RECOVERING PORTUGAL AERIAL IMAGES REPOSITORY

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ABSTRACT:

The principal users of aerial photography have always been the military and mapping agencies. Aerial photographs were considered for several decades as a means to an end and were no longer interesting once the map was compiled. In the era of digital photogrammetry and internet the photograph itself became more important. Nevertheless, traditional and web map producers strive to deliver up-to-date products and old photographs just don't fit in the concept. Other users of aerial photos are found in the areas of geology, geography, history, and archaeology. These are rather interested in old aerial photographs and in series of aerial photos of a particular site or region. In Portugal, aerial surveys for mapping purposes might have started by the end of the thirties of the 20th century as documented by the oldest collection of vertical aerial photos existing in the archives of the Instituto Geográfico do Exército (IGeoE) in Lisbon. Being the oldest visual witnesses of the country, the relevance of the information contained in those photographs is unquestionable. The objective of this project is precisely the recovering of this important national aerial photographic heritage that hibernates in analogue format in the archives, in order to make it accessible and explorable by the scientific community and by the general public.

1. INTRODUCTION

1.1 Motivation and aims of the project

Since the invention of airplanes and their adaption as a platform for photographic cameras allowing systematic surveys of the earth surface, aerial photography has been efficiently applied for the better and the worse of mankind. In fact, if it is true that mapping became much more rentable after the introduction of aerial photo plotting and triangulation allowing the production of good maps as a basis for constructive projects, it is also true that, in war times, aerial photography was used as a strategic weapon, even "the most important weapon available for defensive and offensive operations" as stated 1944 by Medina in the introduction to the preliminary edition of the ASP Manual of Photogrammetry (McCurdy et al., 1944). Photogrammetry and photo interpretation reached, especially during World War II, levels hardly attainable at the same speed in peace periods. Aerial cameras, for instance, underwent incredible development in Europe as well as in the United States of America, as witnessed by contemporary technical literature (Reading &Deeg, 1948; McCurdy et al., 1944). Nearly every working concept modern aerial cameras base on, such as the assembling of four cameras for a wider field of view, the continuous strip camera, the nine lens panoramic camera, can be found in books and magazines prior to 1945 (Lüscher, 1937; McCurdy et al., 1944). The principal users of aerial photography have always been the military and mapping agencies. Aerial photographs were considered for several decades as a means to an end and lost much of their interest once the map was compiled. In the era of digital photogrammetry and internet, however, the photograph itself gained in importance. On one hand orthophoto production became easier with digitised photos and on the other hand, image information about the terrain as a complement to its symbolic representation in a map turned to be a 'must' in web map applications. Nevertheless, traditional and web map producers strive to deliver up-to-date products and old photographs just don't fit in the concept. Other users of aerial photos are found in the areas of geology, geography, history, and archaeology. These are rather interested in old aerial photographs and in series of aerial photos of a particular site or region. Several studies including small sets of aerial photos from old flights together with other geographic information are well depicted in literature (Marques, 2006; Redweik et al.2008, Sequeira, 2006). Geomorphologic and landscape evolution studies prize old aerial photos highly because of the wide visual time window they allow. In Portugal, aerial surveys for mapping purposes might have started by the end of the thirties of the 20th century as documented by the oldest collection of vertical aerial photos existing in the archives of the Instituto Geográfico do Exército (IGeoE) in Lisbon. This period coincides with the start of the production of the military topographic map in scale 1:25000 by photogrammetric means, with enormous economic advantages over the preceding map production by means of extensive field surveys. Being the oldest visual witnesses of the country, the relevance of the information contained in those photographs is unquestionable not only for the already mentioned studies involving temporal evolution of phenomena but also for legal questions regarding old property boundaries registered, for instance, as lines joining stones or other natural objects that have changed or no longer exist. The objective of this project is the recovering of this important national aerial photographic heritage that hibernates in analogue format in the archives, in order to make it accessible and exploitable by the scientific community and by the general public. This includes digitizing the repository, radiometric and geometric recovering of each aerial photograph

and finally organizing a photo-geographic database for the old photo collection.

