tional accuracy approximately 1′) or to obtain in a short time approximation values for precise satellite tracking and location. For this purpose a blink-microscope with three image carriers is used.

Satellite location in the blink microscope takes place by comparison of two consecutive satellite photographs (satellite phase and star phase) placed in two image carriers with the correspondent star map placed in the third image carrier. The position of the satellite is then determined by measuring the righ ascension and declination difference of the satellite image by means of a glass scale with respect to the nearest grid lines.

Conclusion

The fast developing space sciences offers new applications for photogrammetry, especially, in the field of satellite tracking. Considerable effort must be made to improve the photographic tracking methods with regard to precise tracking for geodetic purposes. This opens a new field for photogrammetric research with interesting and fascinating problems.

*A Use of APR for Mapping Control in Difficult Terrain**

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Introduction

When the Hunting Airborne Profile Recorder was put into general operation ten years ago, it was used largely to provide elevations for aeronautical charts. As the instrument was improved, it became practical to use the profiles as a source of elevation control for photogrammetric mapping. More recently, by synchronizing with air-survey photography, the APR has provided elements for control of photogrammetric map-scale, as well. In effect, ground survey has been entirely substituted for certain conditions.

In operation, the APR provides two records, the first of which is the terrain clearance. For this, the distance between an aircraft and the surface of the earth along its flight path, is measured by a narrow radar beam directed downwards from the aircraft, the clearance being recorded continuously on a moving chart. The height of the synchronized survey camera above the ground, and hence the exact scale of the photography, becomes known.

The second record is the terrain profile, within which the vertical movements of the aircraft have been corrected continuously and automatically by a precision electronic hypsometer. This profile is located on the ground by a synchronized 35 mm. positioning camera. For use of the terrain profile, corrections are made for inclination of the pressure altitude plane to which the hypsometer relates, and correlation may be made with known ground values such as sea level, which have been crossed during flight.

This is an operational report to photogrammetrists on a useful APR-controlled mapping technique for rough, inaccessible terrain.

Project Circumstance

In general connection with development planning for the region east of the Andes in Central Peru, and specifically for hydroelectric power studies of the Mantaro River, the Ministry of Development and Public Works required, with relative urgency, reconnaissance topographic maps of a known reliability. The project location is shown in Figure 1.

The range of relief and severity of slopes throughout the area have almost excluded it from previous exploration, of any type. Rises and falls of 2,000 meters in five kilometers are common in the general relief. There are no roads and only a few trails linking scattered mountain Indian settlements. A typical profile is shown in Figure 4.

In this circumstance, to establish conventional ground-survey control for mapping would be an almost impossible task, costly

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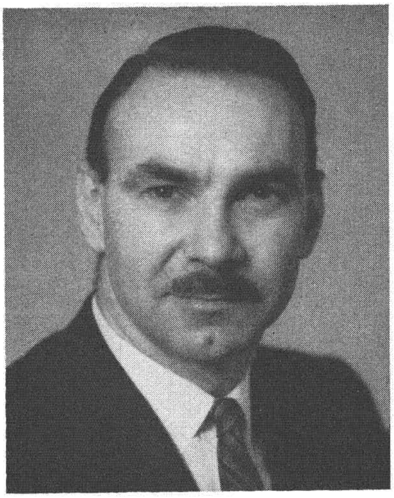

D. A. MacFadyen

and time-consuming. It was decided to use APR-controlled photography as a substitute.

Figure 2 shows the area defined for mapping at 1:100,000 scale with 100 meter contours to be shown. Within this area, priority blocks at 1:20,000 scale with 20 meter form-lines were needed. The region had recently been flown by the National Aerial Photographic Service using its best aircraft and a super wide-angle RC9 camera. This was the only practical means at hand to obtain general coverage of such high ground, and was adopted in spite of some risk of blind areas. The mean scale of this coverage may be taken as 1:30,000, although it is extremely variable.

Ground-control available within the area consisted of stations of a first-order geodetic network, along the western edge, and a first order levelling also along this edge. Figure 3 shows the panel within which ground-surveys existed or could be established with relative ease. It was decided to control the mapping of the problem block by means of an APR-controlled network, aerotriangulated as an extension of the geodetic and levelling systems.

