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EVOLUTION OF PHOTOGRAMMETRY IN BRAZIL

Evolução da Fotogrametria no Brasil

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ABSTRACT

The study of the photogrammetry development is an immersion in one of the most recent areas of human knowledge, compared to other sciences. It is very relevant the fact that measuring on photographs, in the order of millimeters and its submultiples, even after the multiplication by the scale module can still reach a metric quality comparable to direct measuring. It is clear that this development, in the last century, in cameras, restitution equipment and airplanes was greatly pushed by the two great wars, but also by the gain in productivity in large areas. In Brazil's case, it is significant that the development followed closely the other countries and was even pioneer in the use of some of the newest technologies available at the time. This article presents a brief history on the development of photogrammetry around the world, emphasizing the beginnings, at the same time trying to connect the facts with the several Brazilian experiments performed with the direct involvement of public and private entities, mainly during the twentieth century. Finally, it discusses the concepts and paradigm changes introduce by digital photogrammetry.

Keywords: Photogrammetry; Photogrammetric Cameras; Stereo Plotters.

RESUMO

O estudo da evolução e desenvolvimento da fotogrametria é uma imersão em uma das áreas do conhecimento humano mais recente, quando comparado com outras ciências. É bastante relevante o fato que medições sobre fotografias, na ordem de milímetros e sub-múltiplos, após a multiplicação pelo módulo da escala de ampliação, ainda consiga atingir uma qualidade métrica comparável as das medições diretas. Percebe-se claramente que este desenvolvimento, no século passado, em câmeras, equipamentos de restituição e aviões, teve grande impulso devido às duas grandes guerras, mas também pelo significativo ganho em produtividade no mapeamento de grandes áreas. No caso do Brasil é notável o fato que se tenha acompanhado de perto o desenvolvimento do exterior, e até mesmo tenha sido pioneiro em alguns levantamentos com as mais novas tecnologias então disponíveis. Este artigo apresenta um breve histórico do desenvolvimento da fotogrametria no mundo, com ênfase nos primórdios, e ao mesmo tempo tenta ligar os fatos com as diversas experiências brasileiras, executadas com a participação direta de entidades públicas e privadas, principalmente ao longo de todo século XX. Finalmente discute as mudanças de conceitos e paradigmas introduzidos pela fotogrametria digital.

Palavras chaves: Fotogrametria; Câmeras Fotogramétricas; Estéreo-restituidores.

1. INTRODUCTION

The history of photogrammetry began with the simple terrestrial photogrammetry, based on principles of the intersections in perspective, passed through the stereoscopic terrestrial photogrammetry, and in its aerial version passed through balloons, kites, pigeons, and then with the invention of the airplane has adapted quickly to the new platform.

In Brazil the development of aerial photogrammetry followed closely the development in the rest of the world; but terrestrial photogrammetry, applied to medicine, industry, police and forensic expertises and architecture, was narrower and didn't spread in companies and only a few experimental works were performed by Aerofoto Cruzeiro e Esteio Engenharia. However, various important academic works, such as theses and dissertations, can be found in those applications.

The term photogrammetry appeared in 1855, created by the geographer Kersten and was introduced by Albrecht Meydenbauer in the international literature in 1893, when photographing buildings of great architectural value in Germany. Before, the method was called iconometry, metrophotography and phototopography.

In the early years of the twentieth century, photogrammetry started to interest in the scientific community at the time. Eduard Dolezal, in Vienna, created in 1907 the Austrian Society for Photogrammetry and the International Archives of Photogrammetry, being the editor of the first six volumes from 1908 to 1923, and in 1909 created the International Society for Photogrammetry (current ISPRS-International Society of Photogrammetry and Remote Sensing), which continued the series of "Archives". The first international congress of photogrammetry was in Vienna, September 24-26, 1913. This society, as well as the American Society of Photogrammetry, established in 1934, has an important role in the development of photogrammetry until today.

The Brazilian Cartography Society (SBC) was founded on 10.28.1958 with technical and scientific purposes. Its headquarters is in Rio de Janeiro and is constituted by six technical committees, including one of photogrammetry and another photo interpretation. The SBC had, and still has, an important role in supporting and promoting the work done by researchers and engineers of the highest level, through the Brazilian Journal of Cartography (RBC) and the Brazilian Congress of Cartography. The first edition of RBC was first published in November 1970.

This paper attempts to draw a parallel between the development of photogrammetry in the world and in Brazil. Aspects of methodology and characteristics of older equipment are highlighted, as to appreciate the ingenuity of pioneers as to show that some solutions have again been used in modern digital photogrammetry. An important conclusion is that despite being a very sophisticated technology, Brazil has always followed closely the international development and adopting it only a few years later.

The beginning of the evolution of photogrammetry is detailed by Dolezal (1909, 1911, 1913, 1919) and Jordan (1944), in its later stages by Slama (1980), McGlone (2004), Gruen (2008) and Burtch (2008). The Brazilian historical discussion on photogrammetry is presented by Rocha et al (2010) whose work was used as main reference. It is relevant that in the Brazilian literature, in Mesquita (1958) and Spartel (1978), are found the theoretical and practical procedures of terrestrial photogrammetry in the early twentieth century. Other important additional information were found in editions of the Journal of the Brazilian Society of Cartography and Idoeta et al .(2004).

The article is divided into three main parts: the first is a summary of the beginning of photogrammetry in general, the evolution of the methodologies and equipment; the second part relates to photogrammetry in Brazil and the participation and contributions of public and private entities; and the third dealing with aspects of changes in digital photogrammetry.

2. BRIEF GENERAL HISTORY OF THE FIRST SURVEYS

In 1848, the officer of the Engineers Corps of the French army, Laussedat Aimé, have employed the camera lucida principle to draw geometrically accurate view of raised areas and also developed the intersections method for the design of plan using photographs (SPARTEL, 1978). For this reason he is considered the "Father of Photogrammetry". His idea was based on geometrical principles of perspective applied by Carpeller in photographs instead of drawings. This method was recognized in 1862 by the Madrid Science Academy (ROCHA et al, 2010).

In 1855, Gaspard Felix Tournachon, known as Nadar, patented the idea of using aerial photographs for mapping. But only in 1858, using a balloon to 80 m in height got the first aerial photographs of Petit-prone Bicêtre, near Paris (SLAMA, 1980). A caricature of Nadar taking aerial photographs was published in 1863 (Figure 1).

Aerial photographs were taken using balloons, pigeons and kites in the late nineteenth and early twentieth century in Europe, the United States and Canada. But the first surveys were carried out by terrestrial photogrammetry, such as the Grenoble square in France (about 20 km^2), by Captain Javary in 1864 and soon after, the important work of M.J. Vallot that surveyed of Mont Blanc. The Germans have many applications such as map of oasis Gaser Daschel by Jordan in 1873; surveys in Persia with archaeological purposes in 1874 by Stolze, glacier Junfrau by Doernges and Koppe. In Italy the eng. Pius Paganini remade much of the maps of the Alps and in Austria recognition on a large scale in the Alps, Tyrol and elsewhere. (SPARTEL, 1973).

Fig. 1 - Lithograph by Honore Daumier, showing Nadar photographing Paris on a balloon, with the title "Nadar elevating photography to the level of the Art", published in Le Boulevard, May 25, 1863.

In 1881, in Canada, French Edouard Gaston Deville, a former hydrographer engineer of the French Navy, occupying senior positions with responsibility for surveys in Canada, began to develop mapping services with the application of photogrammetry, with first tests in the Rocky Mountains. The first mapping of a large area was about 3300 km^2, scale 1:40,000 and contour interval of 33m.

One of the first practical results in aerial photogrammetry (using balloon), for mapping, were achieved by Captain Cesare Tardivo, Italian officer of the Photographic Section of the Corps of Engineers from Italy, created in 1896. Among his several works described by (GUERRA & PILOT, 2000), in 1911 it set up a mosaic of Venice with photographs by balloon, using the methodology of *Manuale di fotografia, telefotografia e topografia da pallone* by Tardivo (Figure 2).

Also in 1913 Tardivo presented at the 1st International Congress of Photogrammetry in Vienna, several works (GUERRA & PILOT, 2000) for civilian and military use, as a mosaic of the aerial photographs of Benghasi in Libya, due to the invasion of that country by Italy in 1911. The photographs of this mosaic were also obtained from a balloon (DOLEZAL, 1919) and not a plane, as shown in some citations (BURTCH, 2008).

