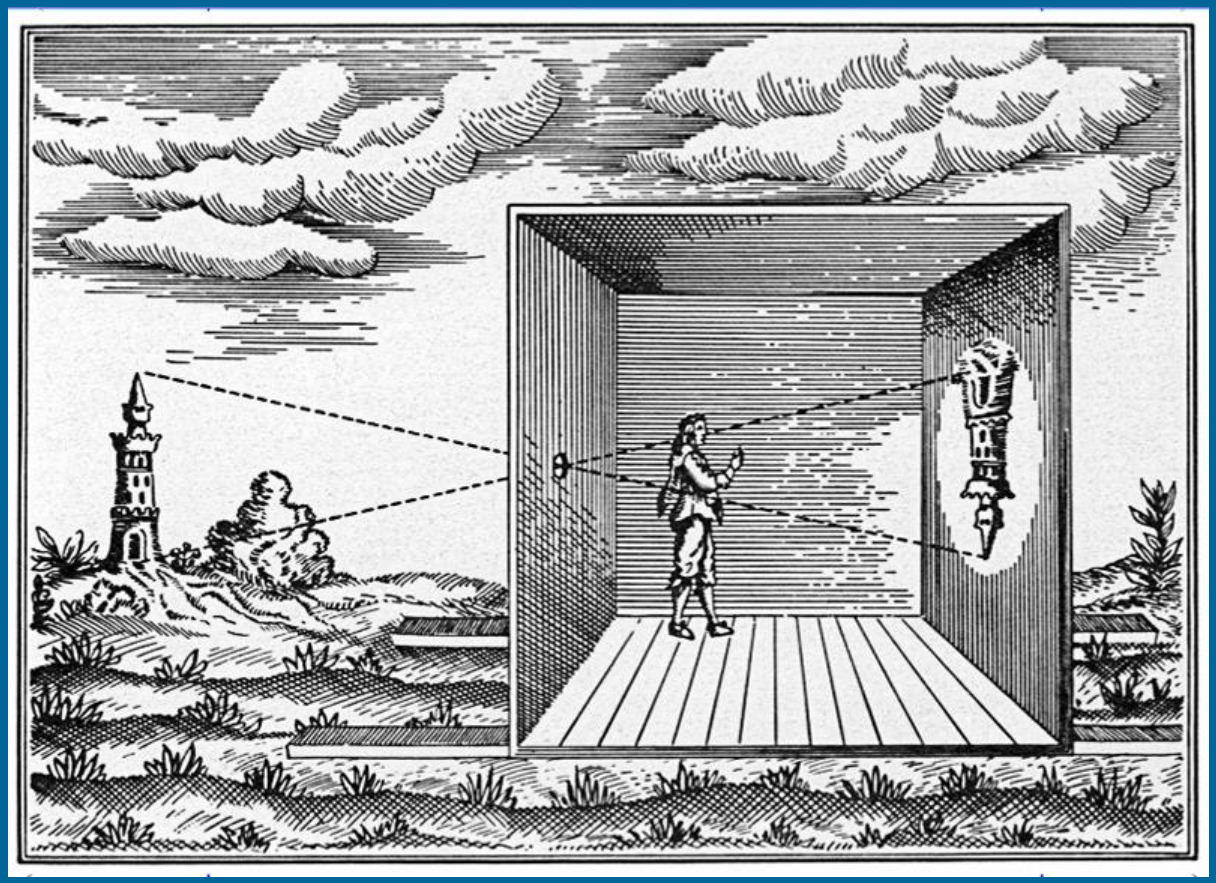


1038: AD - Al Hazen of Basra is credited with the explanation of the principle of the camera obscura. Al-Haitham, known in the West as Alhazen, is considered as the father of modern optics.

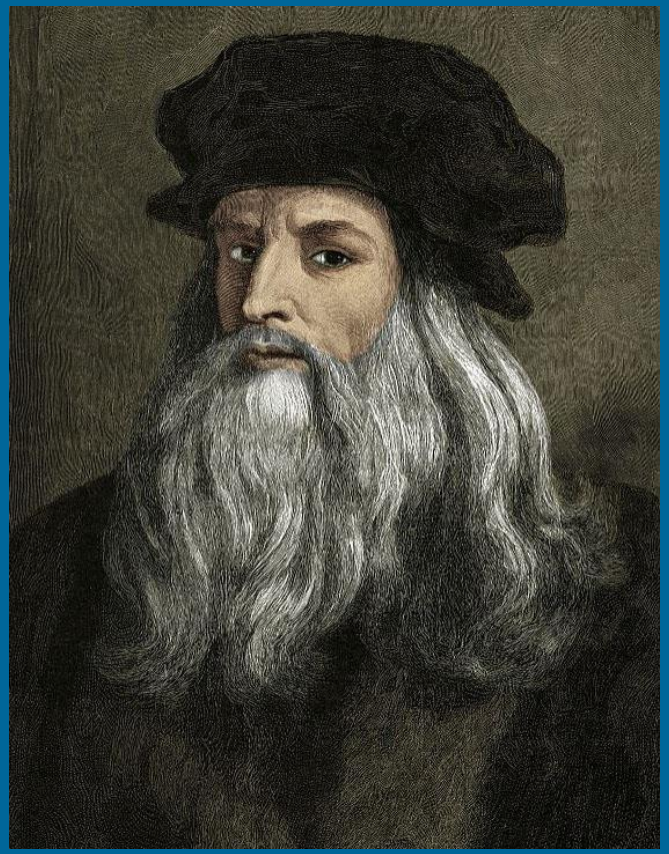


Early developements

1267: Roger Bacon uses the principle of the camera obscura to study solar eclipses without damaging the eyes.



Early developements



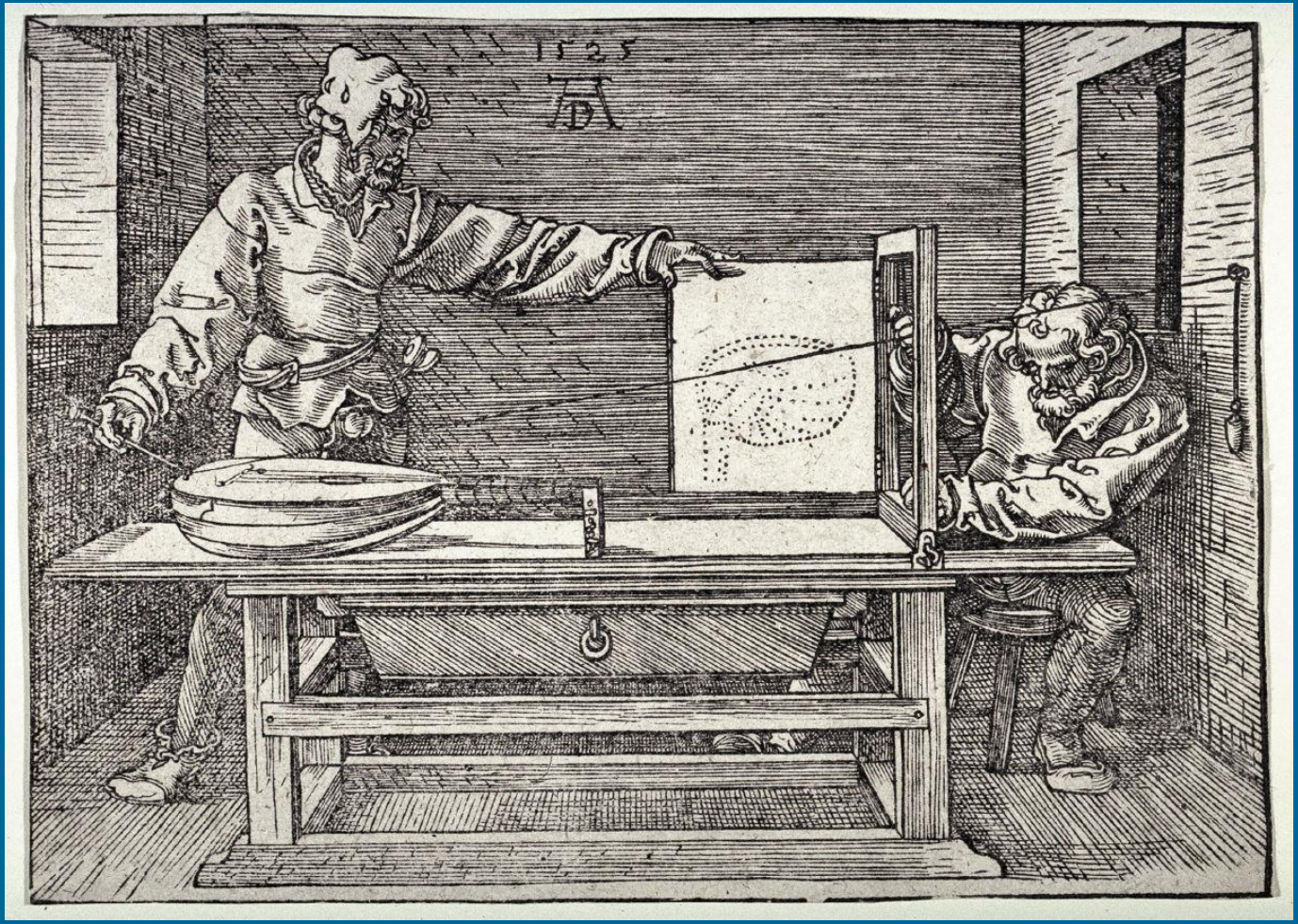
In 1480, Leonardo da Vinci wrote the following:

“Perspective is nothing else than the seeing of an object behind a sheet of glass, smooth and quite transparent, on the surface of which all the things may be marked that are behind this glass”.

In 1492 he began working with perspective and central projections with his invention of the Magic Lantern, although there is no evidence that he actually built a working model and some claim the device actually dates back to the early Greeks.

