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MAPPING FROM AIRBORNE ELECTRONIC CONTROL

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MAPPING FROM AIRBORNE ELECTRONIC CONTROL[1/] [2/]

ABSTRACT

Paper will discuss specifications, acquisition techniques and data reduction processes for mapping from airborne electronic controlled photography. Special emphasis will be given to application of these methods in unsurveyed areas and the project now in progress in Ethiopia.

Estimates of time, cost and accuracy by airborne electronic control will be compared with conventional ground control methods.

Recent and foreseeable future technological advancements in airborne electronic control will be discussed.

1/ By Kenneth W. Rinehart, Assistant Chief, Mapping Branch, Office of Chief of Engineers, Department of the Army.

2/ The illustrations will be issued as addendum to this document.

The requirement for rapid production of maps is accentuated by the increasing needs for man to improve his knowledge of the earth. Of prime importance is the evaluation and exploitation of resources to support improved standards of living and meet the responsibilities of the society of nations. During the second World War, the unsatisfactory status of mapping was emphasized by the lack of adequate maps of many areas where nations were required to commit military forces. The search for peacetime solutions to economic and social problems changes the emphasis from maps for military purposes to maps and related geographic information for planning and execution of long-range development programmes. This change of purpose does not change the sense of urgency. To the contrary - as older nations have continued their involvement in international responsibilities and new nations have struggled to achieve economic stability to parallel their political independence - the need for geographic information has become increasingly important. Many nations now expend a greater portion of their budget on mapping than ever before.

During the past two decades there have been many technological advances which permit increased map production with greater efficiency. One of the most significant of these advances is the evolution of the science of photogrammetry, moving the map compilation process from the plane table in the field to the stereo plotter in the office. The list of accompanying improvements is almost endless - and not yet complete. Perhaps the most important of all is the development of methods to measure distance by electronic equipment. To expedite mapping in remote areas and to minimize costs we are continually investigating procedures for procurement of datum control. Electronic equipment has played a major rôle in this development.

Utilization of electronic distance measuring equipment varies from relatively short range ground measurements of a few hundred metres to highly complex systems involving artificial satellites capable of measuring hundreds of kilometres with high geodetic precision. HIRAN,

which is a modification and refinement of the short range navigation system known as SHORAN, and the Terrain Profile Recorder (TPR), are being used successfully as airborne geodetic measuring equipment. These systems have freed the surveyor and mapper from the limitations imposed by terrain conditions of access and visibility.

HIRAN, when operated with special techniques and auxiliary equipment, can be used to determine the precise distance between an aircraft and each of two ground stations. Distances obtained with the HIRAN system are mathematically reduced to sea level distances which can be applied to the sciences of geodesy and cartography. It is particularly effective for unsurveyed areas where difficulty of ground access all but precludes employment of more conventional techniques.

The United States has used the geodetic application of HIRAN for long range extension of geodetic networks by trilateration over areas where conventional geodetic surveys would have been impossible. These networks are indicated in (figure 1). As it can be seen, the major accomplishments have been the completion of geodetic ties between North and South America, from North America to Europe, and inter-island ties in the Southwest Pacific. The vast area of Northern Canada has been controlled by similar means.

HIRAN trilateration networks are designed to produce first order accuracy. The maximum allowable probable errors of stations referenced to known control is 1:50,000 for stations less than 160 kilometres apart and 1:100,000 where the distance is more than 160 kilometres.

Other papers presented to this conference will discuss the current global geodetic satellite programme which also employs the electronic distance measuring principle.

Here in Africa the Army Map Service has used airborne electronic control for mapping in Libya and is currently co-operating with the Governments of Ethiopia and Liberia in mapping programmes using the same techniques. These methods will permit accomplishment of the

mapping in less time and at lower cost than would be possible by conventional methods. For example, comparative cost estimates for a 58,000 square mile area of Iran were $1,248,000 for ground survey methods versus $850,000 for HIRAN. Similarly, in Liberia the estimated cost for a 37,000 square mile project was $1,300,000 for ground survey versus $814,000. These estimates include the cost of aerial photography. Both situations, although significantly different in terrain and climatic conditions, reflect a fifty per cent savings by using HIRAN techniques.