While the first record of aerial photography, which was obtained by Nadar using the balloon for the purpose of mapping, is generally agreed, that is

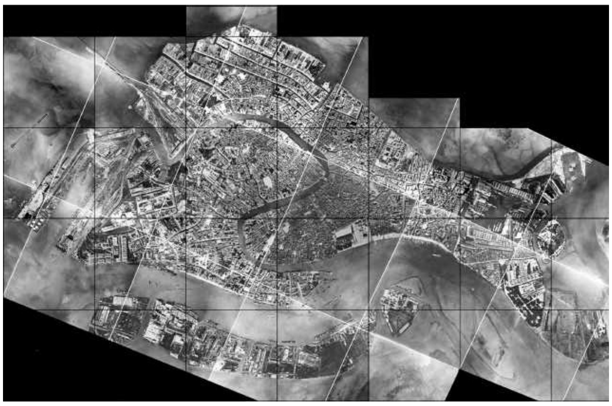


Fig. 2 - Photo Mosaic of Venice (GUERRA & PILOT, 2000).

not the case with the aerial photo by plane. In this case the candidates are at least three.

For some it is attributed to the Wilbur Wright, one of the brothers that invented the American airplane, in Centocelle, Italy, in 1909, but was actually a movie recorded by another occupant of the aircraft, with a camera and without cartographic purposes. For others it is attributed to Captain Cesare Tardivo because the mosaic of Benghasi would be of aerial photographs taken from aircraft. And yet for others it is Friedrich Wilhelm Zinn, or Fred Zinn, an American who was pilot in the French Air Force and that would have obtained the first aerial photographs, but for purposes of military reconnaissance at the beginning of World War I in 1914.

More likely is that the first aerial photograph of plane was of military origin. Stewart (1931) states that since 1912 the Royal Flying Corps began to take photographs of the air by plane. With the start of World War I (1914-1918) the photographs started to be used intensively for recognizing the enemy's camp. As an example Slama (1980) presents a mosaic taken with an automatic camera by German forces, which photographed about 7,000,000 km^2 of the territories of France, Belgium and Russia.

After the War, private companies started investing in photogrammetry for mapping, with the cameras and equipment more refined and productive.

In 1927, tests were conducted near Quebec, in Canada, by the Canadian Royal Air Force. In 1928 he was surveying 10,000 km^2 in the province of British Columbia. In 1920 the Fairchild Aerial Survey was one of the first contracts for airborne surveying, for the state of Connecticut, but was executed in 1934. In Switzerland in 1928 there were studies of precision for aerial photography plotting using Wild Autograph. Topographical Service of Germany in 1929 conducted experiments in order to apply to register land rights and also surveying in 1927 the Amrum island and Harz mountains (JORDAN, 1944; SLAMA, 1980).

Around 1930 the aerial photogrammetry started to be used regularly in Europe and North America. In Brazil was surveyed São Paulo city (more detailed in section 4.1).

In the following years aerial photography established itself as the ideal method for mapping large areas up to the present day, incorporating technological advances in the manufacturing of cameras, film and computer resources. In the year 1960 appeared the analytical photogrammetry with the introduction of computers.

In the 90's the photographs began to be scanned and the first applications of digital photogrammetry appeared.

3. CYCLES AND EQUIPMENTS OF ANALOGIC PHOTOGRAMMETRY

Photogrammetry can be classified according to the position where the camera is installed that can be in the air, aerial photogrammetry, or ground, terrestrial photogrammetry, and about technology, the most common classification is: analog, analytical, and digital.

The cycle developments as showed by (BURTCH, 2008, SILVA, 2004) would be:

· Plane table from 1850 to 1900, with measurements on tables and use of simple pictures;

· Analog from 1900 to 1960, with full use of stereoscopy and development of aerial equipments;

· Analytical from1960 to 1990;

· Digital since 1990.

The plane table photogrametry is also called simple photogrametry and the analog is called stereo photogrametry by Espartel (1978).

3.1 Simple Photogrametry

Photogrammetry is based on the principle of line intersections in photographs, used to measure the details of the land. Before these lines were drawn on photographics paper copies, now a collinearity equation is used. Photographs can be considered perfect conical perspectives and thus, by well-known geometric relationships can be drawn at the scale corresponding orthogonal planes. This is the principle used by Laussedat, illustrated in Figure 3, where the drawings of the planimetric (pyramid) and

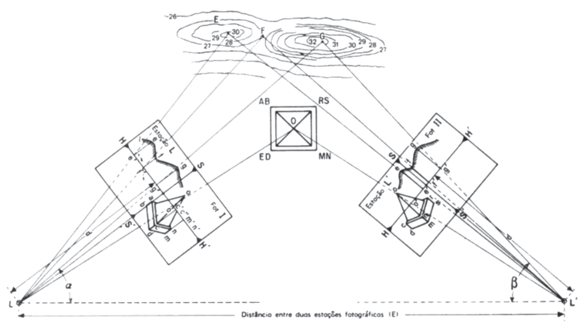


Fig. 3 - Use of perspective in the Laussedat photogrammetric method (ESPARTEL, 1978).

altimetric (contour lines) details are obtained from the photographs I and II.

The method of the intersection, or the plane table, is so named because the determination of the points is made with plane table by direct intersection. From a station's known point are taken photographic views of the terrain, beside this are known the points of orientation of the crystal plate, so can be inferred from photo the azimuth angles of all points and intersections of rays to determine the positions of these points (JORDAN, 1944).

The coordinates of the stations are determined in advance by triangulation or traverse. The heights are determined by leveling. For the exterior orientation is necessary to know the azimuth of the camera axis, which could be obtained with the measurement data of some vertices and with the help of compass. With the phototheodolite this operation was facilitated. Figure 4 shows the Laussedat's phototheodolite.

The description of the Laussedat method is given in Espartel (1978).

The simple photogrammetry uses a simple camera, or phototheodolite, Laussadat type, which could be operated by a reduced staff and would be surveyed, with a certain accuracy and speed, details in areas inaccessible to tacheometric processes, hence its first applications were in the survey of land with great difficulty access. Illustrative examples of practical application of terrestrial photogrammetry

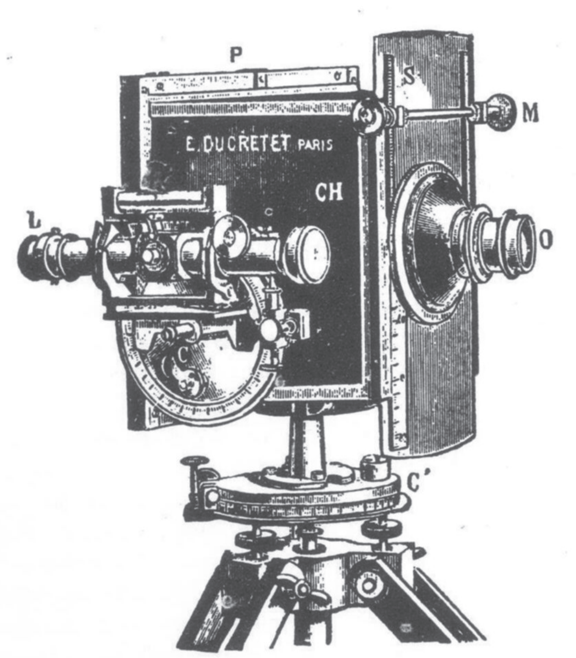


Fig. 4 - Phototheodolite of Laussedat (ESPARTEL, 1978).

simple field work in Porto Alegre in 1936, are given in Spartel (1973) and one of them is shown in Figure 5.

However, the simple photogrammetry has difficulty in identifying different images in the same point on the ground, to measure with the accuracy and precision required. This problem can be solved only by stereo photogrammetry.

3.2 Stereo Photogrammetry

The stereo photogrammetry require more sophisticated equipment and can be applied to work with greater need for accuracy in mapping. So you can better identify the points and measure the photographic coordinates in x, y, and the differential stereoscopic parallaxes.

The stereo photogrammetry can only be implemented in 1901 with the construction of the Pulfrich Stereocomparator (Figure 4). That takes advantage of stereoscopic vision. This has been known since 1600, by the German astronomer Johannes Kepler. For stereo photogrammetry the photographs, two by two, have axis parallel to each other while they are inclined in simple photogrammetry (Figure 5). In the normal case the axis are parallel to each other and normal to the base (Figure 5a), but this reduces the amplitude of the area covered by a survey. To extend this limit can be set up bases with different directions, forming a polygon, or using a base oblique to the optical axis (Figure 5b).