Plan of Operations

Having in mind the aerotriangulation capabilities of the general super wide-angle coverage, and to some extent governed by available flying and mapping equipments, the plan adopted was as follows:

1. At 15 kilometer intervals, parallel APR profiles with simultaneous wide-angle photography were flown across the problem area, each with its western end within the general area of ground control.
2. Additional APR/photo strips were flown across both the western and eastern ends of the parallel strips, and others diagonally. Figure 4 shows the system of flights.
3. Tellurometer survey, between the geodetic stations, established control co-ordinates near the western end of most strips; where the levelling bench-marks could be identified in the strip photographs, this was done.
4. Vertical datum for each profile in the system was established by instrumental correlation of bench-mark values and APR terrain profile values in stereoscopic models at the crossing of level lines.
5. Photogrammetric instrument operators were provided with initiate-controlled APR vertical values for a series of selected best terrain points along each strip—one such terrain point per model.
6. Instrument operators were also provided with tables of APR ground clearance, terrain elevation, and the sum of these two (camera-station elevation) for the principal point of each photograph.
7. A first-order mapping instrument (A7) with automatic co-ordinate registry was used to aerotriangulate alternate strips, crossing strips and diagonals; a Multiplex instrument was used to bridge vertically the intervening strips. This division of the work is shown in Figure 5.

The object of the aerotriangulations of alternative strips was to obtain preliminary horizontal and vertical values for the selected best terrain points along their axes. After adjustment of the system of strips, these stations would control an aerotriangulation of the super wide-angle coverage.

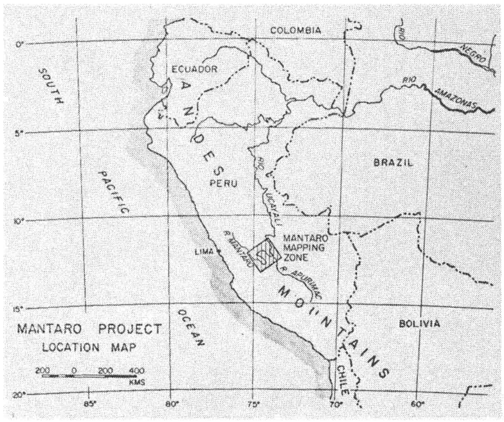

Fig. 1

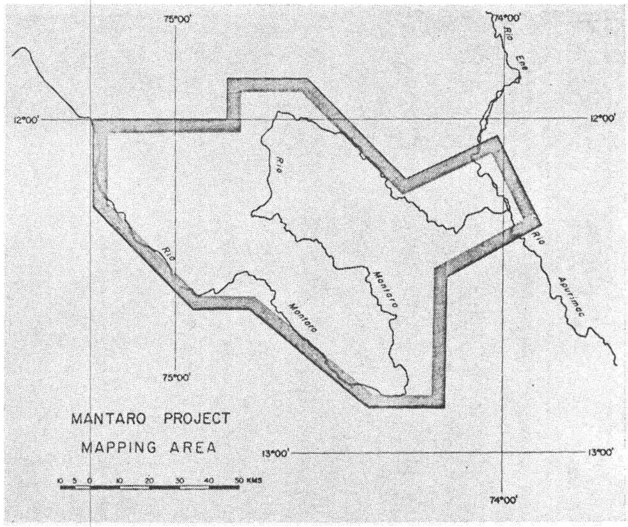

FIG. 2

The object of the Multiplex vertical bridging was to provide preliminary vertical values for the selected best terrain points, needed as intermediate adjustment values in aerotriangulating the super wide angle block.

ADJUSTMENT AND RESULTS

It is beyond the scope of this paper to describe the adjustment processes for the APR-controlled system in detail. In general, the parallel aerotriangulations obtained their initial scales from ground values, and held a plane of reference using the camera-station elevations provided by the APR. The principal scale adjustment was derived from a comparison of original APR terrain clearance values with observed photogrammetric clearances at each camera station. The comparison of APR terrain elevations, with observed vertical values in the aerotriangulation, was used to provide the principal vertical correction data for each line.