1.2 Description of the repository

The repository of old aerial photographs in the IGeoE includes about 60 000 photos preserved in two rooms, one of them refrigerated. Shelves full with photographic material reach from the floor to the ceiling in both of the rooms. Glass plates and diapositives on film are saved in the refrigerated room as well as original films wound on spools kept in metallic cylindrical bins. On the other room paper prints of the photos are gathered in envelopes inside archiving boxes labelled with the number of the map sheet of the 1:25 000 scale topographic map they presumably belong to. This label is also the only existing link between the images and the ground for most of the sets. Age and unusual circumstances, as relocations and a fire occurred 1975 in the former institute's facilities, damaged parts of the collection. There is no report on what is lost or on what is left.

Table 1: Sets of old vertical aerial photos in the IGeoE archives

Name	Date of flight	Format (cmxcm)	Quantity of photos
X	unknown	13 x 18	unknown
SPLAL	1937-1952 (?)	18 x 18	about 40000
RC8	1957- (?)	18 x 18	
RAF	1947	23 x 23	about 12000

A first analysis of the IGeoE collection and related information revealed the existence of four distinct sets of old photographs, either on glass or on film, summary described in table 1. The sets known as SPLAL and RAF constitute the largest and oldest systematic surveys and are, therefore, the most requested. They are also the object of the first phase of this project. Additional information about these particular two photo sets was gathered mainly through a not yet completed historical research undertaken in inland and abroad.

RAF flight

The RAF set was flown by the British Royal Air Force between May and August 1947 and covered originally the whole country with east-west strips. The original images are kept in film rolls in metallic bins to a constant temperature of 13.3ºC and 23% relative humidity. There is an old photo index collection for this set in the archive, drew on a translucent paper over a 1:250 000 map of Portugal. About 150 different sorties are shown in this index (fig.1). According to oral information, a part of this set was lost 1975 in the mentioned fire, but this fact couldn't be confirmed yet. The photos present a scale of ca. 1:29500 and there was neither a calibration certificate nor any information about the used camera. The format of 23 cm x 23 cm, the date just after WW II and the fact that, after the entry of the USA in the war, the RAF was equipped with American mapping and reconnaissance cameras (Evidence in Camera, 1945) led to the presumption that a Fairchild camera could have been used, maybe a K17 with a 6'' Metrogon objective (fig. 2), the most common and versatile mapping and reconnaissance camera at that time in the U.S.. The 'Luftbilddatenbank' in Würzburg, which had access to detailed data related with these RAF sorties 1947 in Portugal, kindly confirmed the presumption. The value of 152.4 mm for the focal length came from the same source (fig.3).

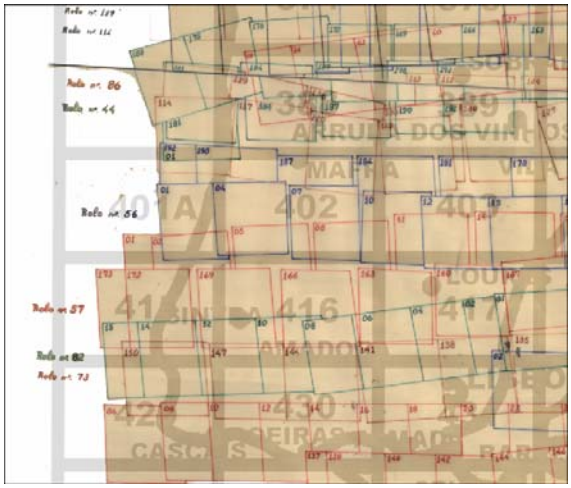


Figure 1. Part of the original photo index over a cartogram 1:25000 (IGeoE archives)

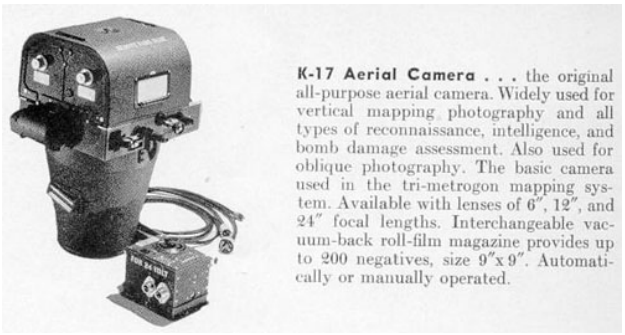


Figure 2. The Fairchild K-17 aerial camera, here with 12"focal length (Verney, 2009)