The old equipment more precise in the measurement of details in photographs, is the stereo comparator, which allows a stereoscopic view of the relief. The equipment is designed so that a stereoscopic microscope increases the distance between the eyes and thus expands the perception limits of the relief. The accuracy of angular

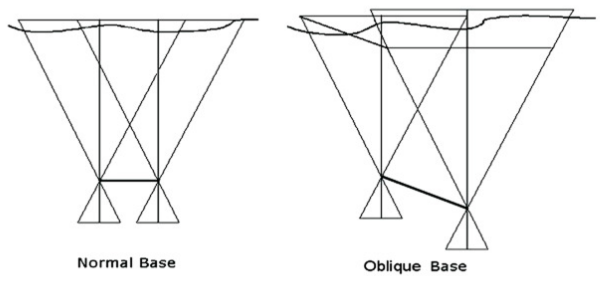


Fig. 5 - Geometries of photographs for stereo photogrammetry. A) Normal case, B) Oblique case.

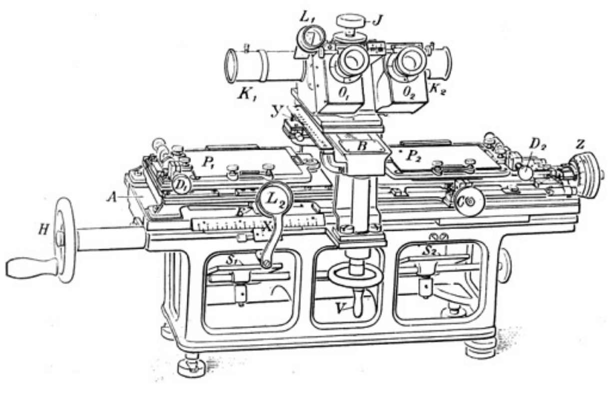


Fig. 6 - Pulfrich Stereocomparator (JORDAN, 1944).

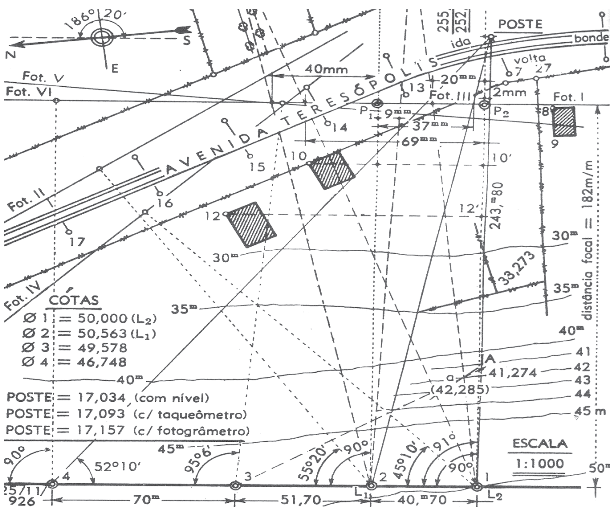


Fig. 7 - Excerpt from a survey conducted by method of Laussedat (ESPARTEl, 1978).

measurements is greatly increased and the vision of the relief could reach about 27km. Calculations of planimetric and altimetric positions of the points are made from the readings of Cartesian coordinates, parallax formula and triangles similarities. (SPARTEL, 1978).

The improvement of the stereocomparator with the addition of a pantograph by Captain Ritter von Orel, a member of the Geographical Institute in Vienna, in 1908 in Germany, created the stereo autograph, which is the first device that allows direct drawing from a photograph for the paper and facilitates the tracing of the contours of the land. The Zeiss later built the first commercial model, the Orel-Zeiss (Figure 8). At the same time, F. Vivian Thompson also built a equipment similar to Orel's, in 1907 for terrestrial photogrammetry (PETRIE, 1977).

The development of tools for stereo plotting was interrupted during World War I, but then there

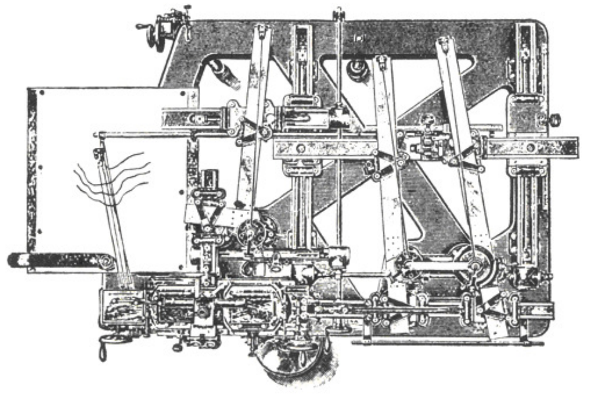


Fig. 8 - Stereoautograph of Von Orel-Zeiss (ESPARTEL, 1978; JORDAN, 1944).

was intense research and significant developments, with emphasis now in aerial photogrammetry (PETRIE, 1977).

It was during this period that has been perfected the basic principles of analog instruments used until recently. The pioneers include optical projection equipment Photocartograph Nistri (1919), the Steroplanigraph Bauersfeld of the Zeiss (1923), the mechanical projection Autoreductor Santoni (1920), Sterocartograph I (1925) and optical-mechanical: Autocartograph Hugershoff (1921) Stereotopograph Poivillier (1923), Aerocartograph Hugershoff (1926), Wild Autograph A2 (1926). The Prédhumeau stereotopometer was built by the house Secretan of Paris for the French Army Geographic Service, around 1922, based on experiments of Deville in 1902 (JORDAN, 1944).

The construction of the stereo plotting obeys two different principles: a) decomposition of the beam in its horizontal and vertical components, or b) the intersection of rays in space, which can be a projection of light or mechanical rods. The Autocartograph and Sterocartograph are based on the first and Stereoplanigraph on the second.

The equipment used for terrestrial plotting were not practical for surveying large areas and the first solution was to use the idea of the double projector, where the pictures were projected onto a projection screen that moves parallel to himself, developed by Austrian Theodore Scheimpflug in 1898. This idea was implemented in 1915-1917 by Gasser, who built the so-called Projector Dual Gasser, but because the war was forgotten and so its principles were later used (JORDAN, 1944; SLAMA, 1980). Based on the same principle the Italian Umberto Nistri, in 1919, also built a projector. The description of the work in projection apparatus is given in the Mesquita (1958).

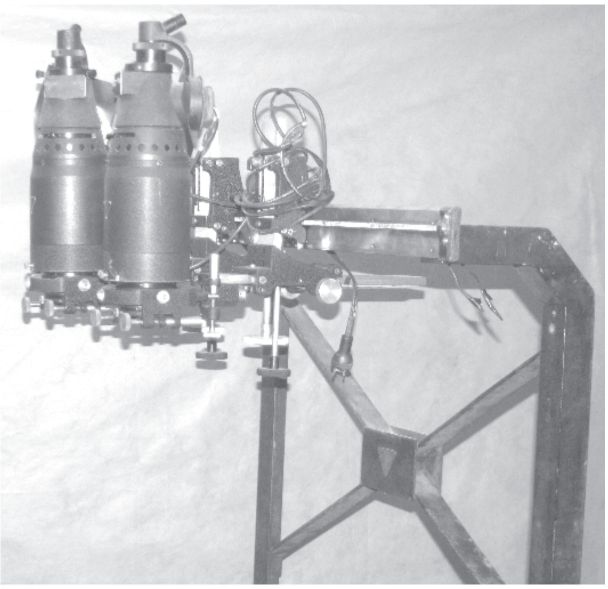
Among the equipment available in the market with light projection the most manufactured was the Multiplex, made by Zeiss since 1940, and after the Word War II by Bausch & Lomb, USA. Figure 9 shows the Multiplex, Bausch & Lomb (Museum of Cartographic Engineering Department, UFPE, Brazil), the anaglyph glasses and small pictures, 4.5 x4.5 cm glass plates used in projectors.

The optical-mechanical plotting were gradually becoming more refined and practically dominated the market, after the plotting of light projection.

The company Otto Meccanica Italiana (OMI) and Rilevamenti Aerofogrammetrici, of Nistri brothers, based in Rome, built various devices such as cameras and photogrammetry plottings (MESQUITA, 1958, SLAMA, 1980).

Among the plotting few worth mentioning: Photocartograph Nistri Aeronormal 2 (FN2), type direct projection to large scales, used in the pioneering study of São Paulo (Figure 10) and Beta 2 model 1952, which was the first equipment to replace the mechanical plotter by electrical output, which was later the solution to convert in the 1980's optical-mechanical equipment for digital output.

Some lists of plotting equipments available in Brazil in 1952 are found in Mesquita (1958) and in the 1970s, in Barreto (1970), whose relationship classifies equipment into phototriangulator and plotting of 1st order (Wild A5 and A7; Zeiss C5 and C7; Nistri-Beta, APC, Santoni-IV, 2nd order (Wild A9); only 1st order plotting (Planimat, Wild-A8, Santoni-III), 2nd order (Kelsh, Wild B8 and



A)

B)

Fig. 9 - A) Multiplex projector, B) Anagliph glasses and glass plates.