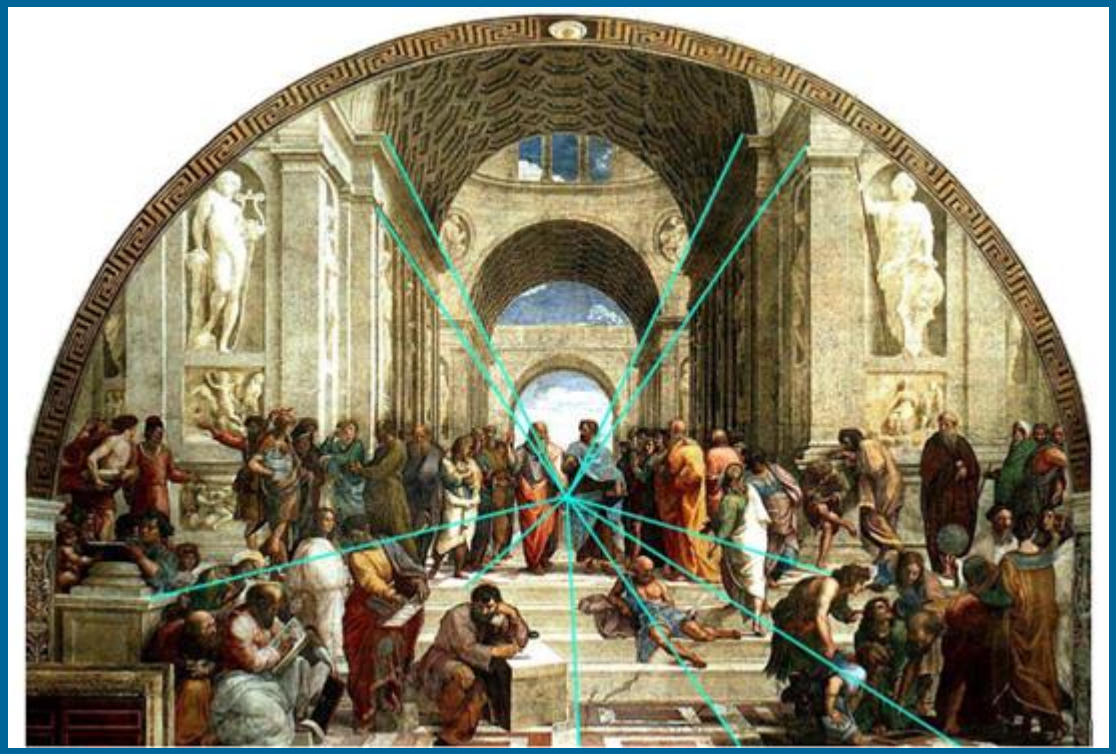
Early developements

Albrecht Dürer, in 1525, using the laws of perspective, created an instrument that could be used to create a true perspective drawing



Early developements

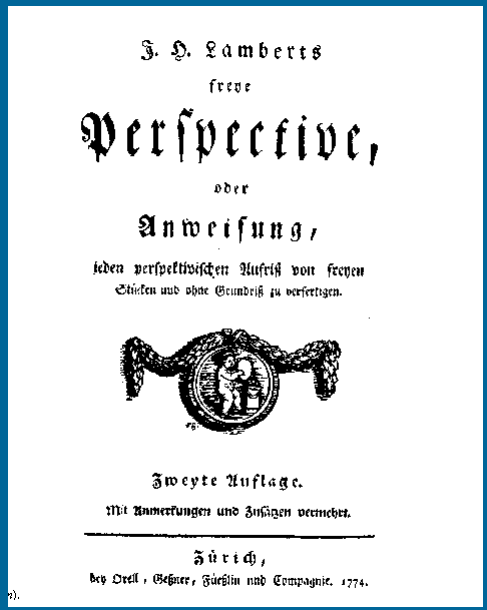
Girard Desargues (1591-1661) founds projective geometry in 1625



Early developements

In 1759, Johan Heinrich Lambert, in a treatise "Perspectiva Liber" (The Free Perspective), developed the mathematical principles of a perspective image using space resection to find a point in space from which a picture is made.

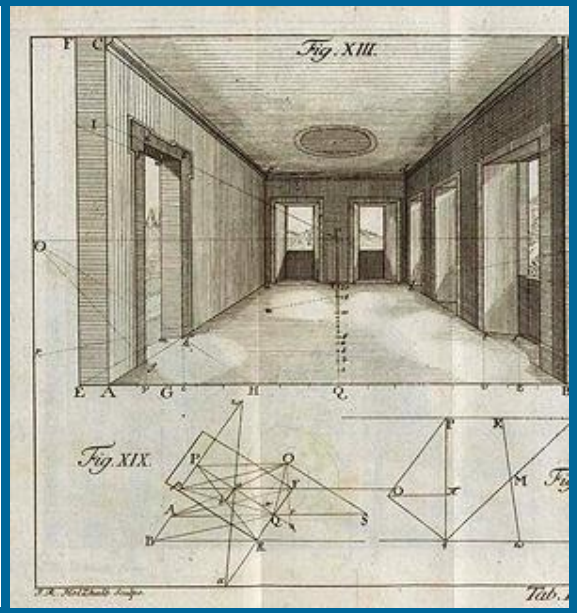
The relationship between projective geometry and photogrammetry was first developed by R. Sturms and Guido Hauck in Germany in 1883.

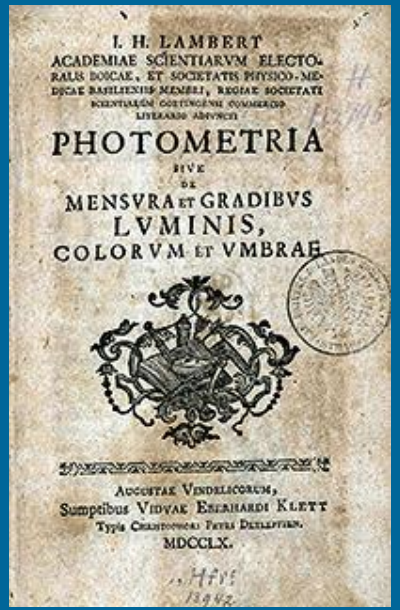


J. H. Lamberts
freye
Perspective,
oder
Anweisung,
jeden perspektivischen Aufriß von freyen Stücken und ohne Grundriß zu verfertigen.

Zweyte Auflage.
Mit Anmerkungen und Zusätzen vermehrt.

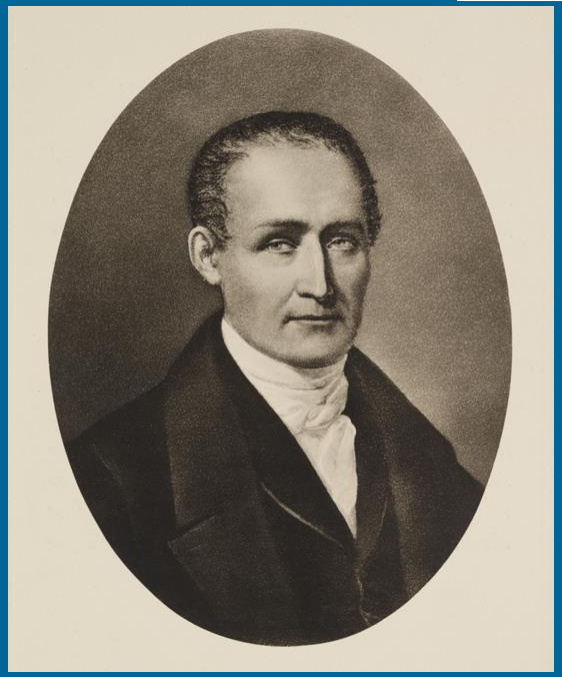
Zürich,
bey Orell, Geßner, Füeßlin und Compagnie. 1774.





I. H. LAMBERT
ACADEMIAE SCIENTIARVM ELECTORALIS BOICAE, ET SOCIETATIS PHYSICO-MEDICAE BASILIENSIS MEMBRI, REGIAE SOCIETATI SCIENTIARVM GOTTINGENSI CONSCRIPTI
PHOTOMETRIA
SIVE
DE
MENSVRA ET GRADIBVS
LVMINIS,
COLORVM ET VMBRAE
AUGUSTAE VINDELICORUM,
Sumptibus Viduae Eberhardi Klett
Typis Christophori Petri Detleffsen.
MDCCLX.

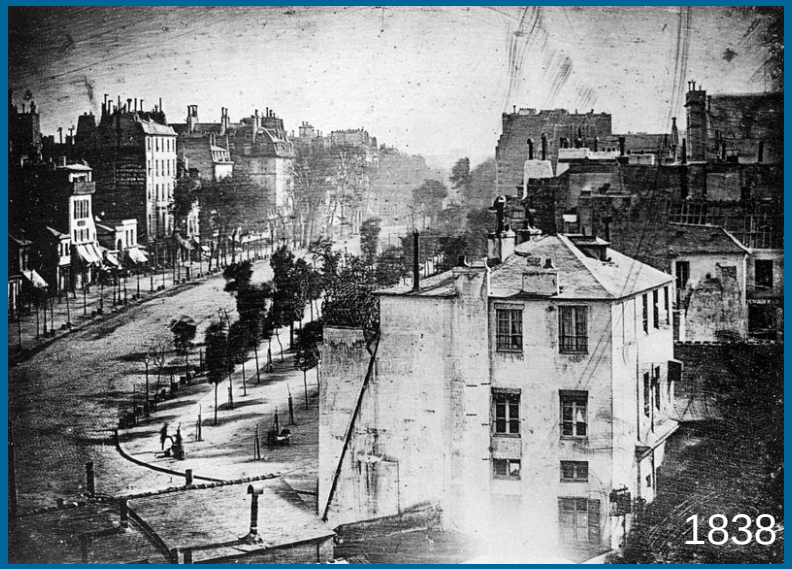
Early developements



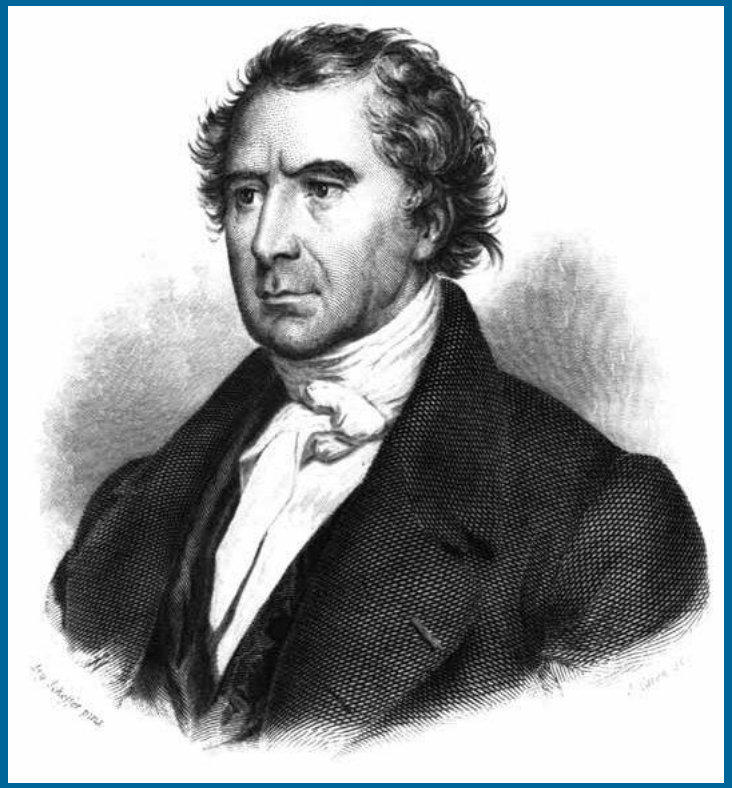
The first photograph was obtained by Joseph Nicephone Niépce (1765-1833). The positive image of Niépce required an eight-hour exposure.