As with most endeavours, success is largely dependent upon proper advance planning. The acquisition, correlation, reduction and processing of airborne electronic control data can be fraught with errors, mistakes, equipment failures, and the vagaries of natural conditions. Based on experience factors, many of these can be predicted and thus avoided through careful planning. In each case the work to be done must be designed to fit the conditions of the terrain and the end product desired.

In the planning of a mapping project utilizing electronic methods, the preliminary design of operation is most important. The first step is an office investigation of all available source materials and references, such as maps, books, climatic records and post reports. Correlation of these data permits a preliminary estimate of necessary resources, the most favourable operational periods, and the time required. Usually it is also possible to select a preliminary network configuration to assure radar coverage for the entire project area.

This is followed by a field reconnaissance to confirm the feasibility of the preliminary plan and to gather such additional information as may be necessary to complete the project. The reconnaissance team will also visit each selected ground station and prepare it for occupancy. A critical requirement for ground stations is a clear line of sight from the station to the areas and altitudes where the aircraft will fly.

The completed reconnaissance surveys, together with the data compiled during the investigative phase, are used in preparing the final plans and project implementation. Specific requirements such as camera type, flight altitude and flight direction, special flights, solar angle, etc. are determined and indicated in a data sheet as part of the specifications.

To maintain quality control there are requirements for pre and post operational testing of all components of the system. An operational service test of the prime cameras and accessories must be performed over a designated test area. The exposed photography must meet the requirements, as set forth in the specifications, for forward overlap, tilt, crab, distortion, flatness and film quality. The TPR system's radar antenna axis and the 35 mm positioning camera axis must be checked for alignment. Several flights must be made over a prominent terrain feature with both radar and positioning camera in operation. From measurements and computations the position of the beam on the 35 mm photography is determined.

Prior to the first photo mission and following the last photo mission in the area, a performance test for each HIRAN set must be made. The ground stations, the airborne equipment, the pressure altimetre, the radar altimetre and other components must be calibrated for accuracy. Measurements are made between two known positions, using the trilateration method of line crossings.

The first phase of project execution is completion of the trilateration for geodetic purposes and establishment of the datum. Since this phase does not necessarily require cloud-free weather, it can usually be completed in a relatively short time and may be accomplished during periods not suitable for aerial photographic missions. This is followed by the aerial photographic phase.

During the photographic missions, radar signals are continuously sent from the aircraft to two ground stations of the trilateration net.

Simultaneously with the exposure of each photograph, the HIRAN distances are recorded, permitting the determination of the horizontal position of each photo nadir point.

Vertical control for photogrammetric mapping is also acquired by electronic methods. The TPR operates on the radar principal. As the photographic mission is flown, signals are bounced off the terrain and the altitude of the aircraft above the terrain is recorded on a graph in the form of a continuous profile. A 35 mm camera, aligned parallel with the radar beam, records the path of the beam. As each exposure is made, a tick on the chart is recorded for correlation. Also, the moment of exposure of the prime mapping camera is recorded on the chart.

The vertical reference is an isobaric datum. At the start of a mission the plane flies over a known elevation — preferably a large body of water - and establishes the isobaric datum by means of the clearance and a constant pressure surface. As the flight progresses, variations from the pressure surface are measured by a hypsometre. These variations are corrections that are applied to the aircraft clearances above the terrain which are then recorded on the graph as a corrected profile.

At intervals along the flight line, the drift angle, airspeed, latitude, and distance flown must be recorded. This is to determine any change in atmospheric pressure level relative to height above mean sea level at specific intervals along the line. After termination, the true heights of the selected pressure level — isobaric surface — is again measured over a flat surface of known elevation to determine the true pressure level change.

The correlated and reduced data are used in a more or less conventional method to perform an adjustment and establish orientation control points for photogrammetric map compilation. However, data reduction is quite lengthy and proper analysis of the TPR data is most critical. The so-called "narrow beam" radar is a one degree cone. From 9,150 metre

altitude it covers an area of a circle about 150 metre in diametre. The exact point of return is not known. Methods have been developed at Army Map Service to process the raw data so that TPR data will provide vertical control with an accuracy of 3 metres in flat terrain and approximately 6 metres in mountainous terrain. The Army Map Service has prepared several technical memoranda regarding the data reduction process. These can be made available upon request.