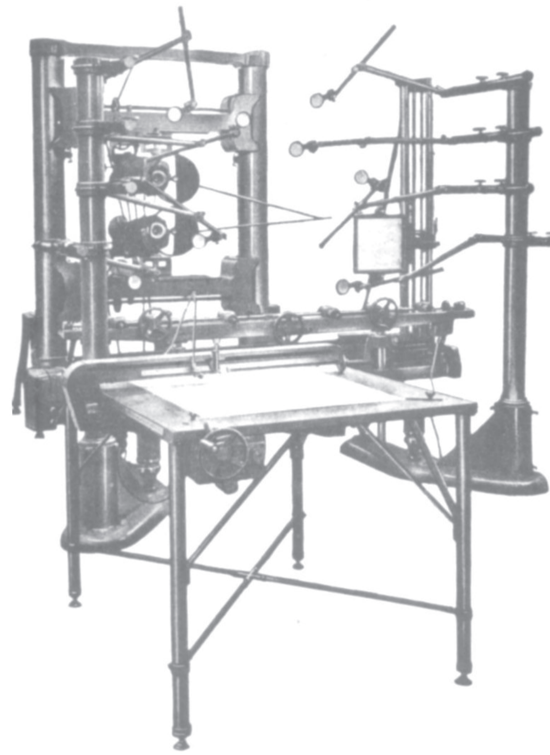


Fig. 10 - Photocartograph Nistri 2. (MESQUITA, 1950, 1958).

A6, Kern-PG2, Dual Projector Zeiss), 3rd order (Multiplex, Wild B9) 4th order (stereotopo, Rest Kek).

3.3 Brief history of photogrammetric cameras

The photographs for terrestrial photogrammetry were taken from phototheodolites (Figure 1) and cameras mounted on theodolites. In Jordan (1944), Spartel (1978), Mesquita (1958) and Slama (1980) can be seen several models. Jordan (1944) shows the procedures of phototheodolite orientation.

With the arrival of the aircraft, the photogrammetry had considerable momentum. On October 23, 1906, the Brazilian Alberto Santos Dumont, in an experiment inspected by the Scientific Committee of the Aero Club of France achieved flight with the 14-Bis. From that, photographs could be obtained of areas much more extensive and with more flexibility than with balloons, but several improvements were needed in the aircraft and cameras. The aerial photography plane had great use in World War I.

The analog cameras for photogrammetric aerial photographs were all manual and only in 1915 appeared the first automatic aerial camera (SLAMA 1980). Figure 11 illustrates how the first photographs were acquired in an airplane flight with manual camera.

The manual cameras were more commonly of glass plates and small angular field, as examples: in Switzerland there was a Wild camera f = 165mm for plates of 10x15 cm; HMK Zeiss in Germany with four chassis and six plates each or roll film for 120 photos, format 13x18 cm, f = 210mm; in France, the cameras SOM Poivilliers, plate 13x18 (JORDAN, 1944).

The Italian company OMI (Nistri) built several aerial cameras (MESQUITA, 1958):

• AFL 92 for plates 13x18, f = 200mm, two chassis capacity of 84 sheets each

• FOMA 93 / A for film 18x18

• FOMA 93 / B for film 30x30

• Aeronormal

The model AFL 92 (Figure12) was used in the survey of São Paulo.

The automatic frame type film cameras have become standard, with a 23x23cm format and sets of interchangeable lenses with focal lengths like 88mm, 152mm, 200mm and 300mm. Also have been developed further in the period 1930 to 1970, various types of cameras with special features such as panoramic, continuous band, multi-band (multi-cameras, lenses and multi-beam splitter) and spatial (SLAM, 1980).

An arrangement of multi-camera was used especially in Brazil: the Trimetrogon. Trimetrogon is the name given to the set of three photogrammetric cameras of the American Fairchild who used the lens known as Metrogon, manufactured by Bausch & Lomb in the U.S.. The term was extended to the surveying process for small-scale photogrammetry of extensive recognition.

Fig. 11 - Taken aerial photographs with manual camera (photo: author unknown).

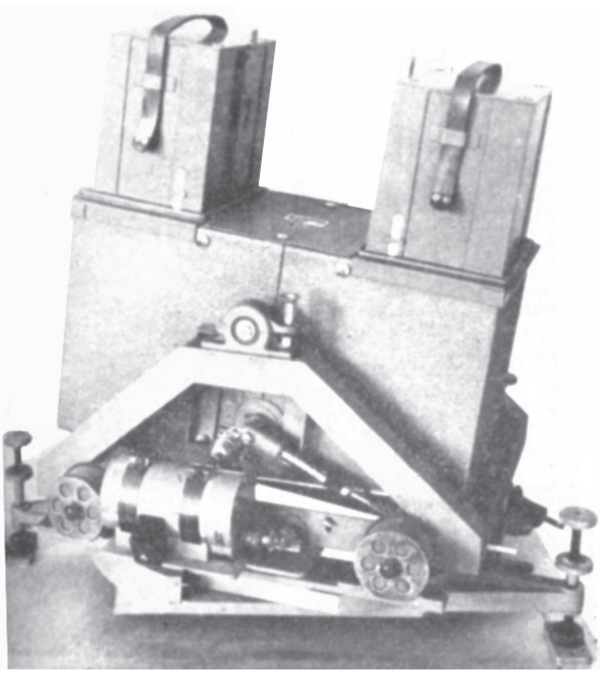


Fig. 12 - Câmera Nistri AFL 92 (MESQUITA, 1958).

3.4 The Stereograph Wolf

The stereograph Wolf (Figure 13) is a simplified planimetric and altimetric plotting, which is a Brazilian participation in the construction of photogrammetric equipment. This device was used for making drafts cartographic scale by SGE 1:50,000. It was designed and built under the guidance Emilio Wolf Austrian military during stay in Brazil (see section 3.1). Then it was perfected by Benjamin Arcoverde Cavalcanti, who made fully automatic and he named "*Autoestereógrafo*". Details of construction and operations are given by Mesquita (1958). Figure 14 shows a soldier operating the stereograph.

4. FEATURED INSTITUTIONS OF PHOTOGRAMMETRY IN BRAZIL

The development of photogrammetry in Brazil had a very substantial contribution of government entities, like the current DSG (Directorate of Army Geographical Service), the IBGE (Brazilian Institute of Geography and Statistics), SUDENE (Superintendency of Northeast Development) and UFPR (Federal University of Paraná) through the Graduate Program in Geodetic Sciences. Were also significant the participation of the Brazilian Society of Cartography and commitment of surveying photogrammetric companies.

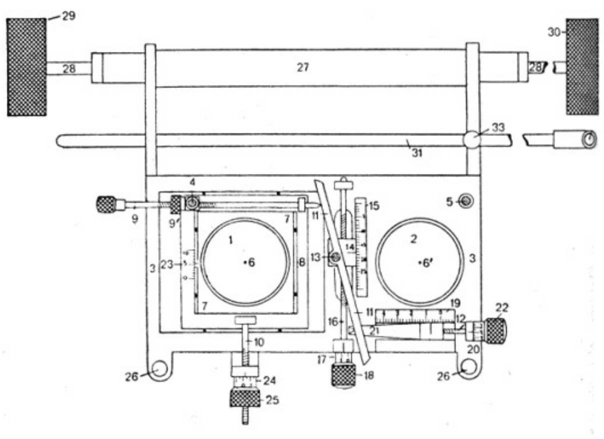


Fig. 13 - Stereoautograph Wolf (MESQUITA 1958).

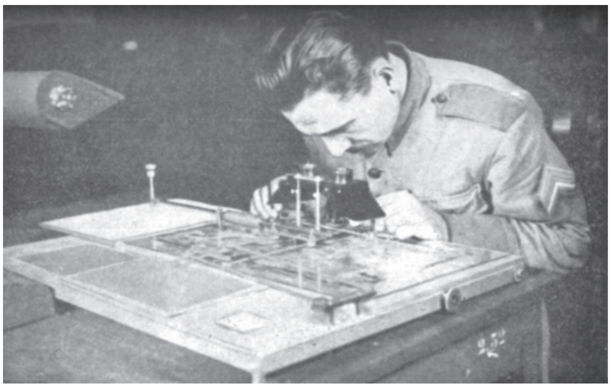


Fig. 14 - Soldier of SGE operating the stereographo Wolf (MESQUITA, 1958).

4.1 DSG

In 1890, it created an institution which would be one of the most fulfilling jobs in photogrammetry in Brazil, this institution was originally called the Commission of General Chart, later the SGE (Army Geographical Service), currently DSG.