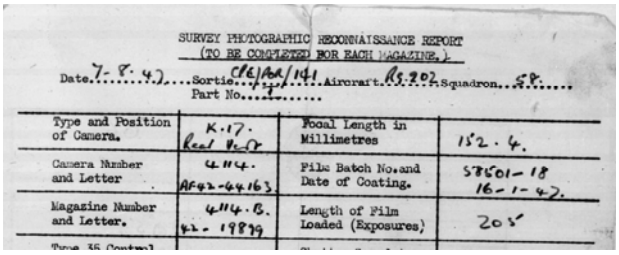


Figure 3. Part of the original survey report (Courtesy of Luftbilddatenbank-Würzburg)

SPLAL flight

The first ever existing Portuguese photogrammetry company, named Sociedade Portuguesa de Levantamentos Aéreos Limitada – SPLAL, was engaged for the first national mapping flights. The SPLAL set seems to have been flown block wise in several years according to the needs of map production. Sparse registers state that the company existed between 1937 and 1949 (Matos, 2007), other refer 1930 as the begin (SPLAL, 1947). In addition, a cartogram was found in the archives dating the several blocks over the whole country between 1937 and 1952

(fig.5). Samples of photos indicated as belonging to the block of 1952 (in the South) look exactly the same as samples from 1942 and 1943 as coming from the same camera.

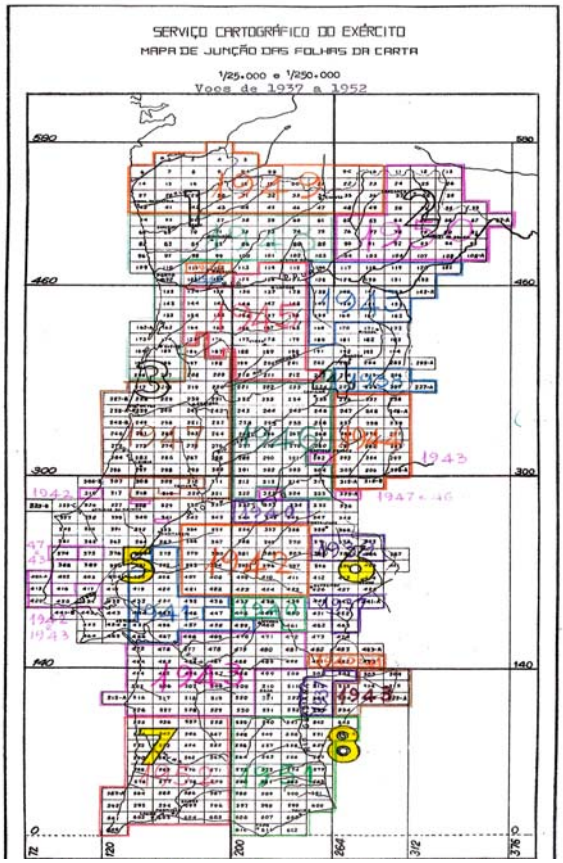


Figure 4.Dating of SPLAL flights over cartogram for 1:25000 (original in crayon- IGeoE archives)

This fact leads to the conclusion that either the company existed at least till 1952 or the camera was sold and another company did the later flights. In the archive there is another set of photographs mixed with the SPLAL photos and also (erroneous) classified as SPLAL, a term apparently applied somewhere in time by the archivists, with the meaning of 'old photos' or 'unusual formats'. Both sets are sized 18cm x 18cm. and have an approximate scale from 1:15000 and 1:27000. The first set presents a focal length of 204.4 mm and the second 115.14 mm on their margins (fig. 5).

Figure 5. Examples of photos of the repository: left –SPLAL; right – RC8 (IGeoE archives)

Once more, there is no calibration certificate or any other information about the cameras except for the focal length. The camera of the second set could be definitely identified as a Wild RC8, presumably one possessed by the Portuguese Air Force (FAP). These facts locate the second set a bit later in time, namely after 1956, date of the phase-in of this camera in the market. As for the real SPLAL flights, identifying the camera used here for hasn't been an easy task. An activity report from 1947 existing in the National Library in Lisbon refers to "several aerial cameras existent" without further specification (SPLAL, 1947). Besides the focal length of 20-21cm, the position and form of the fiducial marks, the format 18 x 18 and the time interval 1937-1952 should be clues enough for a definite identification. However, a thorough research in contemporary publications, such as several published editions of the ASP Manual of Photogrammetry since 1944, the Photogrammetric Engineering issues from 1940 till 1950, the BUL issues since 1927 till 1950, has only revealed an astonishing reduced number of reproduced aerial photos in several thousands of pages about photogrammetry! Dozens of cameras were candidates but a photo like the SPLAL ones couldn't be found anywhere.