Early developements

In 1837, Jacques Mandé Daguerre obtained the first "practical“ photograph using a process called the Daguerreotype.



Early developements

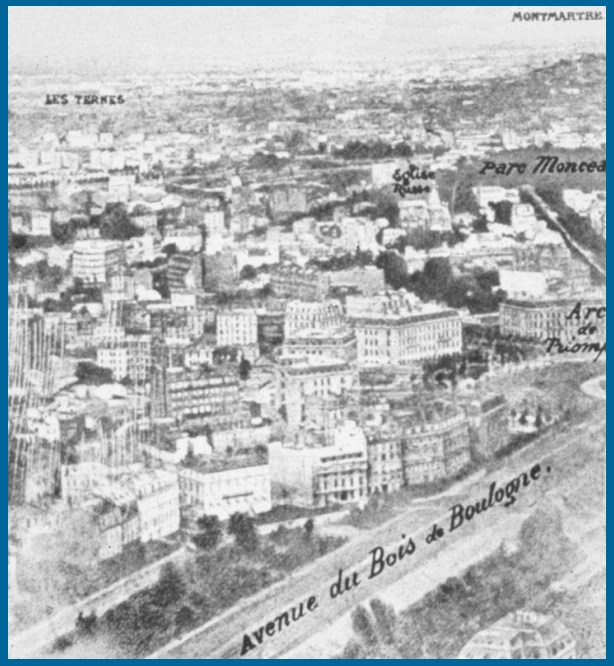


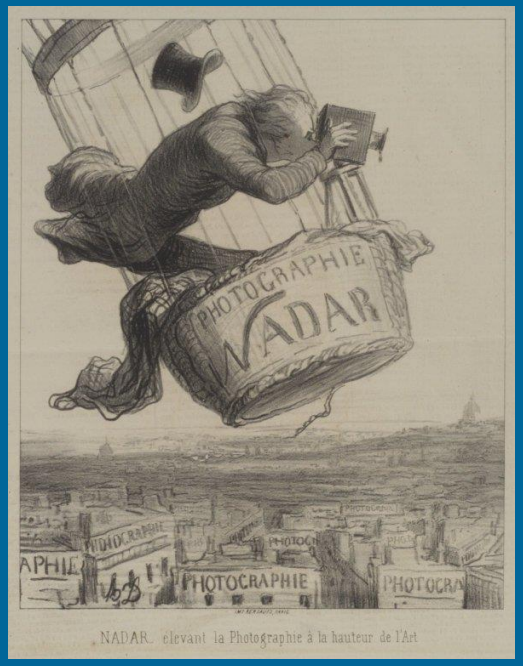
Around 1840, the French geodesist Dominique François Jean Arago began to advocate the use of "photogrammetry", using the daguerreotype, in front of the French Arts and Science Academy.

Early developements

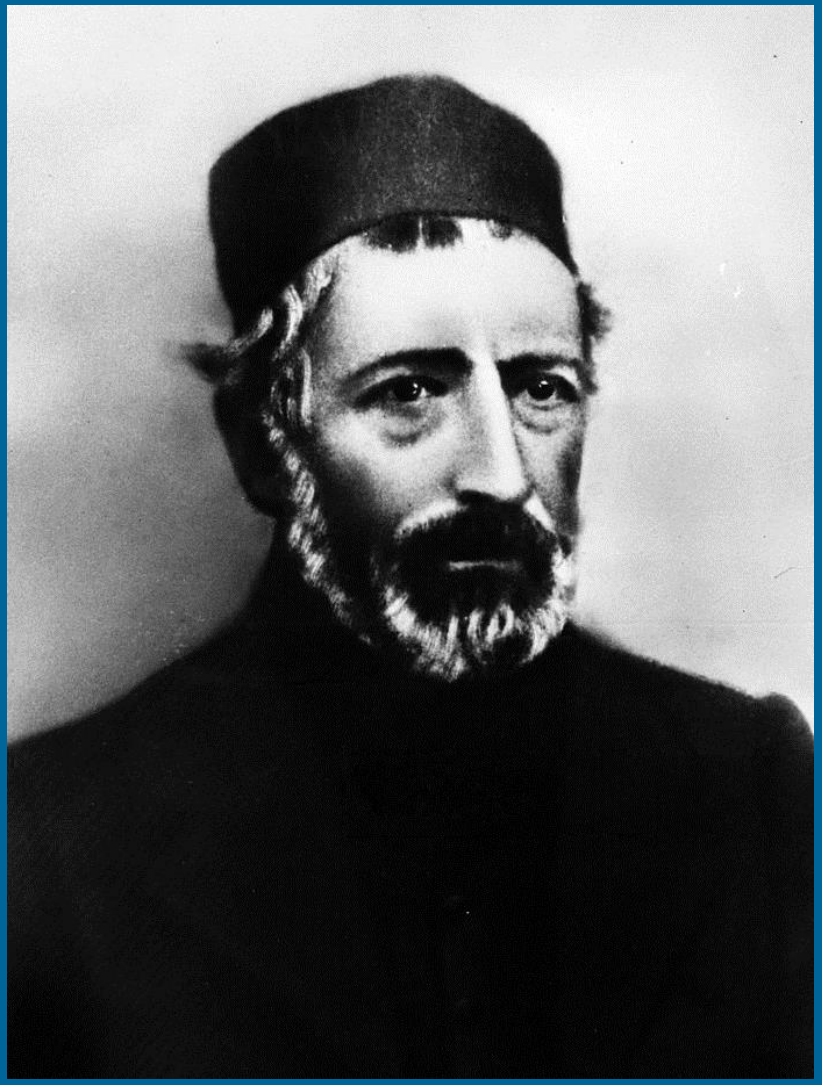
In 1855, Nadar (Gaspard Felix Tournachon) used a balloon at 80-meters to obtain the first aerial photograph.

In 1859 the Emperor Napoleon ordered Nadir to obtain reconnaissance photography in preparation of the Battle of Solferino.



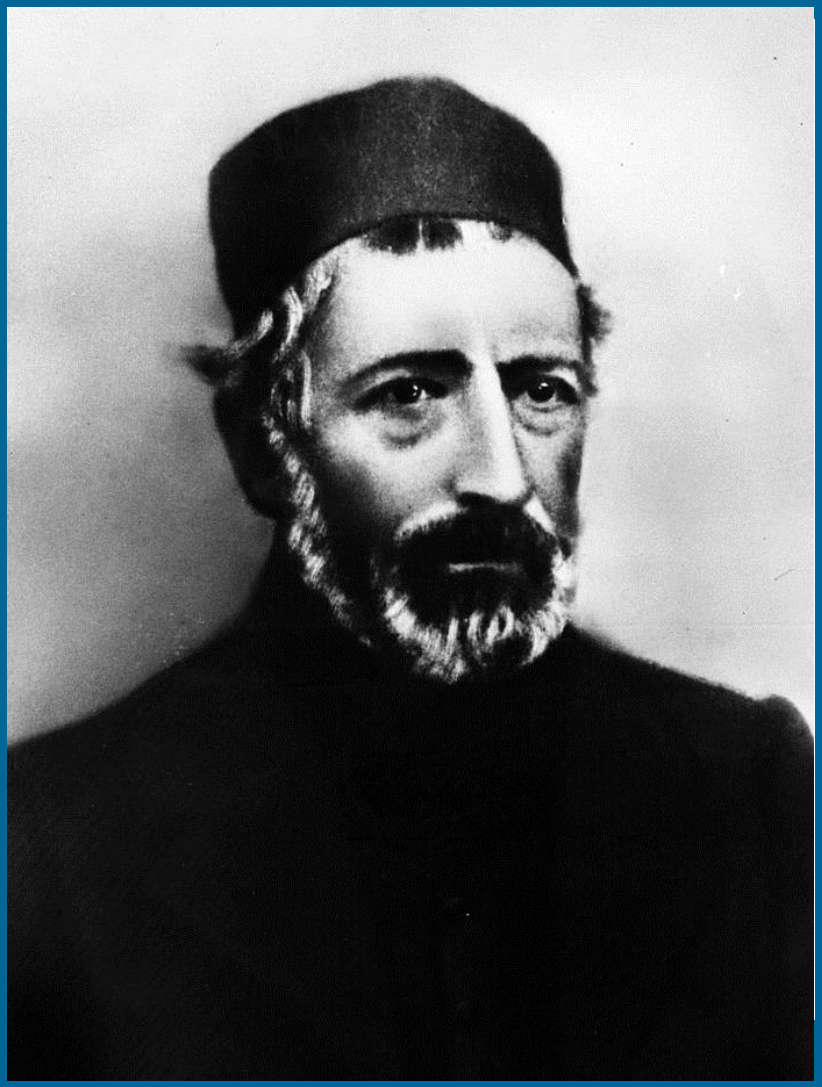


Early developements



Paulo Ignazio Pietro Porro (1801–1875) was an Italian geodesist and optical engineer.
As a geodesist, he invented the first tacheometer (his instrument was called a tachymeter) in 1839. In 1847 he was able to improve image quality of a lens system all the way to the edges by using three asymmetrical lens elements. He also developed an erecting lens imaging system in 1854.
Porro developed a panoramic camera in 1858 that was equipped with a sighting telescope, compass, and level. The image was recorded on sensitized paper mounted on a cylinder.

Early developements



In 1865 Porro designed the photogoniometer. This development is significant in photogrammetry because of its application in removing lens distortion. His approach was to look at the image with a telescope through the camera lens.