Among the key events and importance of the DSG for the cartography of Brazil in general, and for the development of photogrammetry in particular are as follows (BAKER, 1978; LEAL, 1972):

- In 1912, the then Major Alfredo Vidal with the support of the mayor of Rio de Janeiro, General Bento Ribeiro, creating, in the Fortress of the Immaculate Conception, a section of stereo photogrammetry. Major Vidal publishes "Introduction stereo photogrammetry in Brazil."
- In 1914, the same general authorized the purchase of two stereoautographs Orel-Zeiss and invites the Austrian military Emile Wolf to coordinate services
- With the beginning of World War I, Wolf returned to his duties in the army of his country.
- In 1918 the Major Vidal manages the hiring of the Cartographic Austrian Mission to organize the SGE, which arrived in 1920. The Austrian Mission, hired by the Army Staff, is intended to provide the technical foundation necessary for the mapping of the National Territory. There was also the return of Wolf, who oversees in 1922, an important work of mapping the Federal District (Rio de Janeiro), at the scale of 1:50,000.

After the founding of the DSG, civilian government agencies, federal and state governments, began deploying divisions of photogrammetry.

The DSG, by Decree-Law 243 of 2.28.1967, is responsible for the systematic mapping of Brazil at scales 1:250,000 to 1:25,000. With its units in: Brasilia, Porto Alegre, Olinda, Manaus and Rio de Janeiro; operates throughout the country, performing work of surveying, photogrammetric and radarmetric mapping. It carried out work over large areas, such as photogrammetric compilations and printing of map sheets, within their own activities or in partnership with SUDENE in the years 1970 to 1980. Other major projects were: the mapping of the Southern Frontier Project, from 1995 to 1999, with production of 1597 sheets in the scale 1:25,000 of the Brazil-Uruguay- Argentina border, and Coordination of the Amazon Mapping.

Radiography of the Amazon Project began in 2008 through 2012 predict the planimetric mapping of 1,800,000 km^2 of forest and non-forest in the region of the mapping emptiness of the Amazon, using polarimetric and interferometric SAR sensors, for the purpose of obtaining digital maps at scales 1:50,000 and 1:100,000. (DSG, 2010).

4.2 IBGE and CONCAR

IBGE (Brazilian Institute of Geography and Statistics) is responsible for the demographic surveys, various statistical surveys, geographical information, and also by the Brazilian Geodetic System. It was created by Decree No. 24609 of 1934 and in 1938 was incorporated into the Council of Geography (CNG) and the National Statistics Institute (INE).

Were established in 1967 "Guidelines and bases of the National Cartography" by Decree-Law 243 of 28 February 1967. This decree instructed the IBGE to create the COCAR (Cartography Commission) and gave assignments of normalization technique of geodetic national network and systematic mapping of the map scale smaller than 1:250,000; and instructed the DSG the normalization of map scales 1:250,000 and larger.

The COCAR should have an important participation to complement the regular instructions from the National Technical Standards of Cartography (Decree No. 89817) in 1984, but was deactivated in 1990, because the administrative reform carried out by the federal government. Over and over again suffered other activations and deactivations, and is currently working with the name CONCAR (National Commission of Cartography) due to Decree 4781 of 16 July 2003, and has the administrative support of the IBGE.

Since 2003, the IBGE is working on incorporating digital photogrammetry techniques in its production line of planimetric and altimetric systematic mapping. Are available from the IBGE (www.ibge.gov.br) sheets in PDF format, which can be accessed and plotted by users as well as photos in JPG. These activities were taken up with Project GO-MG-SP-50, which covers an area of 54,000 km^2 in the region of Minas Gerais, Goias and Sao Paulo. At the same time the services are running photogrammetric compilation to generate 73 sheets at a scale of 1:50.000. The urban areas of some cities will also be compiled at the scale of 1:25.000.

4.3 SUDENE

In the Northeast in the '60s there were only a few islands of mapping. Only with the creation of SUDENE, which prepared the Northeast Mapping Project, several domestic firms were hired, mainly the Cruzeiro do Sul SA, and was given major advance in the systematic mapping of the region on a scale of 1:100,000. These contracts were an important incentive that opened the door for private companies, who were encouraged to equip themselves properly for the task and even encouraged other organizations to step up official mapping activities (ROCHA, 1971).

The SUDENE as a result of the First Development Plan 1961-1963, established the DC (Division of Mapping), multiple assignments, between them to promote and coordinate the activities of aerial photogrammetric, topographic and planimetric surveys in the Northeast. At this time agreements were signed with the DSG, which gave initial support to the organization of the DC, and with the unit of FAB (Brazilian Air Force) 1°/6° GAV, to perform some photogrammetric flights.

Between 1967 and 1974 there was the collaboration of the MCA (Mission Cartographic German), which was part of the Basic Agreement on Technical Cooperation between Brazil and Germany (Decree 54075 of 07.30.1964). Also by this agreement were donated to the SUDENE geodesy equipments, including telurometers, barometers and plotter Planimat; for 3rd DL, unit of DSG in Olinda, equipment of geodesy, 12 plotter B-8, a ortoprojetor GZ-1 and for the 1°/6° GAV, a photogrammetric camera and full photo lab (BARRETO, 1970, SILVA et al, 2002).

SUDENE sponsored, along with geological mapping, cadastral and other cities, 436 maps on the scale 1:100,000 (area of about 000 km^2 in 1308) run by private companies and DSG, totaling 67.8% of the area, which includes the northern state of Minas Gerais. Were also produced maps on the scale 1:25,000 Northeast East.

Besides acting in systematic mapping SUDENE was among the first institutions to define clear rules about the type and quality desired of the survey since 1962 (ROCHA, 1971). This was important at the time because there was not still quality standards, which were established only in 1984 by the Regulatory Instructions of Technical Standards of Cartography (National Decree No. 89817).

The mapped areas on the SUDENE initiative are listed in SUDENE (1968) and Silva et al (2002).

4.4 PPGCG

In 1970 there were an enabling environment for national mapping, when new companies were established at Curitiba airborne at the same time was the creation of undergraduate and graduate, responsible for the hand of skilled labor in Brazil. The PPGCG (Graduate Program in Geodetic Sciences), UFPR, Curitiba-PR, coordinated by Professor Camil Gemael, was the first in Brazil to cover the areas of concentration of knowledge in geodesy and photogrammetry (KLOTZEL, 1984, IDOETA et al, 2004).

This center is responsible for training the vast majority of teachers and doctors who are spread throughout Brazil, in other graduate programs that deal with photogrammetry and related disciplines, at UFSC, UFPE, USP, UNESP, EMI, in courses engineering, surveying and cartography.

The participation of former teachers PPGCG in the publication of high-level teaching materials, as Gemael Camil (GEMAEL, 1994), John Bosco Lugnani (LUGNANI, 1987) and José Bittencourt de Andrade (ANDRADE, 1998), who have their doctorates abroad was of fundamental importance for the development and consolidation of knowledge in photogrammetry in Brazil.

In this context the area of Remote Sensing, which in many countries is intertwined with the photogrammetry, in Brazil is mainly based on development research center of the INPE (National Institute for Space Research) in Sao Jose dos Campos, who has great body of scientific and technicians.

5. SOME IMPORTANT PHOTOGRAMMETRIC SURVEYS IN BRAZIL

Were chosen few among the many photogrammetric surveys performed in Brazil, which because of their characteristics, may illustrate the evolution of photogrammetry for mapping, both by the pioneering and technical merit.

5.1 Historical Surveys

An early work using the photogrammetric technique in Brazil was conducted by Professor Pereira Reis, in 1893, who executed the map of the Federal District at the time (Rio de Janeiro) by the method developed by Laussedat (ROCHA et al, 2010). In Rio Grande do Sul, 1902, the engineer Rodolfo Ahrons made the map at 1:10,000 scale of the first six districts of Porto Alegre, with details of the hills and contours (SPARTEL, 1978).

Emile Wolf, during his performance in the SGE in 1914, conducted an experimental mapping of the hill of Cantagalo. In 1915, preliminary surveys carried out the Governor's Island, also in Rio de Janeiro. In 1922, oversees the work of large-scale mapping of the Federal District (Rio de Janeiro), at the scale of 1:50,000.

The survey of the capital São Paulo for aerial photography from 1928 to 1930, was performed by SARA (*Società per Azioni Rilevamenti Aerofogerammetrici*) Brazil S/A, a company with its headquarters in Rome, belonged to the brothers Humberto and Amedeo Nistri, who also worked in the construction of photogrammetric equipment. The public bidding and contract was authorized by municipal law nº 3203, from 1928, of São Paulo municipality (IDOETA et al, 2004; MESQUITA, 1958).