Since the form of the fiducial marks (fig. 6) is somehow similar to the ones from later Zeiss Oberkochen RMK cameras, retired Zeiss collaborators and Professors, from Oberkochen and Jena, were asked for advice.

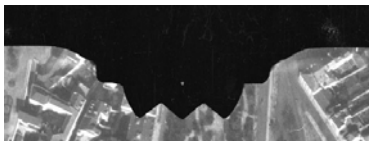


Figure 6. Fiducial mark from SPLAL set

According to them, there is a high probability that the SPLAL flights were done with a Carl Zeiss Jena RMK S1818 or a RMK HS1818 camera, using an Orthometar 1:4.5 objective with 21cm focal length, distributed by Zeiss-Aerotopograph in Jena since 1935.

2. RECOVERING THE RADIOMETRY

A test region was defined in order to organize a suitable workflow from the analogue archive to the digital photo-geographic database. The region was an approximate square with 40 km side length located in the Lisbon peninsula. 13 E-W strips from RAF flight, with 171 photos, and 35 strips with variable orientation from SPLAL flight, with 356 photos, cover the test region. Although representing only about 1.5 % of the complete coverages this is a significant sample from both sets in terms of different preservation stages and image quality. The first step consisted in scanning the original negatives using an Intergraph PhotoScan TD1000. A pixel size of 21 μm was chosen as a compromise solution. Some SPLAL photos presented indeed a better resolution but most of the RAF photos would be oversampled if a smaller pixel had been chosen. The amount of data to keep in the database was also a decisive criterion. The indexing of the photos over a digital map 1:25000 was performed parallel to the scanning (fig.7) as well as a first quality classification. The used reference map was a set of digitized first editions of the 1:25000 military topographic map, dating from 1928 till 1946. The detail resemblance between the photos and contemporary maps turned the indexing task easier and more accurate. Most of the obtained digital images present several radiometric problems. These could be classified in three main types:

- general haze or darkness affecting the whole image, mostly in SPLAL photos,

- non uniform illumination in almost all RAF photos,
- partial lack of emulsion in isolated cases

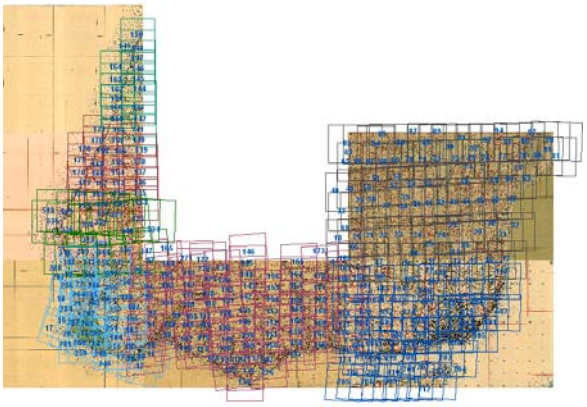


Figure 7. Photo index over 6 first editions of 1:25000 map

While the latter can be seldom removed or repaired, combinations of digital processing operators are being tried to solve the other radiometric problems.
For the radiometric optimization of the SPLAL images a "Contrast-limited adaptive histogram equalization " (CLAHE) technique has been applied, which enhances the contrast of images by transforming the intensity values on small data regions (tiles) rather than the entire image. A batch file was implemented in Matlab® basing on the 'adapthisteq' function. Several groups of photos with homogenous contrast situation were automatically processed by using different configurations of input parameters such as number of tiles, clip limit or distribution (fig.8).