Employing the adjusted lengths of each aerotriangulated strip, plotted instrumentally at 1:20,000 scale on stable material, positions were found by "trilateration" for the

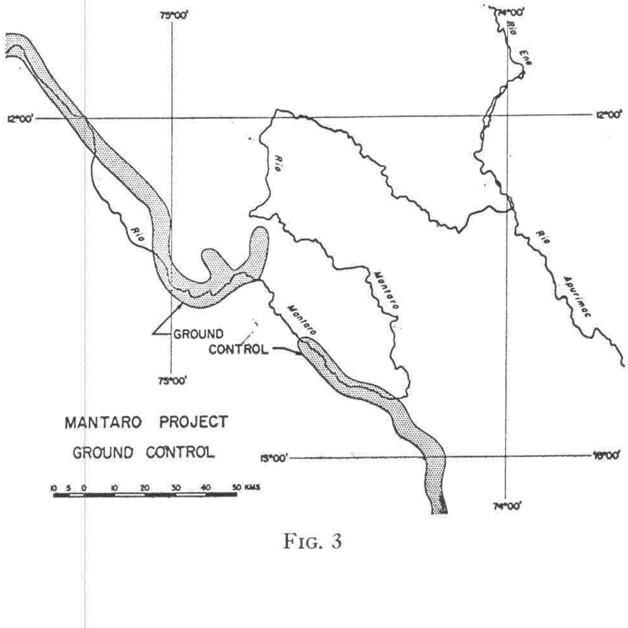

FIG. 3

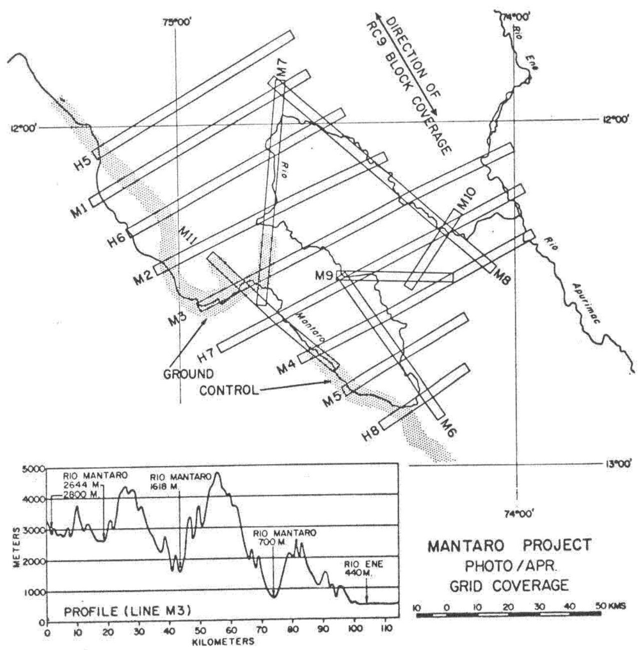

FIG. 4

crossings of lines M1 and M7, then of M8 and H7, and then of M10 and M9, and M6 and M5.

The parallel Multiplex vertical bridges obtained their initial scales from ground values. APR terrain values were generally of a low order of accuracy due to slopes, and the observed values of ground points were therefore taken directly from the bridging. Each bar of six models was best mean-fitted to the corresponding camera-station elevations, by means of mechanical measurements from the Multiplex table to the projectors, using a special tool.