São Paulo was the first city and municipality in the world that had a large-scale cadastral survey (MESQUITA, 1958). For the downtown area map at scale 1:1000 (approximately 36 km^2), contours with 1m contour interval, error less than 30cm; and for all municipality map at 1:5000 scale (1000km^2), with 5m contour interval. The work was coordinated by the brothers Nistri. Some results were presented at the Fourth Congress of Photogrammetry in Paris, held in 1934. (MESQUITA, 1958).

The aerial photographs were conducted with the camera (Figure 12) on glass plates of 18cm x 13cm and compiled in Photocartograph (Figure 10).

The maps were made on a local topographical surface, originating in the Park D. Pedro and altimetry originating in a CN (Geographic Comission) Benck Mark also located in this park (IDOETA et al, 2004). Figure 15 shows a clipping of the plant in scale 1:1000 and Figure 16 shows a cut in the scale 1:5000.

In the following decades the mapping of Sao Paulo began to be organized by national companies, and aerophotogrammetric survey in Brazil became commonplace.

Among the surveys of capital deserves the mapping of the area for future Brasilia. In 1953 it enacted the federal law 1803 authorizing the federal executive to define the location of the new capital in the site of the Planalto Central site. In the same year created the Commission on New Location of Federal Capital, which hired Cruzeiro do Sul Aerofotogrametria to carry out the aerophotogrammetric survey of 52,000 km^2, which was completed in 1954. Studies of photo-interpretation and elaboration of mosaics and maps of the top five places were made by Comissão do Vale do São Francisco and the American company Donald J. Belcher and Associates Incorporated (SILVA, 1971).

5.2 Surveys of large areas

In addition to the surveys carried out within the work programs of systematic mapping of the DSG and IBGE, which are still in progress, and others, like the SUDENE, already discussed, there were surveys carried out by international agreements or by special programs such as RADAM, covering extensive areas in Brazil.

Brazil has not completed its systematic mapping at 1:100,000 scale so far, although having at its disposal large surveys of the projects Trimetrogon and AST-10-USAF, run by the U.S. Air Force, which could have been more used.

In 1940 an intensive campaign was conducted to map the entire Brazilian territory on the scale of 1:1,000,000. At this time the municipalities were required to submit their maps, and the mapping was done mainly by topography. Of course there was the need for larger-scale maps such as 1:50,000 to 1:250,000, but mapping in these scales only started began in the 1960's (PINTO, 2006).

Surveys were performed using the Trimetrogon cameras by the U.S. Air Force during the World War II, between 1943 and 1945, when more than half the national territory was photographed, at scale 1:40,000. The photographs were in the custody of the former CNC (National Counsel of Cartography) in Rio de Janeiro. Figure 17 shows a section of the Trimetrogon flight map (SUDENE, 1968).

The flight AST-10-USAF was conducted by the U.S. Air Force between 1964 and 1967, in a 1:60,000 scale, covering an area of about 1,447 sheets at 1:100,000 scale, under the responsibility of the CME Brasil-EUA (Executing Joint Commission Brazil-USA), based in Rio de Janeiro (SUDENE, 1968). The field support was carried by the Shiran method.

But up to year of 1970 photos of AST-10-USAF flight were not converted into maps (BARRETO, 1970). The deficiency in Brazilian mapping of Brazil is also shown by Barreto (1972) that accounts for all the sheets printed by different agencies in the period between 1895 and 1971: for maps on the scale 1:100.00 there were only 390 sheets or 12.8%; and for 1: 50,000 only 678 sheets or 5.7%.

The RADAM project aimed to study and perform geological research in the Amazon and part of the Northeast. It was an initiative of the DNPM (National Department of Mineral Production), and performed the mapping of about 1,500,000 km^2, in 1971, between the parallels 0º 30'S and 11º 00'S and the meridians 42º 00'W and 63º 00'W, creating 125 sheets of 1º x1º (CORREA, 1971; MOURA, 1972).

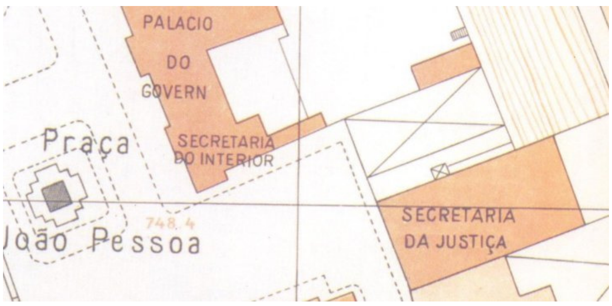


Fig. 15 - Cut out of the first map of São Paulo, 1:1000 scale (IDOETA et al, 2004).

Fig. 16 - Cut out the first map of Sao Paulo, 1:5000 scale (IDOETA et al, 2004).

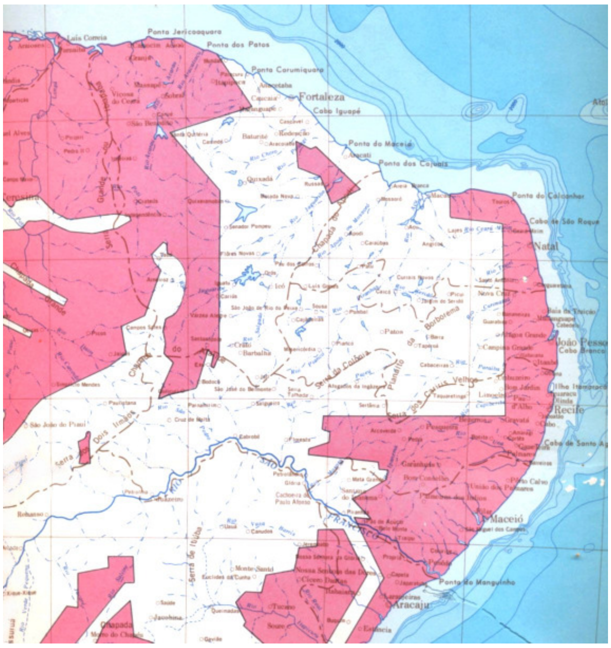


Fig. 17 - Excerpt from the area of the Northeast with Trimetrogon survey (in magenta) (SUDENE, 1968).

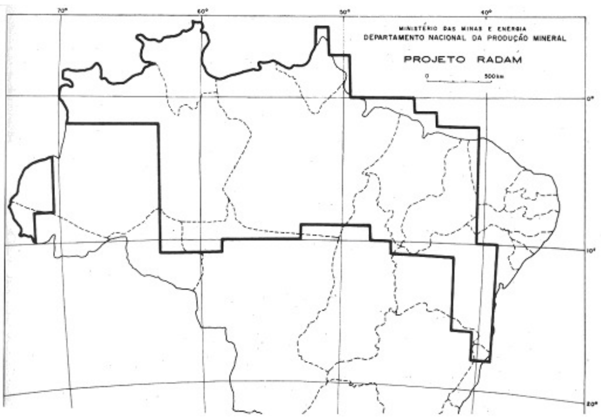


Fig. 18 - Area covered by the RADAM project (MOURA, 1972).

In the RADAM project was used the most advanced technology available at the time: side-looking airborne radar (SLAR), which was applied in an area with these proportions for the first time. The sensor was Goodyear's Radar model 102, resolution of 20m in the band X. The project was executed by Lasa Engenharia e Prospecções S.A, with the participation of companies Serviços Aéreos Cruzeiro do Sul, Serviços Aerofotogramétricos Cruzeiro do Sul, and American companies: Aero Service Corporation and Goodyear Aerospace.

During the flight were simultaneously acquired six different images of the ground with radar, and more two photographs: one color infrared (scale 1:130.000) and one multi-spectral (scale 1:73.000).

The original project was expanded to more 604,000km^2 (MOURA, 1972). In addition to maps and images were produced sheets of 1:250,000 (1°x1° 30 ') by the IBGE to address areas in need of that scale topographic maps. Figure 18 shows the area covered by the RADAM project.

5.3 Digital Mapping

The first aerial photogrammetric mapping with numeric or analytical plotting specifications, in Brazil, supported by the CAD program, was conducted between 1988 and 1990, for the Metropolitan Region of Recife, by the former FIDEM (Development Foundation of RMR) in an area of 200km^2 in 436 sheets, scale 1:1000. (CARVALHO, 2003). Because that requirement all companies participating in the project had to adapt their analog equipments with servo motors, to digital-analog converters of mechanical movements for signals interpreted by computer.

5.4 Companies of Aerial Photogrammetry

The first aerial photography company to operate in Brazil was the SARA, followed by Sindicato Condor. For several years the largest companies were Serviços Aerofotogramétricos Cruzeiro do Sul, in Rio de Janeiro, and VASP Aerofotogrametria, in São Paulo, both now extinct. A more detailed history about the creation of aerial photogrammetric companies of Brazil is found in Idoeta et al (2004). Currently, mid-2011, there are 28 companies qualified for photogrammetry in Brazil.