This concept was also independently considered by Carl Koppe (1884-1910). Therefore, this concept is called the Porro-Koppe Principle.

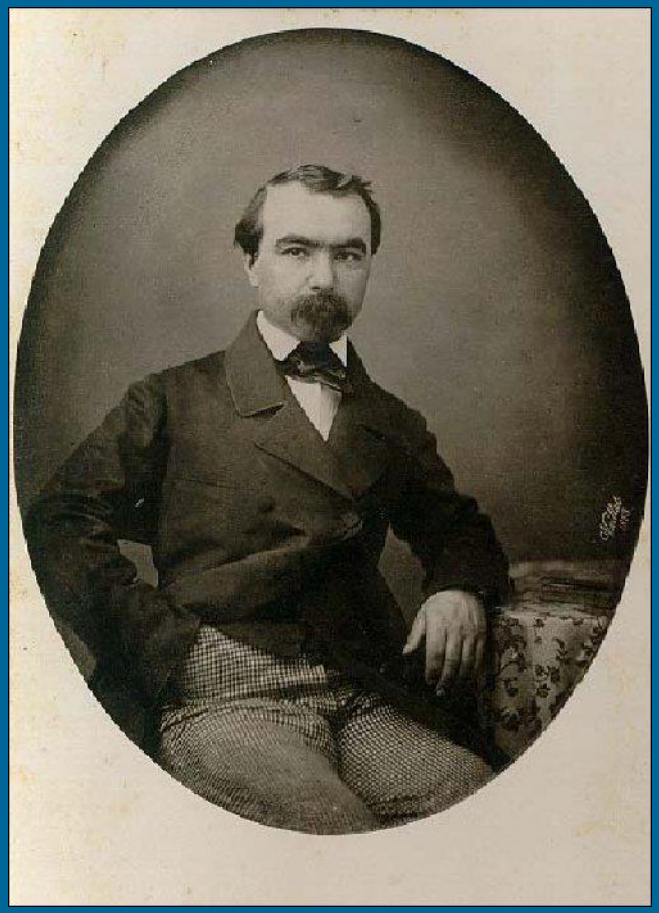
Early developements

The English meteorologist E. D. Archibald was among the first to take successful photographs from kites in 1882.
In France M. Arthur Batut took an aerial photographs using a kite, over Labruguiere, France, in May 1888.

Early developements

P. Moëssard, a French military engineer, in 1884, developed a “cylindrographe” that was also used for mapping purposes.

Early developements



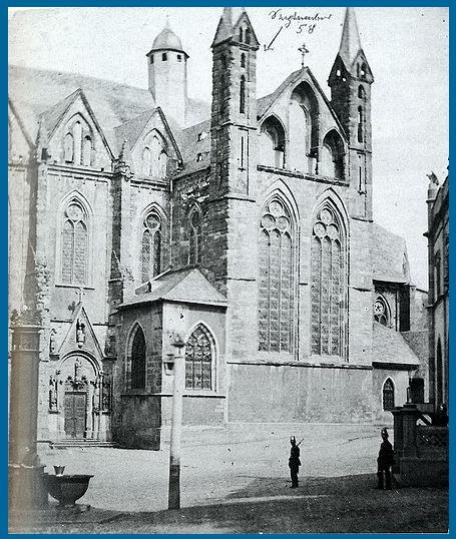
Aimé Laussedat (1819-1907)

Aimé Laussedat (1819-1907) was the first person to use terrestrial photographs for topographic map compilation in 1849.

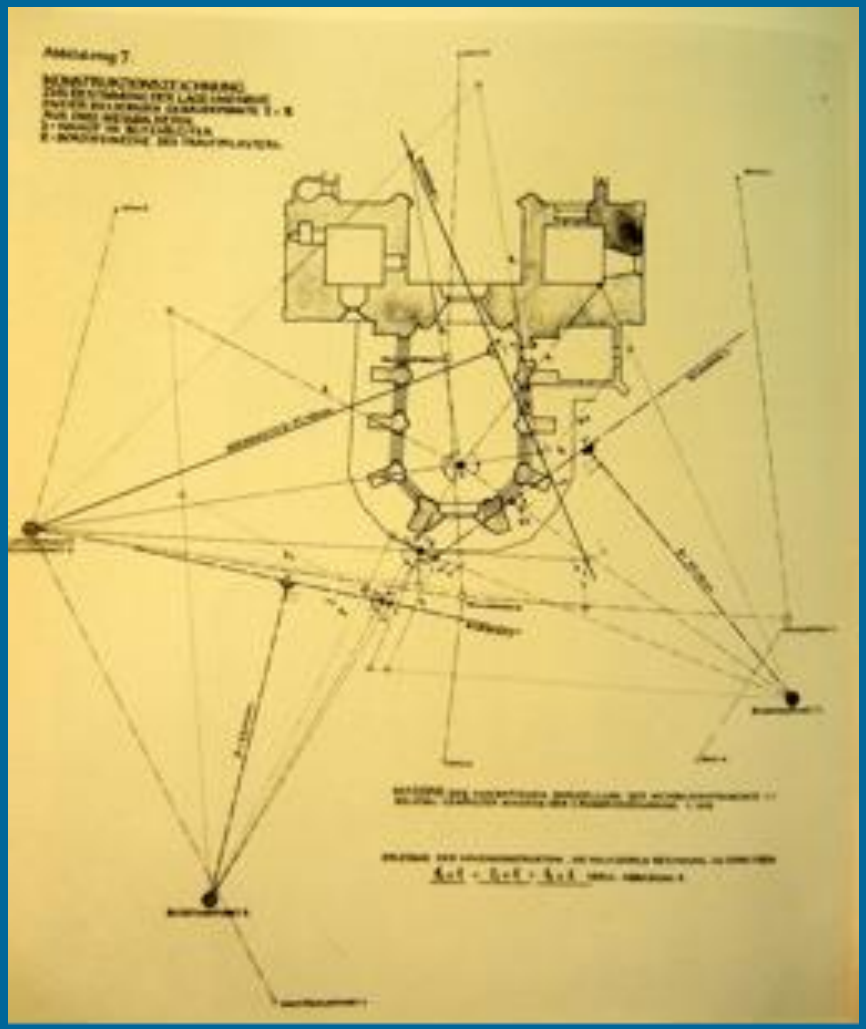
Early developements

Albrecht Meydenbauer (1834-1921)

In 1893, Dr. Albrecht Meydenbauer (1834-1921) was the first person to use the term "photogrammetry".

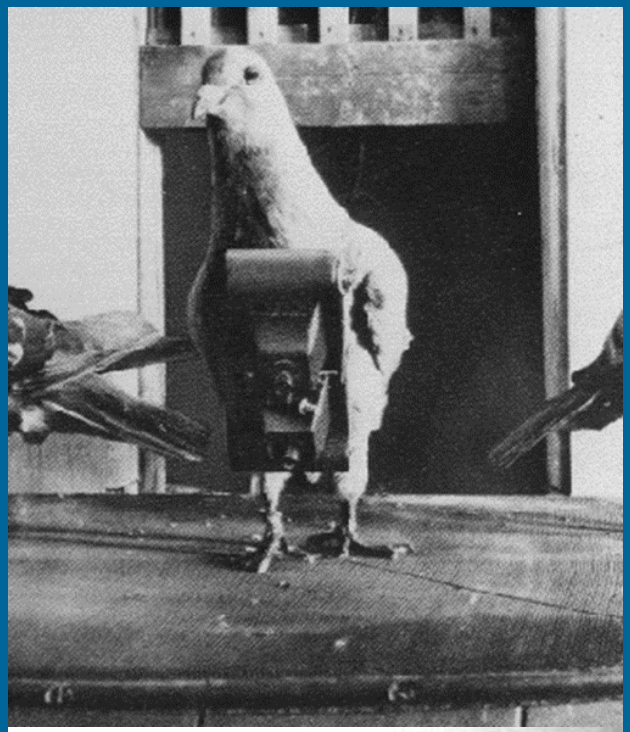


Early developements

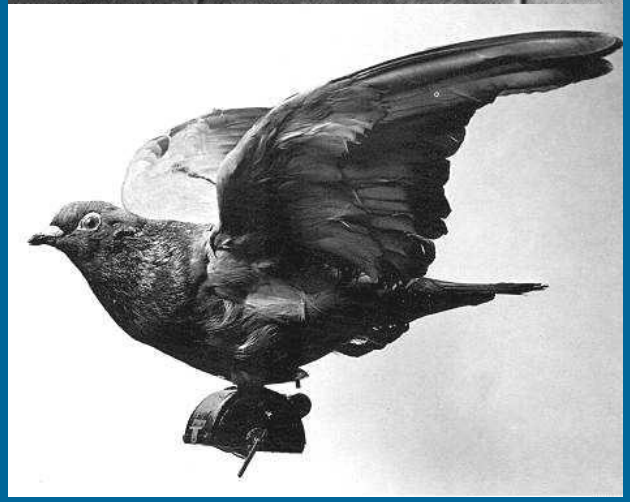


Meydenbauer is known for his architectural surveys using photogrammetry.
In 1867 he designed the first wide-angle lens camera used for mapping.
The photograph was used to map the terrain by intersection.
Directions from ground control points were graphically plotted from the imagery.