Briefly, HIRAN is used to accomplish two independent missions - trilateration and controlled photography. A trilateration mission, for the establishment of first order horizontal control networks, is accomplished by making 12 acceptable line crossings, 6 at each of two altitudes. At least four of the individual crossings in each group must be within 4.83 metres of the mean of the group, and the mean of the two groups must not differ by more than 4.83 metres. A controlled photography mission, to determine relative positions of points on the earth's surface for horizontal control, is accomplished by measuring distances from the aircraft to two ground stations of known geographical positions in order to determine the aircraft position in space. The position of the point on the surface of the earth directly beneath the aircraft can then be computed. A vertical aerial photograph is exposed simultaneously with the recording of the HIRAN distances thus permitting horizontal control of each photo nadir point.

Through various tests, it was found that the photography and control data collected by these airborne systems is adequate for Class A medium scale mapping and very nearly approaches the accuracy requirements of Class A large scale maps at 1:50,000 scale. With further improvements, meeting the large scale requirements will also be feasible with a high degree of confidence.

Regardless of the many opportunities and advantages offered by the equipment and techniques currently in use, one recognizes that there are also limitations and disadvantages. Within the United States, government agencies and commercial industries constantly seek methods for

improvement. At the Nairobi Conference in 1963, the concept of a sophisticated system called AN/USQ-28 was introduced. This system is a group of equipment integrated to provide the fastest and most accurate means ever available for obtaining geodetic raw data. With the exception of the aerial photography, all supporting data are recorded on magnetic tape for direct input into a ground digital computer for accurate and rapid data editing and reduction.

SHIRAN, which utilizes a higher frequency wave length or S-band than HIRAN, is one of the basic components of the USQ-28 system. The ultimate capabilities of SHIRAN are not known, but preliminary tests have indicated greater accuracies than the present HIRAN system. Measurements to four ground stations are made simultaneously 10 times each second. Data are recorded on a magnetic tape in a computer-compatible format, which may be forwarded to a computer centre for rapid reduction. Preliminary tests indicate that for trilateration the probable error for an individual line crossing is $\pm$ 2.19 metres. Tests of the SHIRAN controlled photography show the absolute horizontal bridging accuracy to be 8.27 metres. With the complete USQ-28 system it is anticipated that the accuracy will improve. This entire system will be mounted in a long-range jet aircraft, capable of higher altitudes and speeds than are feasible for propeller driven aircraft.

This system is expected to become operational by mid 1967. Such a system will be particularly applicable to the rapid acquisition of mapping data over large areas where ground surveys and basic mapping are essentially non-existent.

Laser Profiler

One of the United States commercial firms has announced development of a new terrain profile recorder which uses a laser beam instead of a radar signal as the means of measurement. While this development still has some recognized limitations, it holds forth the promise of great improvement over the radar profiler. Basically it uses the same

principle as the radar type profiler except that a LASER beam is employed for measurement instead of a radar wave. The prime difference is the beam width. The area illuminated on the ground surface is approximately .3 metre square as compared to the 150 metre diametre circle of the radar beam. Preliminary flight tests performed by a commercial company of the LASER TPR were conducted and the indicated accuracies were within 30 cm at a 300 metre altitude, and within 1.5 metres at about a 4,000 metre altitude. The high accuracy and high resolution of the altimetre are a result of the ability to focus the intense beam of light energy onto a small spot. The Corps of Engineers will conduct operational tests to determine specific accuracies of the system.

The profile is recorded on a chart similar to that of the TPR except that it is a continuous recording and not a pulse type. This would simplify the correlation to the mapping photography and increase the efficiency of the photogrammetric operation.

At present the LASER profiler is limited to approximately a 4,570 metre altitude because of power and other minor limitations. Preliminary tests have indicated that this device has great potential as a system for acquiring vertical control data. By continued research, one can confidently expect additional significant technological advances to speed up the mapping processes while simultaneously reducing the over-all costs.

The current estimate is that less than 25 per cent of the world's land masses are adequately mapped. I think we all recognize the importance of mapping to the accomplishment of our defined social and economic objectives. I do not necessarily suggest that airborne electronic control offers the ultimate solution to all the mapping problems. However, I do submit that the opportunities offered are too great to be overlooked when planning for the accomplishment of cartographic requirements.

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