The Aerofoto Cruzeiro do Sul was created in 1937 as a section in the old Sindicato Condor, Lufthansa subsidiary, a German company, which has created a Photogrammetry section, and for which personal tech and equipments were brought from the Zeiss house, but was nationalized during the World War II. At that time the Division of Photogrammetry was known as "Aerofoto". When the Condor was nationalized became a department of the company Serviços Aéreo Cruzeiro do Sul S.A. In 1948 that same Division of Photogrammetry was transformed into a standalone company named Serviços Aerofotograméricos Cruzeiro do Sul and some time later named Aerofoto Cruzeiro do Sul

(AEROFOTO CRUZEIRO DO SUL, 1972; IDOETA et al, 2004).

The enterprise Aerofoto would be considered one of the major photogrammetry organizations in the world and made surveying of about 7,858,000 km^2, with only flights in Brazil, and also participated in the largest survey with radar at that time, RADAM project, of about 4,600,000 km^2.

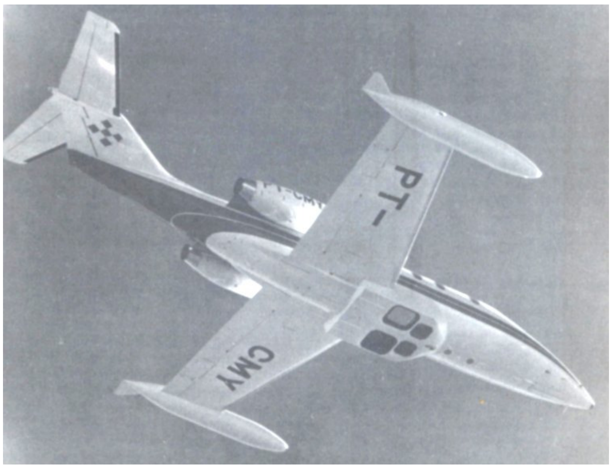


Fig. 19 - Aerofoto Cruzeiro's Jet, published in the Manual of Photogrammetry 4th edition of 1980 (SLAMA, 1980).

In the late 60's Mesquita (1958) related the assets of the company: six planes, two C-5 stereoplanigraphics, one C-7 stereoplanigraphic, more than 10 Aerialmultiplex, and equipment for terrestrial support.

The Aerofoto Cruzeiro was the owner of the Lear Jet JC 2 Intercontinental, speed 890km/h, able to reach an altitude of 15000m (KLOTZEL, 1984). Only with an aircraft at this altitude it is possible to get pictures on a small scale (up to 1:100,000 scale with f = 150mm) and until now few companies in world have that capacity. Curiously, appears in the Manual of Photogrammetry 4th Edition, 1980 (SLAMA, 1980), on page 292, a photograph of that cited Learjet, with registration PT-CMY (Figure 19).

In Sao Paulo, in 1952 was founded the VASP Aerofotogrametria SA. The company had a Nistri camera, 23x23 film, which were converted to glass plates for use in the Photocartograph stereoplotter Beta, also from Nistri. Between 1962 and 1964, the company was modernizing and equiping itself with telurometer MRA3, stereoplotter A7, A8 and B8 and camera RC8 WILD. The VASP changed its name to Terrafoto SA Atividades de Aerolevantamentos, Decree No. 8451 of September 1, 1976, of the Governor of São Paulo, and became extinct in 1992. The current company BASE Aerofotogrametria e Projetos SA is that holds the responsability of keeping the entire photo collection of the extinct VASP. (IDOETA et al., 2004).

6. DIGITAL PHOTOGRAMMETRY

The first operational digital system appeared in 1980 from a contract between the company Helava Associates and the U.S. government (SILVA, 2000).

Since 1990 the digital photogrammetry is a rapid development, follows several technology areas and at the current stage can be seen important changes in concepts and operational standards.

6.1 New concepts and standards

The most interesting advances in photogrammetry are driven by technology in areas such as electrical engineering, computer science, machine vision, robotics, visualization, animation, artificial intelligence, multi-media and geosciences. The development is continuous and step by step, from integration and data fusion between photogrammetry, terrestrial and aerial laser scanner, high resolution satellite imagery, InSAR; trough generation of DSM, automatic extraction of features such as roads, buildings and vegetation; to the generation and integration of photogrammetric data for GIS (GRUEN, 2008).

These main developments can identified in:

· complete system with automatic functions

· integrated systems for close range, aerial e sattelital images

· news standards of photogrammetric digital images.

The concept of digital photogrammetry has evolved to Digital Photogrammetric System, which integrates digital photogrammetry with the computer sciences and computer vision to perform automatic operations. These automation functions can be found into three forms: semi-automatic (operator interacts with the computer), automatic (operator enters inputs) and fully automatic (works completely by the computer) (HEIPKE, 2001).

There is a change in the three common distinct lines of software development for processing:

satellite, aerial photogrammetry and close range photogrammetry. Today the trend is to integrate everything into one. The flexibility of these systems allows radiometric manipulation, special features for remote sensing, 3D modeling, animation and GIS functions. Everything can be integrated (GRUEN, 2008).

Aerial photogrammetric digital cameras, frame or push-broom, on the market, has some differences from the analog cameras (TRINDER, 2007):

- Coverage are smaller that of standard film cameras;
- The opening angle of cross-track and along-track is less than 50 º;
- The ratio B / H is about 0.7 for push-broom camera to 0.3 for frame camera;
- Frame camera tends to use high overlap of 85%, therefore get highly redundant imaging;
- True or near-true orthophotos are possible.

In Brazil photogrammetry companies have followed the development of global digital photogrammetry closely. Aerial photogrammetric digital cameras came onto the market in 2001 and in 2006 the company Esteio Engenharia e Levantamentos S.A.had already acquired one of them. Nowadays some of them already have digital cameras and laser scanning systems, aimed at acquiring data for DSM and DTM. Also, the FAB (Brazilian Air Force) is already equipped with ADS-80 camera.

As a result of research was developed at UNESP an imaging system type multi-camera, the system SAAPI (Airborne System of Acquisition and Pos-processing of Digital Imaging). The imaging platform consists of two digital cameras Hasselblad, medium format (22 Mp) and a Sony digital camera (8 Mp) with an infrared filter, used for environmental applications. The camera is being used commercially by the company Engemap Engenharia e Mapeamento (RUY et al, 2007; BAZAN, 2008).

6.2 High-resolution satellite

The images of high resolution satellites began to compete with the aerial imagery for mapping since the late 1990s (SILVA & DALMOLIN, 1997).

After the success of the satellites Spot-5, IKONOS, QuickBird Eros A and B, CARTOSAT 1 and 2, Rocsat-2, KOMPSAT-2, Worldview-1 and 2 and GeoEye definitely the high-resolution images have taken hold in the market. As most of these sensors are capable of stereoscopic images for 3D processing is required to use the photogrammetric method (GRUEN, 2008).

Brazil is also developing a satellite program, the CBERS (China Brazil Earth Resources Satellite), which has the effective participation of INPE. The first satellite, CBERS-1, was released in 1999 (active until 2003), followed CBERS-2 launched in 2003 (active until January 2009), 20m resolution, and who had the ability to take images to form stereo pairs. This capability was not exploited, but some of these images were tested aiming at systematic mapping by the IBGE (RAIVEL & MARANHAO, 2005). The CBERS-2B, launched in 2007 (active until April 2010), had a HRC (High Resolution Camera) sensor panchromatic, 2.7 m resolution, but without the possibility of stereoscopy. The other satellites CIBERS-3, CIBERS-4, don't have dates for their releases. The projects include four sensors, one of which with the possibility of stereoscopic images with a resolution of 5m panchromatic and 10m multispectral.

CONCLUSIONS

This work is a review about the uses, developments, applications and historical accounts of the general development of photogrammetry in the world and more specifically in Brazil, which has given rise to the following conclusions:

- The local development of photogrammetry followed the development of abroad, with a few years apart, or even pioneered, such as the survey of São Paulo and the Project RADAM.
- Even when the photogrammetry, in the early twentieth century, was practically still experimental, the DSG has acquired the most modern equipment available and also sponsored the development of one, the Autoestereógrafo.
- Today private companies and governmental entities are already equipped with the new digital photogrammetric cameras and most modern processing systems on the market.

The author may have omitted any names, facts or important data, and therefore earnestly request that the failures are reported to him so he can make corrections in time of need.

BIBLIOGRAPHIC REFERENCES

AEROFOTO CRUZEIRO DO SUL. **Revista Brasileira de Cartografia**. n. 7. p. 28-33. 1972.

ANDRADE. J. B. **Fotogrametria**. Curitiba: SBEE. 242 p. 1998.