Early developements

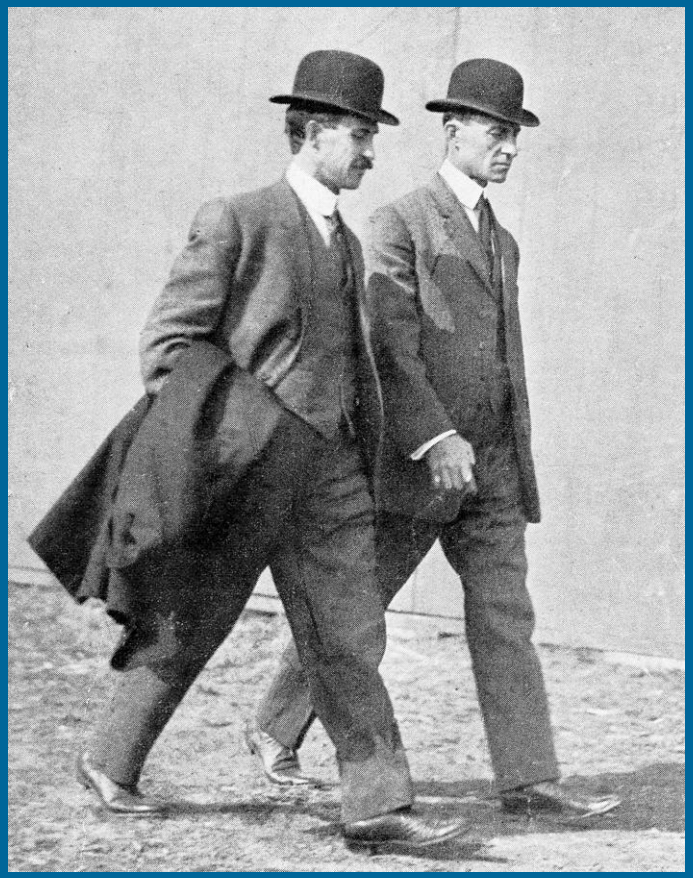


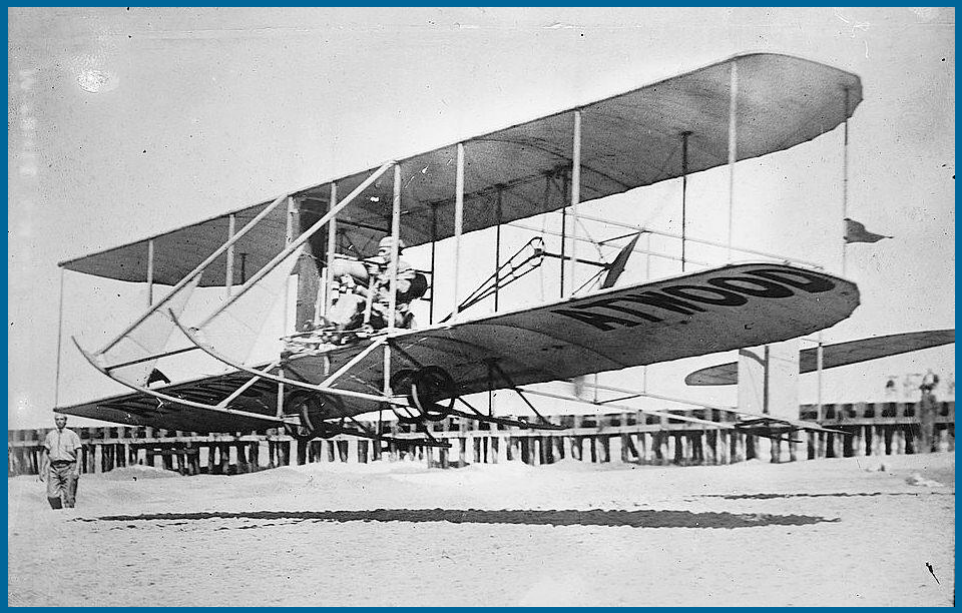
In 1903, Julius Neubranner, photography enthusiast, designed and patented a breast-mounted aerial camera for carrier pigeons



Early developements

1903:
Airplane invented by Wright brothers
1909:
the Wright brothers take the first photograph from a plane over Centocelli, Italy.



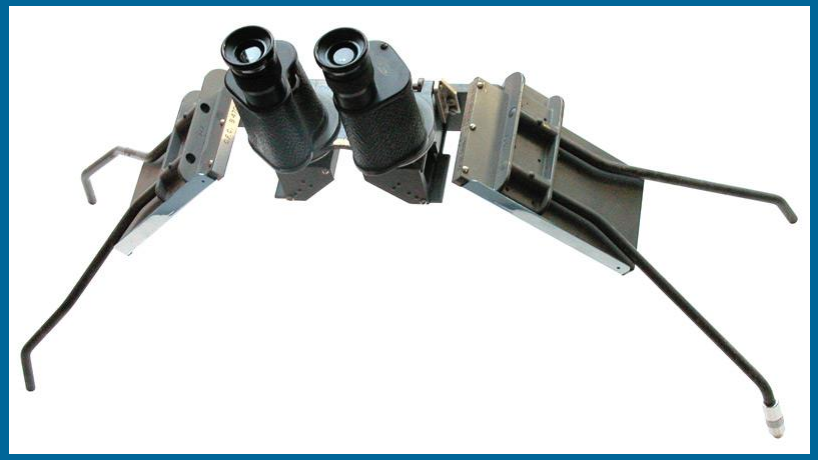


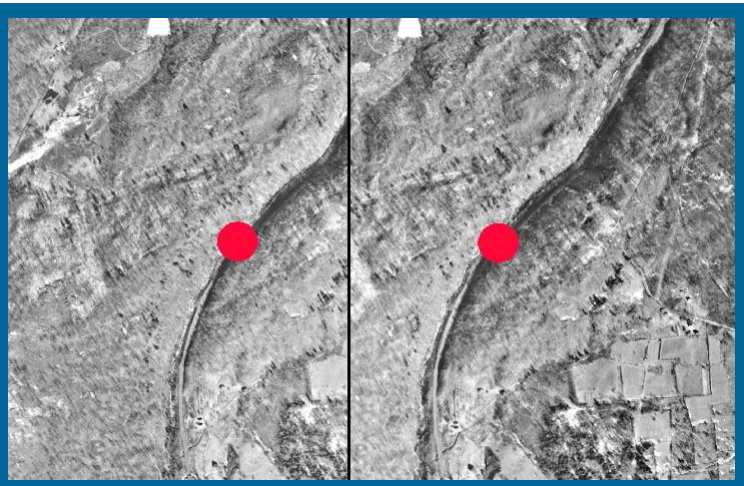
Early developements

Captain Cesare Tardivo (1870 - 1953)
is thought to be the first to use aerial photography from a plane for mapping purposes. He created a 1:4,000 mosaic of Bengasi in Italy that was described in his paper to the 1913 International Society of Photogrammetry meeting in Vienna.

Analog Photogrammetry

Analog instruments are based on the concept of stereometric vision.
2 photos are relatively oriented (= intersection of homologous bundle rays) to produce a 3D model, where details and contours are drawn.





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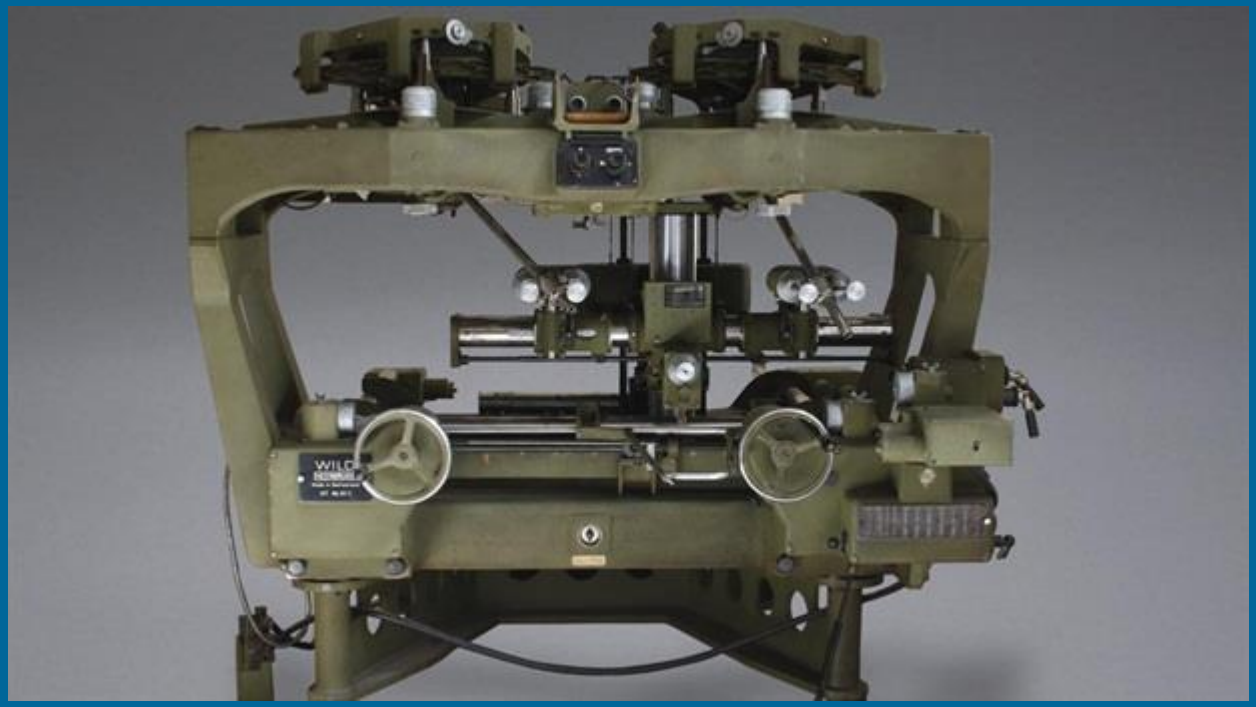
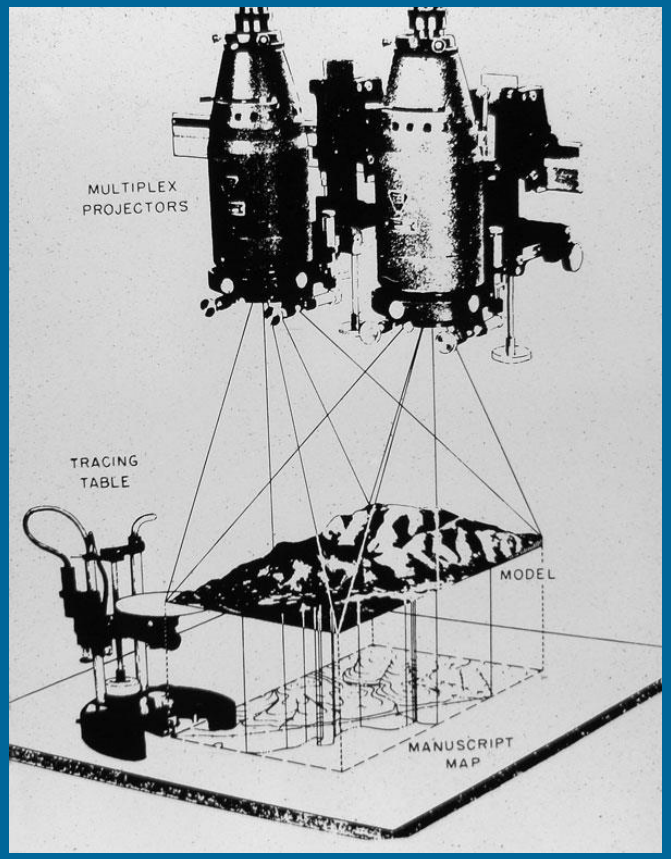