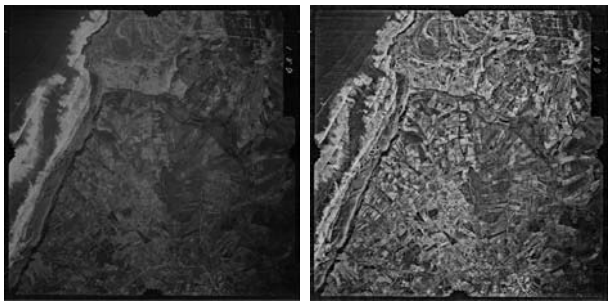


Figure 8. SPLAL photo before (left) and after (right) applying 'adapthisteq' .

A similar approach using tiles is performed by RADCOR, a routine from the software package BLUH from the Leibniz University Hannover basing on the Wallis filter. Haze affected images showed much more detail after having been processed with RADCOR (fig.9).

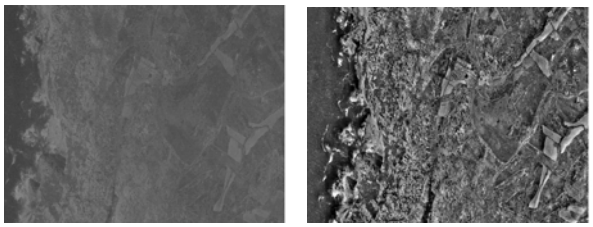


Figure 9. Haze affected photo detail (left) and same detail after applying RADCOR (right).

The radiometric situation by RAF is more heterogeneous. In some photographs vertical bright strips are visible (fig.10), while in others the central zone of the photograph is much brighter than the corners (fig. 11 left).

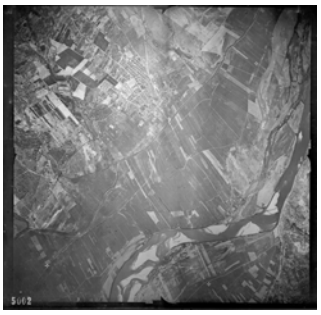


Figure 10. Example of a RAF photo with vertical light effects

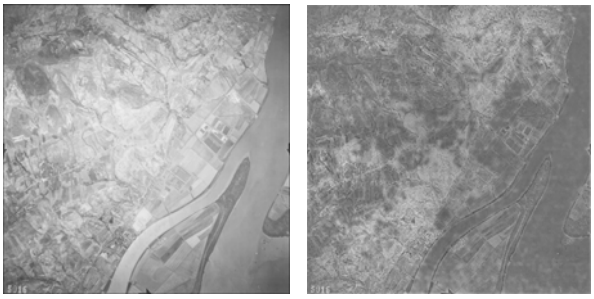


Figure 11. RAF photograph with radiometric problems, before (left) and after (right) processing.

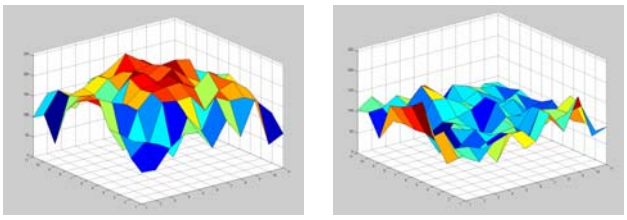


Figure 12. Surface showing the luminosity of the photograph background before (left) and after (right) processing.

In order to minimize the non uniform luminosity of these images, a program was developed in Matlab® allowing a batch processing of the photos. Basically the program performs a morphological opening of the image. This operation allows its details to be "erased" leaving only the background (fig.12). This temporary image contains the luminosity effects and must be subtracted from the original image. This way it becomes possible to obtain an aerial photograph with all the details on it and with uniform luminosity (fig.11 right and 12 right). Since each photograph in digital format occupies almost 115 Mb, a compromise between performance, memory usage and processing time is necessary. These constraints force the division of each image in smaller tiles, in which the morphological opening is applied independently. After joining the intermediate images, there are many discontinuities at the boundaries. An average filter smoothes the result. This final image is then subtracted from the original one. The geometry of the objects remains unchanged after this operation. Consecutive photos on a strip show a better general radiometric 'resemblance' than the originals (fig.13), where the luminosity effects change drastically the local radiometry of an object and

its neighbourhood from photo to photo, affecting the success of automatic homolog point detection algorithms.