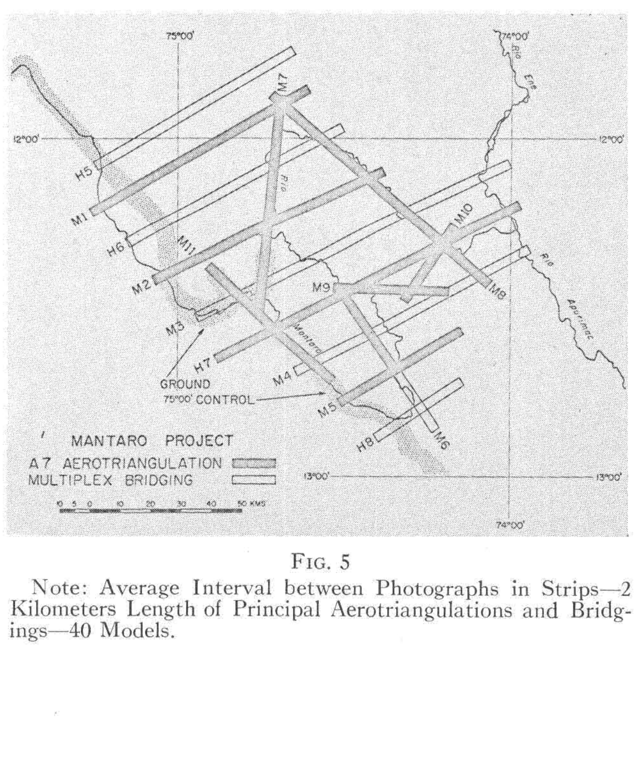

FIG. 5

Note: Average Interval between Photographs in Strips—2 Kilometers Length of Principal Aerotriangulations and Bridgings—40 Models.

When the graphic trilateration of adjusted line lengths from M1 and M7 had positioned the north-east corner of the system, the most northerly available ground-survey co-ordinate, not used in the aerotriangulation, was compared with the assumed position in M7. This was found to have no visible error at 1:20,000 scale, in distance along the strip from control. However, a lateral displacement occurred, such that at the mid-point of M7, the adopted bow correction amounted to 30 meters.

After adopting a position for the intersection of M8 and H7, the line M2 was used to check M7 and M8. The sector of M2 west of M7 was found compatible with the bow corrected line M7. The sector of M2 east of M7 required a bow correction of M8 at its mid-point, of 26 meters.

Vertical adjustments to make the 6 strips M1, H6, M2, M3, M7 and H7 compatible with M8, required respectively −5, 0, +4, +10, −2, and 0 meters of slope of their assumed datums.

On the basis of discrepancies for common pass-points throughout the system, and the vertical datum slope corrections, it is estimated that 60 per cent of the vertical values produced will fall within 10 meters of correct, and 90 per cent within 15 meters of correct. An estimated maximum of 60 meters is given for horizontal displacement from true position.

The co-ordinates of the system have been supplied to the Military Geographic Institute and the National Aerial Photographic Service of Peru, for their respective block aerotriangulation and restitution works, which will complete the mapping.

Merits of the Method

This project is brought to the attention of photogrammetrists, not because the results of the work carried out have been remarkable, but because they have been adequate for the purpose. Satisfaction with the results is rather more because the conditions have been as difficult as are likely to be encountered anywhere at anytime.

Some time ago, T. J. Blachut of the National Research Council of Canada, reflecting on the limitations of the Airborne Profile Recorder revealed by his meticulous photogrammetric checking of terrain profiles, drew attention to the probability that the relatively high "exterior" accuracy of the APR, combined with relatively high "interior" accuracy of instrumental photogrammetry, should result in an improvement in the effective performance of both.

In the project described, the complement of APR and photogrammetry has been exploited in several forms:

(a) Simultaneous photography has allowed the accurate photogrammetric correlation of the APR datum with ground levelling—single stereo-models, at the crossing of the level traverse, scaled by the APR terrain clearance, and oriented by bench-marks in one sense, and APR terrain profile values in the other, have allowed placing in accurate datum on each profile as near as possible in the pressure altitude pattern to the general APR data in use. A remote reference, such as a lake or airport, has been avoided.

(b) Simultaneous photography of the aerotriangulation-type strips has provided a means of accurately pre-calibrating the terrain clearance record over ground-survey values at the commencement of each such strip and better overall scaling has been achieved.

(c) Simultaneous photography and instrumental photogrammetry have allowed the correlation of APR vertical datums over rough ground, where no repeatable features occur. A better overall vertical adjustment and result has thus been obtained.

(d) Values of APR terrain clearance and camera station elevation have allowed the maintaining of aerotriangulation plane of reference and scale, far beyond the capability of the photogrammetric instrument alone and resulting in an improved horizontal control.

(e) APR profiles have allowed a Multiplex vertical bridging over long distance, maintaining both scale and vertical datum.

(f) Instrumental technique in both cases has selected the good values of the APR, in spite of terrain problems, enhancing its value in both scaling and vertical control.

The practical photogrammetrist will see many additional secondary advantages arising out of the combined use of APR and photogrammetric techniques. It is proposed that after the completion of the mapping operations in Peru, a more complete analysis of procedure and results will be made and reported, and the basis established for similar operations elsewhere.