Autograph Wild A7

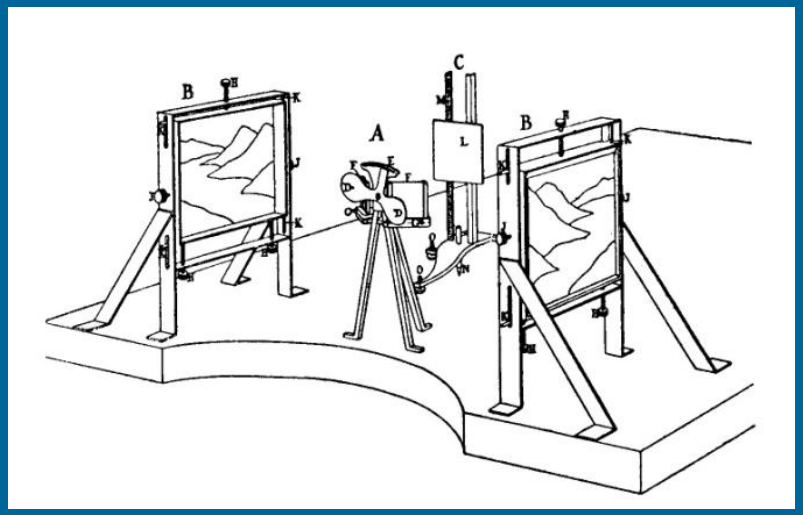
Analog Photogrammetry

Alternatively the 3D model is realized through projection of the two relatively oriented images



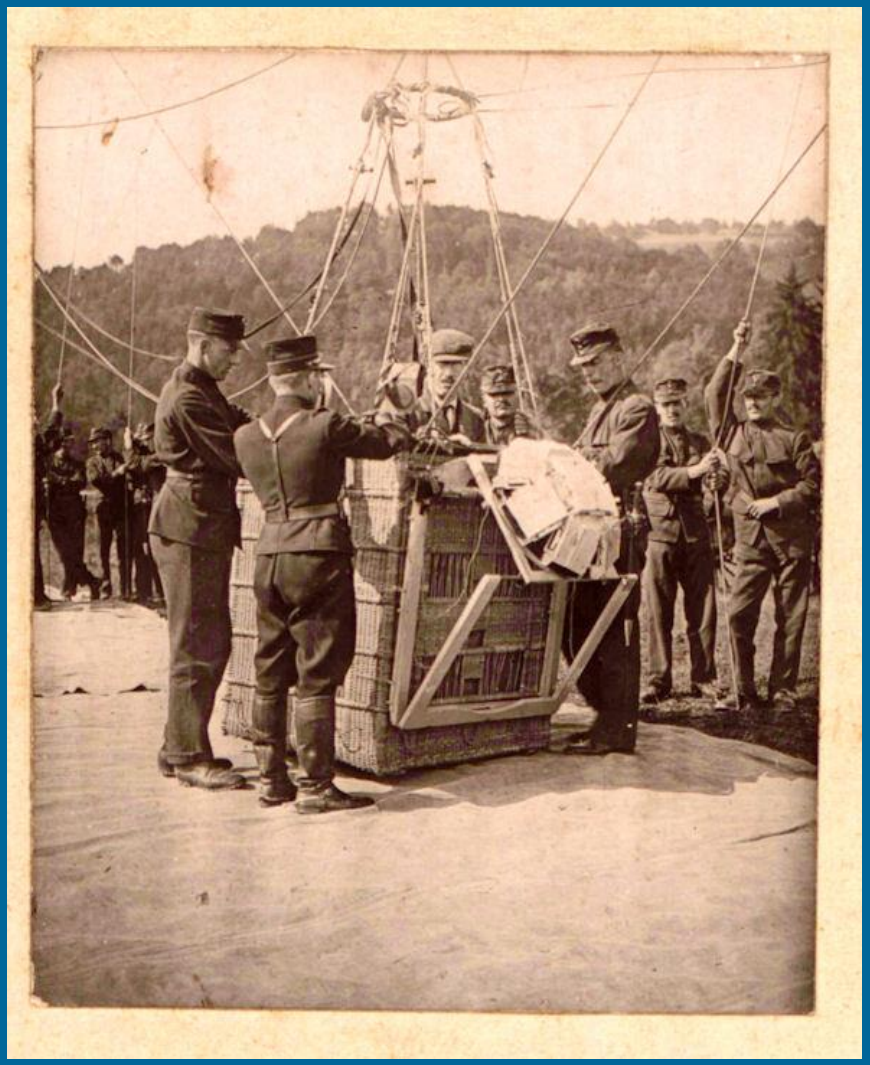
Analog Photogrammetry

Canadian surveyor Edouard Deville (1849-1924), invented the first stereoscopic-plotting instrument called the Stereo-Planigraph in 1896, which used stereo overlapping photos.
Referred to as "Canada's Father of Photogrammetry" and noted for his photographic surveys of the Canadian Rockies.

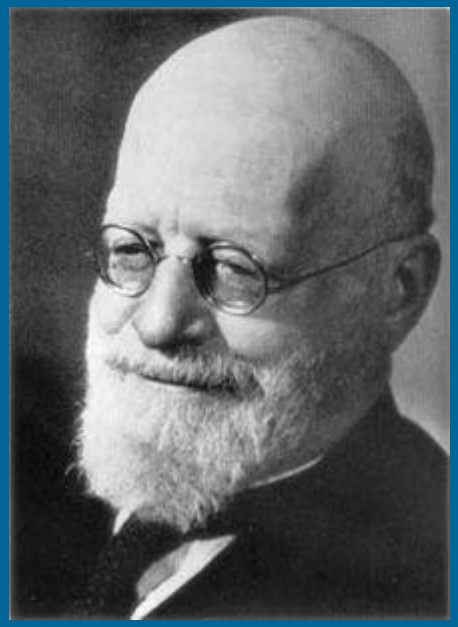


Analog Photogrammetry

Theodor Scheimpflug (1865–1911), an Austrian, developed the theory of the double projector, which offered direct viewing of the projected images. Scheimpflug also worked with kites but moved to balloons and later to dirigible balloons. Scheimpflug introduced the concept of radial triangulation and is sometimes considered the initiator of aerial photogrammetry since he was the first to successfully use aerial photographs for practical mapping.

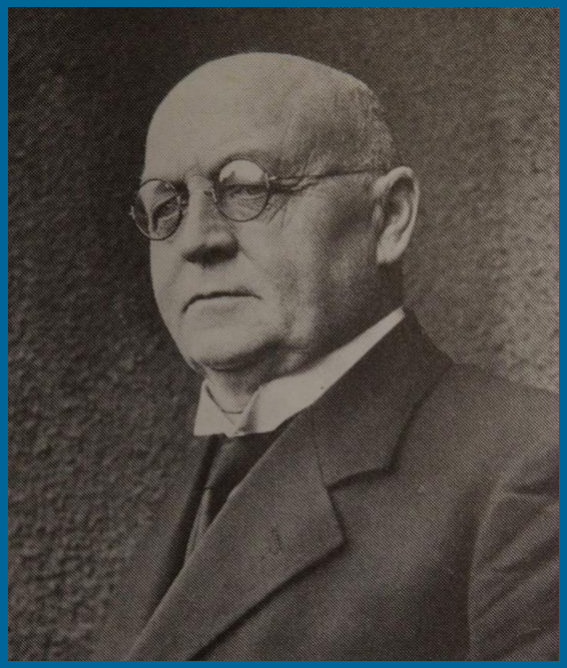


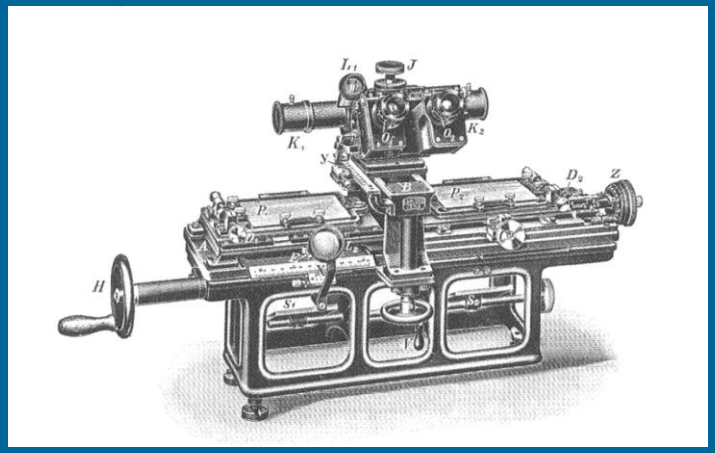
Analog Photogrammetry



In 1899, the German Sebastian Finsterwalder described the principles of modern double-image photogrammetry and the methodology of relative and absolute orientation. In addition, he introduced the necessity of redundant rays to recreate the proper geometry and used least squares theory to describe the relationship of the vectors between corresponding rays.