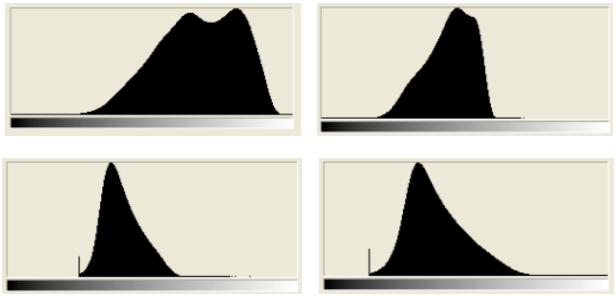


Figure 13. Histograms of two consecutive photographs before (top) and after (bottom) being processed.

3. RECOVERING THE GEOMETRY

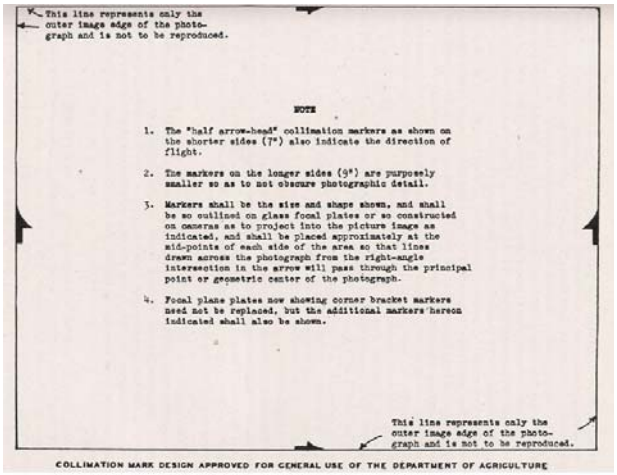
In order to allow a photogrammetric utilization of the old photos in the future it is intended to associate to each image in the database the respective interior and exterior orientation parameters so that the primitive spatial orientation of the image can be easily recovered. Since old aerial coverages don't meet nowadays standards, several aspects must be considered to overcome the consequent problems in the determination of those parameters as described below.

3.1 Interior Orientation

Since there are no calibration certificates available, the only camera information existing is a value for the focal length for RAF and another for SPLAL. There are neither calibrated photo coordinates for fiducial marks and principal point, nor any lens distortion information. SPLAL presents four fiducial marks in the middle of the sides with a very well defined white dot in the interior, as shown in figure 6. Unfortunately, all four white dots are not visible at a time in every photo. In most of them only three are clear. For the transformation between pixel and photo coordinates, an approximate camera could be defined by measuring the fiducials in a set of original negatives where all four dots appear and considering the mean values for each mark, in relation to the fiducial centre, as pseudo-calibrated photo coordinates. For the images with four marks, the 6 parameters of an affine transformation between pixel and photo can be calculated and for the images with three marks only the 4 of an Helmert transformation. RAF fiducials are not so well defined (fig.14). They consist of four half-arrows in the middle of the sides in two different sizes. A pair of bigger half-arrows indicates the flight direction. The other pair is intentionally smaller in order not to occupy too much of the photo area. According to the preliminary edition of the Manual of Photogrammetry (1944), this kind of fiducials was approved for general use by the United States Department of Agriculture in 1937.

Figure 14. Fiducial mark of RAF

Their design appears in the "Standard Specifications for Aerial Photography for General Map Work and Land Studies Approved for Federal Use on May 27, 1937" (fig.15). Photos with these fiducials are found in several books for aerial photo interpretation training from the fifties. This kind of marks was useful for recovering the interior orientation in an analogue way. The straight side of the markers pointing to the centre was aligned with the reference lines of the stereo plotting instrument without the necessity of calibrated coordinates of the fiducial marks as it was usual in the era of analogue photogrammetry. Although contemporary, SPLAL photos demonstrate a higher accuracy potential than RAF photos in terms of interior orientation recovery. It is possible that the objective of the RAF coverage was the making of mosaics rather than accurate stereoscopic plotting.


This line represents only the outer image edge of the photograph and is not to be reproduced.