BARRETO, A. Mapeamento do Brasil a Curto Prazo. **Revista Brasileira de Cartografia**. n. 1. p. 38-43. 1970.

BARRETO, A. Mapeamento do Brasil. Folhas Impressas pelos diferentes órgaos no periodo compreendido entre 1895 e 1971. **Revista Brasileira de Cartografia**. n. 7. p. 14-15. 1972.

BARRETO, A. Sinopse Cronológica dos órgãos Cartográficos no Brasil. **Revista Brasileira de Cartografia.** n. 20. p. 14-15. 1978.

BAZAN, W. S. **Calibração de um Sistema Dual de Câmaras Digitais**. Dissertação de Mestrado. Presidente Prudente: Programa de Pós-Graduação em Ciências Cartográficas. 158 p. 2008.

BURTCH, R. **History of Photogrammetry**. 2008. Institute for Digital Mapping, Ferris State University. Disponível em: <www.ferris.edu/faculty/burtchr/sure340/notes/history.pdf.> 36 p.

CARVALHO, R. C. **Estudo das Distorções do Sistema Geodésico de Referência da Região Metropolitana do Recife.** Dissertação de Mestrado do PPGCGTG da UFPE. Recife. 99 p. 2003.

COELHO, L.; BRITO, J. N. **Fotogrametria Digital.** Rio de Janeiro: Editora da Universidade do Rio de Janeiro.196 p. il. 2007.

CORREA, H. V. Levantamento Radarmétrico da Amazônia no Programa de Integração Nacional. **Revista Brasileira de Cartografia**. n. 2. p. 14-16. 1971.

DSG. **Radiografia da Amazônia**. Dsg Diretoria do Serviço Geográfico do Exército. Disponível em http://www.dsg.eb.mil.br/index.php/projetos-e-convenios/radiografia-da-amazonia.

ESPARTEL, L. **Topografia**. Porto Alegre: Editora Globo. 655 p. il. 1973.

GEMAEL, C. **Introdução ao ajustamento de Observações Aplicações Geodésicas**. Curitiba: Editora UFPR. 319 p. 1994.

GRUEN, A. Cap 2 Scientific-technological developments in photogrammetry and remote sensing between 2004 and 2008. In: **Advances in Photogrammetry, Remote Sensing and Spatial Information Sciences: 2008 ISPRS Congress Book** – Li, Chen & Baltsavias (Eds). Londres: Taylor & Francis. P. 21-25. 2008.

GUERRA, F.; PILOT, L. Historic Photoplanes. In: **IAPRS** v. XXXIII, Part 5, Amsterdam. CD-ROM, p. 611-617. 2000.

HEIPKE, C. A Review of the State-of-art for Topographic Application: Digital Photogrammetric Workstations,.**GIM International**, Vol.15 No. 3. 2001.

IDOETA, I.; IDOETA, I. V.; CINTRA, J. P. **São Paulo Vista do Alto 75 Anos de Aerofotogrametria**. São Paulo: Editora Érica Ltda. 96 p. il. 2004.

DOLEZAL, H. E. (Ed). **Internationales Archiv für Phtogrammetrie**. Internationalen Gesellschaft für Photogtrammetrie. I Band. 1908-1909 em pdf. Disponível em: <www.archive.org/details/archivesinternat01inte>. 1909.

DOLEZAL, H. E. (Ed). **Internationales Archiv für Phtogrammetrie**. Internationalen Gesellschaft für Photogtrammetrie. II Band. 1909-1911 em pdf. Disponível em www.archive.org/details/archivesinternat02inte . 1911.

DOLEZAL, H. E. (Ed). **Internationales Archiv für Phtogrammetrie**. Internationalen Gesellschaft für Photogtrammetrie. III Band. 1911-1913 em pdf. Disponível em www.archive.org/details/archivesinternat03inte . 1913.

DOLEZAL, H. E. (Ed). **Internationales Archiv für Phtogrammetrie**. Internationalen Gesellschaft für Photogtrammetrie. V Band. 1915-1919 em pdf. Disponível em: <www.archive.org/details/archivesinternat05inte>. 1919.

HOBBIE, D. **The Development of Photogrammetric Instruments at Carl Zeiss in Oberkochen**. Munique: Deutsche Geodatische Kommission. 144 p. 2010.

JORDAN, W. **Tratado General de Topografia** Tomo II. Barcelona: Editorial Gustavo Gili S.A. 572 p. 1944.

KLOTZEL, E. (Ed). Aerofotogrametria no Brasil. **Flap Internacional**. Grupo Editorial Spagat. N. 157, v. 23. p. 20-26. 1984.

LEAL, P., R. B. A Obra Cartográfica dos Militares no Passado e no Presente do Brasil. **Revista Brasileira de Cartografia**. n. 6. p. 8-10. 1972.

LUGNANI, J. B. **Introdução à Fototriangulação**. Curitiba: Impressa Universitária da UFPR. 134 p. 1987.

MARANHÃO, M. R. A; RAIVEL, J. P. C. Análise de pares estereoscópicos obtidos pelo CBERS II – Primeiros testes utilizando fotogrametria digital. In: **Anais** XII Simpósio Brasileiro de Sensoriamento Remoto, Goiânia. INPE, p. 999- 1004. 2005

MCGLONE, J. C. (Ed). **Manual of Photogrammetry** 5th edition. American Society for Photogrammetry and Remote Sensing. 1151 p. 2004.

MESQUITA, P. F. **Curso de Topografia**, 2ª ed. (mimeografado). São Paulo: Escola Politécnica da USP. 489 p. il. 1950

MESQUITA, P. F. Capt 1: Tratado de Aerofotogrametria. In: **Enciclopédia Técnica Universal**. Vol. 1. Porto Alegre: Editora Globo. 1958.

MOURA, J. M. Levantamento dos Recursos Naturais das Regiões Amazônica e Nordeste do Brasil, por meio de Radar e outros Sensores. **Revista Brasileira de Cartografia.** n. 6. p. 4-7. 1972.

PETRIE, G. A Short History of Bristish Stereoplotting Instrument Design. **Photogrammetric Record**. v. 50, n. 50, p. 213-238. 1977.

PINTO, S. S**. Impactos da Mudança do Referencial Geodésico no Mapeamento Municipal.** Dissertação de Mestrado. Rio de Janeiro: Instituto Militar de Engenharia. Mestrado Engenharia Cartográfica. 160 p. 2006.

ROCHA, C. H. O.; PIORNO, J. L; FREIRE, R. R; MEDINA, I. A. Uma Discussão Histórica sobre a Fotogrametria. In: **XXI Congresso Brasileiro de Cartografia**. CD-ROM. 10 p. 2010.

ROCHA, G. A. Mapeamento do Nordeste. **Revista Brasileira de Cartografia**. n. 2, p. 29-33. 1971.

RUY, R. S.; et al. Sistema aerotransportado leve de aquisição de imagens digitais – SAAPI. In: Anais **XIII Simpósio Brasileiro de Sensoriamento Remoto**, Florianópolis, Brasil, 21-26 abril 2007, INPE, p. 1329-1335.

SILVA, D. C.; DALMOLIN, Q. Expectativas com os Satélites de Alta Resolução Espacial no Mapeamento In: **Coletânea de Trabalhos Seminário: Impactos das Novas Tecnologias na Engenharia Cartográfica**. Presidente Prudente: UNESP. 11 p. 1997.

SILVA, D. C.; CARNEIRO, M. C. S. M. Balanço do Plano Cartográfico do Nordeste com a Extinção da SUDENE. In: **COBRAC 2002**. Florianópolis. CD-ROM. 10 p. 2002. 10 p.

SILVA, E. **História de Brasília**. Brasília: Coordenada/INL. 292 p. 1971.

SILVA, I. A Fotogrametria é Definitivamente Digital. **Revista Mundogeo**. Disponível em: <http://mundogeo.com/blog/2000/01/01/a-fotogrametria-e-definitivamente-digital/>.

STEWART, N. C. Surveying from the Air. **Journal of the Royal Astronomical Society of Canada**. p. 153-165. 1931.

SLAMA, C. C. (Ed). **Manual of Photogrammetry** 4th edition. American Society of Photogrammetry. 1056 p. 1980.

SUDENE. **Inventário dos Levantamentos de Recursos Naturais do Nordeste**. Ministério do interior, Superintendência de Desenvolvimento do Nordeste, Divisão de Cartografia. 9 mapas. 1968.

TRINDER, J. **State of The Art of Photogrammetry and Remote Sensing**. In: Earth from Space, Third International Conference. Moscow. 2007. Disponivel em: www.transparentworld.ru/conference/2007/Trinder.ppt