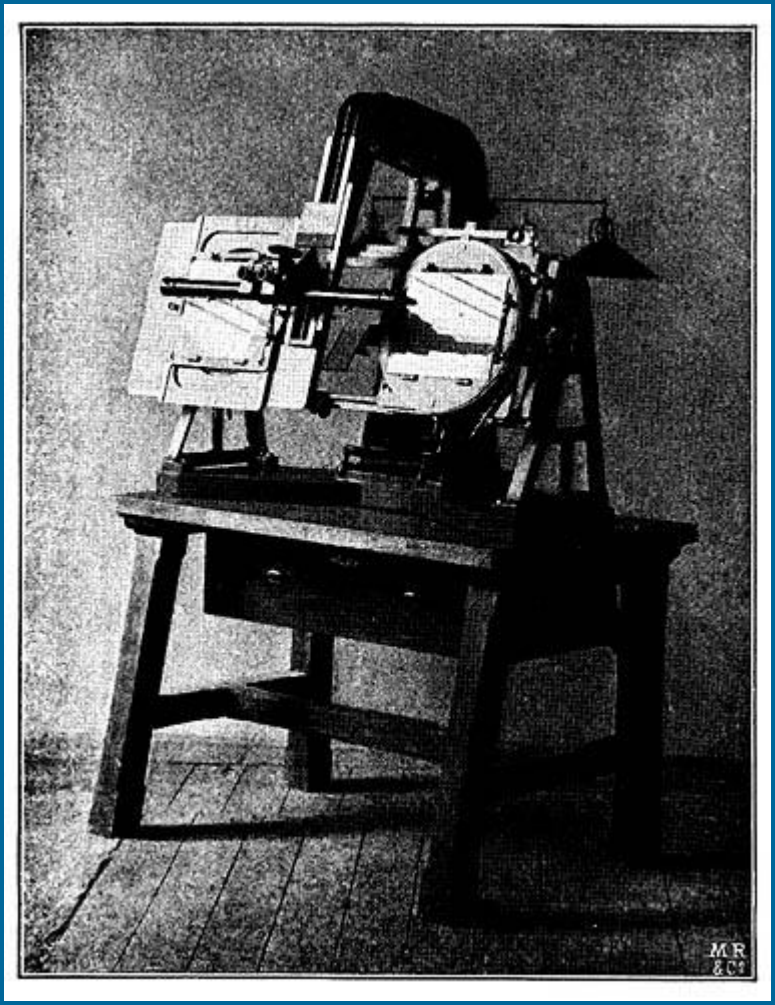
Analog Photogrammetry

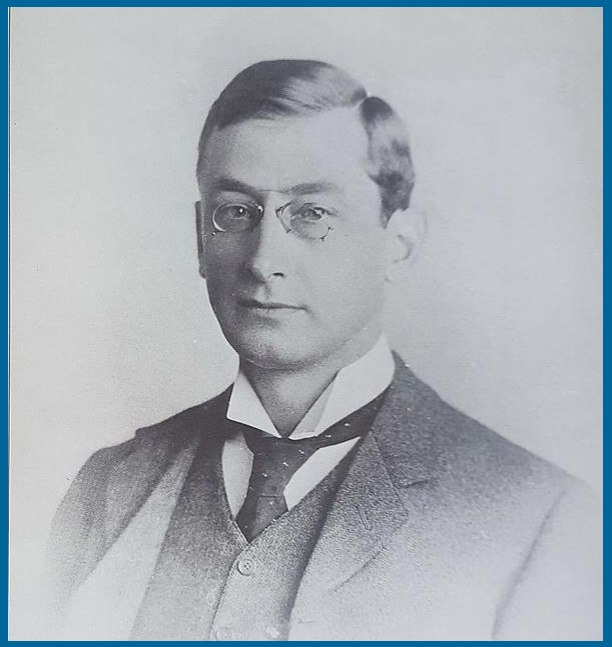




In 1901, Dr. Carl Pulfrich (1858-1929), a German physicist, designed the first stereocomparator employing x and y coordinate scales and presented the results at the 73rd Conference of Natural Science and Physicians in Hamburg [Doyle, 1964]. This was the first photogrammetric instrument manufactured by Zeiss. Pulfrich is sometimes referred to as the "Father of Stereophotogrammetry".
What was remarkable about Pulfrich was his research on stereoscopy and stereoscopic instrumentation despite the fact that he had no vision in his left eye.

Analog Photogrammetry





At about the same time, Dr. Henry George Fourcade (1865-1948), from South Africa, independently developed a similar stereocomparator. Because of the independent development, many refer to the stereocomparator as the Pulfrich-Fourcade stereocomparator.

Analog Photogrammetry

In Germany, Eduard von Orel (1877-1941), in 1908, developed the first stereoautograph.
This plotter was significant because its construction principles made terrestrial photogrammetry practical in mountainous areas.
It allowed the operator to trace elevation contours directly.

Analog Photogrammetry

Max Gasser built a double projection plotter for vertical photography (forerunner of the Multiplex plotter)

The Italian Umberto Nistri (1895-1962) created a double projection plotter using alternating image projection.

Frederick Vivian Thompson developed his stereoplotter in 1908.

Prof. Reinhard Hugershoff (1882-1941) created the first analog plotter in 1921 called the Hugershoff Autocartograph and his Aerocartograph in 1926.

Otto von Gruber (1884-1942) derived, in 1924, the projective equations and their differentials, which are fundamental to analytical photogrammetry.

His method of relative orientation of a stereoplotter makes the process of orientation easier and quicker. This procedure is still in use today and the six model points where parallax is cleared in the model are often referred to as the von Gruber points.

Earl Church (August 11, 1890 - May 11, 1956) also contributed to the theory of analytical photogrammetry. He developed the analytical solutions to space resection, orientation, intersection, rectification, and control extension using direction cosines. Church, a professor at Syracuse University and one of the founding members of the American Society of Photogrammetry, is referred to as the "American Father of Photogrammetry".

Dr. Bertil Hallert from Sweden is best known for his investigation into errors, stereoplotter orientation procedures, and standards for plotter calibration.

Analog Photogrammetry

During the early part of the twentieth century, many of the figures in analog stereoplotter manufacturing began to develop their unique brand of instrument.

Heinrich Wild, who had already made significant advances in surveying instrumentation, developed the “Autograph”.

In Italy, Professor Santoni, who was at the Officine Galileo, developed the Autoreductor in 1920 and the Stereocartograph in 1925.

The production of the C4 by Zeiss in 1930 is important because it is the first Zeiss plotter that could be used with both terrestrial and aerial photography.

The French. G.J. Poivilliers designed the Stereotopograph in 1919.

Early American photogrammetric pioneers included the brothers Arthur Brock Jr. (1887-1943) and Norman H. Brock (1890-1965) who, along with Edward H. Cahill, developed aerial cameras and plotting instruments. They were the first in 1914 to create an aerial camera that was mounted in the plane instead of holding the camera over the side.

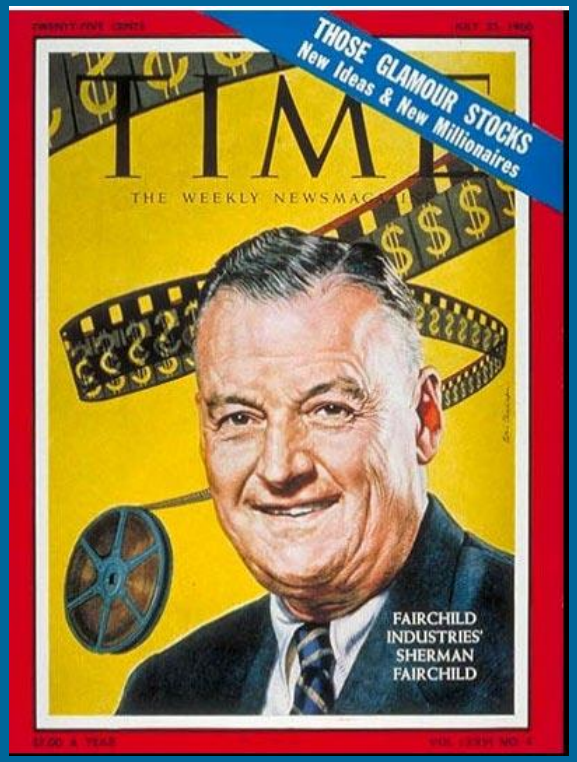
Analog Photogrammetry

Sherman Mills Fairchild (1896–1971) was one of the true giants in photogrammetry in the American private sector.

In Fairchild Aerial Camera Corporation he developed the K-3 camera and its successors.

In Fairchild Airplane Manufacturing Corporation his FC-2, made him the leading monoplane manufacturer.

In his later years, Fairchild became more involved in the semiconductor industry where he made a significant impact on the electronics field.



Analog Photogrammetry

1936: Robert Ferver, from France, was awarded a U.S. patent for the Gallus-Ferber Photorestituteur, which was the first orthophoto production instrument.

In the U.S., Russel Kerr Bean in 1956 he was awarded a patent for an "Ellipsoidal Reflector Projector for Stereo-Photogrammetric Map Plotting" known as the ER-55 and was later manufactured by Bausch and Lomb Optical Co. as the Balplex plotter.

Harry T. Kelsh (1889-1979) made an important contribution to photogrammetric instrumentation in the development of the Kelsh stereoplotter in 1945.

Analog Photogrammetry

Significant influences on photogrammetric developments from instrument makers:

In 1819, Kern of Aarau, Switzerland, was founded and began manufacturing precision surveying and mapping instruments.

Kern introduced the highly popular PG2 analog stereoplotter (over 700 of these instruments sold worldwide).

In 1980, Kern introduced the DSR1 analytical stereoplotter.

One of the early leading photogrammetry manufacturers was Zeiss. In the early part of the 20th century many of the early pioneers were employed by the company, includIng von Orel, Pulfrich, Walter Bauersfeld, Willi Sandor, and von Gruber.

Milestones at Zeiss in photogrammetry include:

1901 Zeiss' first photogrammetric instrument, the Stereo-comparator1921 Stereoplanigraph C1 produced

1930 C4 went into production

Analog Photogrammetry

Significant influences on photogrammetric developments from instrument makers:

Wild Heerbrugg was founded in 1921 and became a world leader in the manufacture of accurate surveying and mapping instruments.
Their A8 and B8 Aviograph stereoplotters were very successful analog instruments with over 2000 sold worldwide.

In 1988, Kern and Wild merged and eventually formed Leica in 1990. Using the expertise from both companies, the SD 2000 analytical plotter was launched in 1991.

In 2001, Leica acquired Azimuth Corporation, ERDAS, and LH Systems giving Leica the capabilities of offering clients LIDAR scanning systems, remote sensing/image processing software packages, and digital stereoplotter capabilities.

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Significant influences on photogrammetric developments from instrument makers:

Wild Heerbrugg was founded in 1921 and became a world leader in the manufacture of accurate surveying and mapping instruments.
Their A8 and B8 Aviograph stereoplotters were very successful analog instruments with over 2000 sold worldwide.

In 1988, Kern and Wild merged and eventually formed Leica in 1990. Using the expertise from both companies, the SD 2000 analytical plotter was launched in 1991.

In 2001, Leica acquired Azimuth Corporation, ERDAS, and LH Systems giving Leica the capabilities of offering clients LIDAR scanning systems, remote sensing/image processing software packages, and digital stereoplotter capabilities.