NOTE

1. The "half arrow-head" collimation markers as shown on the shorter sides (7") also indicate the direction of flight.
2. The markers on the longer sides (9") are purposely smaller so as to not obscure photographic detail.
3. Markers shall be the size and shape shown, and shall be so outlined on glass focal plates or so constructed on cameras as to project into the picture image as indicated, and shall be placed approximately at the mid-points of each side of the area so that lines drawn across the photograph from the right-angle intersection in the arrow will pass through the principal point or geometric center of the photograph.
4. Focal plane plates now showing corner bracket markers need not be replaced, but the additional markers hereon indicated shall also be shown.

This line represents only the outer image edge of the photograph and is not to be reproduced.

COLLIMATION MARK DESIGN APPROVED FOR GENERAL USE OF THE DEPARTMENT OF AGRICULTURE

Figure 15. Collimation (Fiducial) Mark Design. The example refers a rectangular photo format (7 "x 9 ") (McCurdy et al., 1944)

A program, ORIRAF, was developed in Matlab® in order to determine the 6 parameters of an affine transformation between pixel and photo coordinates in a direct way instead of deriving them from two sets of identical points. For the RAF photos, an automatic detection of the straight sides of the fiducial marks allows the performance of the interior orientation in a batch mode. (fig. 16). For the SPLAL photos an automatic detection of the white dot is already implemented and a location of the invisible dots through the symmetry of the black marker is in a final developing stage in order to allow also the processing in a batch mode.

Figure 16. Screenshot of the program ORIRAF

The determined parameters for each photo are being exported to the aerotriangulation software ISAT from Intergraph.

3.2 Exterior Orientation

The exterior orientation of the photos will be determined by aerotriangulation of the test block using the software ISAT from Intergraph. The archives of IGeoE have been searched in order to find old field notes with drawings and coordinates referring to Ground Control Points (GCPs) former collected for earlier map versions. A geographic database was built with this information providing an easier location of the points (fig.17). A great number of GCPs (~87%) could be identified in the RAF and SPLAL images and the measuring process of their photo coordinates is in course.

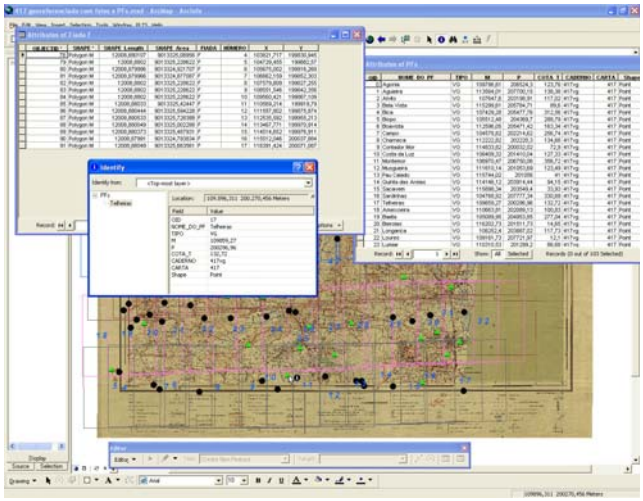


Figure 17. Data view in the GCP geographic database

This approach has been chosen not only because it was the least expensive but also because of the difficulty in finding suitable GCPs in the present days due to considerable changes in the landscape in the past 60 -70 years. From the aerotriangulation results a refinement of the interior orientation parameters is expected, as well as a model for the image distortions caused mainly by the objective but also due to age, maintenance conditions and scanning.

4. CONCLUSIONS

Organizing a photo-geographic database from an analogue archive is a huge task, often overlooked by the later users. Besides the organization, the principal objective of this project is that users be able to explore the images, including their geometric information, without needing to acquire ground control anymore. More than the time consuming scanning of the old aerial photos, their radiometric and geometric recovery represent a demanding process. The fact that nowadays standards are not met in almost any facet of the process requires new routines to be developed, either to perform part of the photogrammetric processing or as an interface to current digital photogrammetric software packages. Such routines, for instance the interior orientation program for RAF and SPLAL, have to be specially tailored to each of the sets. 356 SPLAL photos and 171 RAF photos have been digitized so far, organized in a digital database, radiometric corrected for automatic triangulation and their interior orientation has been determined. Old ground control points have been organized, identified in the images and are being measured for aerotriangulation at the time this paper is being compiled. All the work already done as well as the parallel research in order to identify the cameras lead to the conclusion that working with old aerial photos is a hard but indeed fascinating challenge.

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