Analog Photogrammetry

Significant influences on photogrammetric developments from instrument makers:

Milestones for Wild in photogrammetry:

1921 Wild is founded by Jacob Schmidheiny, Robert Helbling and Heinrich Wild
1922 First phototheodolite
1925 First Universal Autograph is manufactured
1926 Wild begins production of the A2 Autograph
1927 First C1 aerial camera manufactured
1928 Begin production of the C2 and C3 aerial cameras
1932 Wild manufactures the E1 Rectifier, A3 Autograph and a mirror stereoscope
1933 C12 Stereometric Camera and A4 Autograph being to be built
1937 Wild introduces the A5 Autograph and RC Automatic Aerial Camera
1938 Wild manufactures the A6 Second-Order Stereoplotter and S3 stereoscope. It also begins to design the BC2 Ballistic Camera
1942 The RC5 Automatic Aerial Camera and ST1 and ST2 mirror stereoscopes are produced.
1948 The Aviotar high-precision photogrammetric lens is produced.
1949 Wild produces the A7Autograph.
1950 The A8 Autograph and RC7 aerial camera with Aviotar lens are manufactured.

Analog Photogrammetry

Significant influences on photogrammetric developments from instrument makers:

Milestones for Wild in photogrammetry (cont.):

1952 The BC4 Ballistic Camera and the Aviogon lens are produced.
1954 The RC8 Aerial Camera with the Aviogon lens is produced.
1955 Wild produces the STKL Precision Stereocomparator that is used in analytical photogrammetry.
1957 The A9 Autograph, RC9 Aerial Camera, U3 Diapositive Printer and VG1 Enlarger are produced. The RC9 is a super wide-angle camera and the A9 is the plotter designed to accommodate the super wide-angle photography.
1958 Wild begins manufacture of the B8 and B9 Aviograph stereoplotters and the E3 Rectifier.
1962 The BS Stereomat, C120 and C40 Stereometric camera, U9 Fixed-Ratio Printer, E4 Rectifier-Enlarger and the U4 Diapositive Printer enter the photogrammetric marketplace.
1963 Wild introduces the Universal-Aviogon lens which is corrected for visible and infrared light wavelengths.
1964 The A40 Autograph is rolled out for the ISP Congress

Analog Photogrammetry

Significant influences on photogrammetric developments from instrument makers:

Milestones for Wild in photogrammetry (cont.):

1968	Wild introduces the A2000 Stereomat at the ISP Congress and begins production on the EK8 Coordinate Printer, RC 10 Universal Film Camera with Super-Aviogon 11 lens, A10 Autograph and ST10 Strip Stereoscope.
1971	The B8S Aviograph, P32 Terrestrial Camera and APK1 Panorama Camera are manufactured.
1972	New models of A8 Autograph and P31 and P32 terrestrial cameras introduced.
1976	The OR1 Avioplan begins production
1980	Wild begins manufacturing of the AC1 Aviolyt and TA2 Aviotab.
1982	Wild BC1 begins delivery.

Analytical Photogrammetry

Analytical instruments (analytical plotters) are based on the digitization of the homologous coordinates on two photographs identified by stereoscopic vision. Computer software produce three dimensional coordinates of the point which are used for detail plotting and contour drawing in topographic maps.

Analytical Photogrammetry

Already mentioned:

In 1899, the German Sebastian Finsterwalder described the principles of modern double-image photogrammetry and the methodology of relative and absolute orientation. In addition, he introduced the necessity of redundant rays to recreate the proper geometry and used least squares theory to describe the relationship of the vectors between corresponding rays.

Otto von Gruber (1884-1942) derived, in 1924, the projective equations and their differentials, which are fundamental to analytical photogrammetry.
His method of relative orientation of a stereoplotter makes the process of orientation easier and quicker. This procedure is still in use today and the six model points where parallax is cleared in the model are often referred to as the von Gruber points.

Earl Church (August 11, 1890 - May 11, 1956) also contributed to the theory of analytical photogrammetry. He developed the analytical solutions to space resection, orientation, intersection, rectification, and control extension using direction cosines. Church, a professor at Syracuse University and one of the founding members of the American Society of Photogrammetry, is referred to as the "American Father of Photogrammetry".

Analytical Photogrammetry

The invention of the computer is responsible for the development of analytical photogrammetry.

In 1947, Ralph O. Anderson, working for the Tennessee Valley Authority, developed a semi-analytical approach for analytical control.

In the early 1950s, Everett Merritt published works on analytical photogrammetry. He developed a series of analytical solutions for camera calibration, space resection, interior and exterior orientation, relative and absolute orientation of stereo airs, and analytical control extension.

In 1953, Dr. Hellmut Schmid, developed the principles of modern multi-station analytical photogrammetry using matrix notation, including a rigorously correct least squares solution, the simultaneous solution of any number of photographs, and a complete study of error propagation.

Dr. Paul Herget at The Ohio State University developed a new approach to analytical control extension using vector notation.

Analytical Photogrammetry

In Canada, G. H. Schut used the coplanarity concept to analytical triangulation. An advocate for a simultaneous block adjustment, recognized the limitations of computer technology at the time and developed a method of strip adjustment.

Duane Brown (1929–1994) is also responsible for continued work in analytical photogrammetry. He was involved in geodesy using the ballistic cameras to determine the orbital path of satellites.

In 1955 he developed new approaches to camera calibration and the mathematical formulation of the bundle adjustment.

In 1961, Duane Brown joined the Instrument Corporation of Florida and two years later purchased the Research and Analysis Division, where he was the Director, and formed DBA (Duane Brown and Associates), where he developed a number of high-accuracy, large-format, close-range photogrammetric cameras.

Houssam Mahmoud (Sam) Karara (1928–1992), along with Y.I. Abdel-Azis, developed the Direct Linear Transformation (DLT) in 1971.

The father of the analytical plotter is Uuno (Uki) Vilho Helava (1923– June1994). Born in Finland, Helava moved to Canada. He developed the analytical plotter in 1957.

Digital Photogrammetry

Gilbert Louis Hobrough (1918–2002) was one of the pioneers in digital photogrammetry. Born in Toronto, he has been awarded at least 47 patents in many diverse areas. His photogrammetric career began with his employment at Photographic Survey Corporation Ltd. in 1951.

In 1957 he demonstrated his concept of image correlation on a Kelsh plotter.

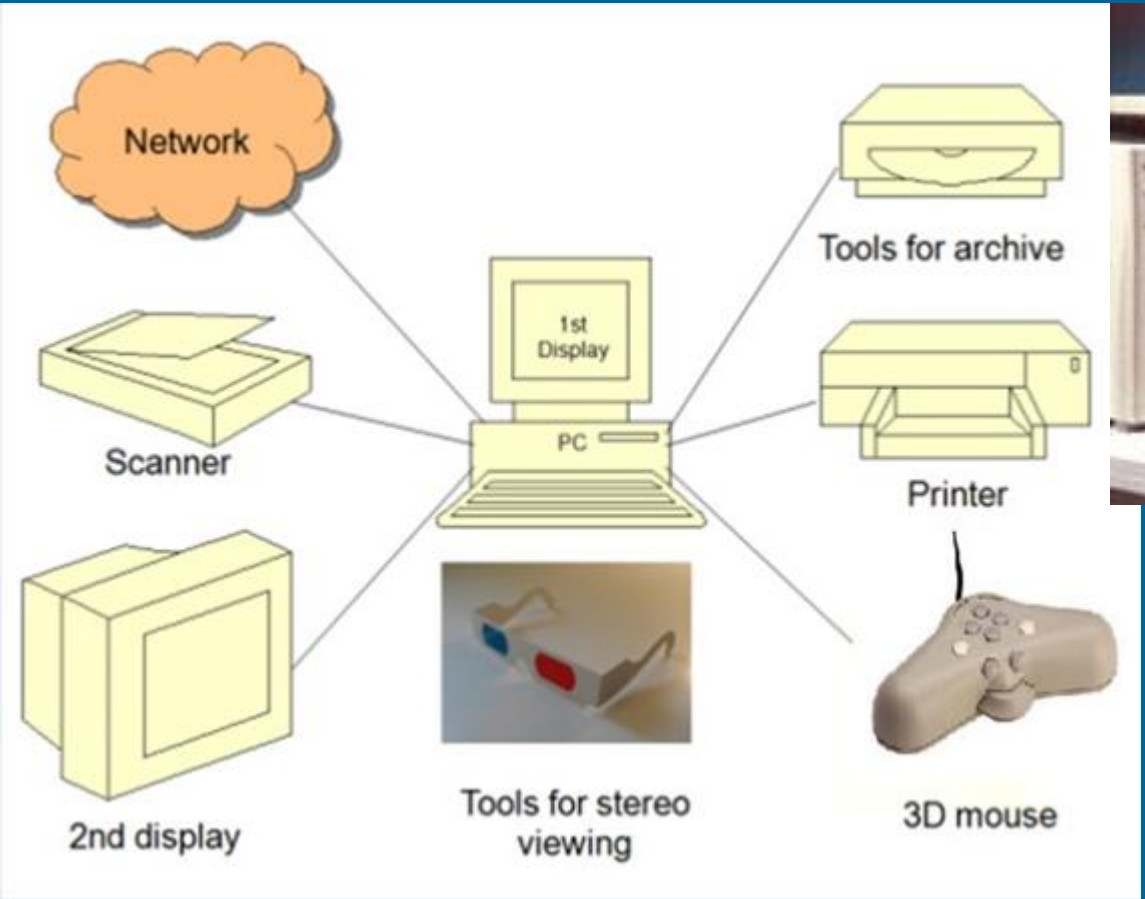
In 1961, Hobrough moved to California where he worked with George Wood on the Automatic Registration Electronic Stereoscope (ARES). The purpose of this instrument was to “correlate high-resolution reconnaissance photography with high-precision survey photography in order to enable more precise measurement of changeable ground conditions” .

In 1967 he moved to Vancouver, Canada, to establish Hobrough Ltd. and he developed the Gestalt Photo Mapper (GPM), an automated ortho-photographic system utilizing correlation of stereo imagery.

Uki Helava also played a central role in the development of digital photogrammetry, first as a research scientist at Bendix and later at Helava Associates, Inc. (1979). He helped develop digital photogrammetric workstations for the Defense Mapping Agency . When General Dynamics divested its Electronics Helava Associates became formed a joint partnership with Leica Geosystems in 1997 forming LH Systems.

Digital Photogrammetry

In digital photogrammetry the identification of homologous points is eliminated.
It is replaced by “correlation” based on computer software and the photogrammetric process is fully automated.



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