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Mapping in Tropical Forests: A New Approach Using the Laser APR

The Laser Airborne Profile Recorder was used not only for establishing vertical control but also for determining vegetation heights.

Introduction

A new and innovative application of the Laser Airborne Profile Recorder (APR) to the problem of topographic mapping in tropical forest areas is described and analyzed in a comparative and critical way.

Abstract: *Topographic mapping in dense tropical forest has in the past usually involved laborious cutting of lines through the timber at great cost in time and money.*

Development of new techniques involving the Laser Airborne Profile Recorder (APR) appears to offer a practical solution to this problem. The narrow laser beam, in addition to recording profiles of the tree canopy, can penetrate small openings to the ground. Tree heights can be determined by comparing recorded profiles.

This technology was applied by TRANARG, C. A. in mapping the proposed Rio Caura reservoir in southern Venezuela. Topographic maps showing 5- and 10-metre contours of the 800-square-kilometre, trackless remote area were completed in five months. Laser APR flights at 1.5 km intervals were flown over the site. New control was established on mountain tops which had to be cleared before survey crews could occupy them. A special three-channel Autotape was mounted in a helicopter for locating photogrammetric control by trilateration from ground stations to the hovering aircraft.

Many APR-derived elevations were identified on the 1:50,000 existing photography used for the mapping. Using the independent-model method, as programmed by Professor Ackermann, a block adjustment was made with satisfactory results. Internal checks indicate results should prove satisfactory for pre-feasibility studies of the proposed reservoir.

The conclusions offered regarding the feasibility of this procedure are based on completion by TRANARG, C. A. of topographic mapping for pre-feasibility studies of a hydroelectric project on the Caura River in Southern Venezuela, and on other projects.

The successful use of the Laser APR system for mapping in heavy tropical vegetation may, in turn, lead to other applications in the general mapping field such as rapid preliminary mapping of remote areas with a minimum of ground control. Its most valuable use will be, however, in profiling and penetrating hitherto unmappable areas in tropical or subtropical forests.

The following points will be discussed:

- general mapping problems in tropical forests regions,
- the specific case of the Caura River Project as an experimental area,
- the use of the Laser APR system as the proposed solution, and
- evaluation and discussion of results.

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General Problem of Mapping in Tropical Forests

Adequate maps are generally lacking in the world's equatorial forest regions, most of which are still unexplored (Hotine, 1967). The expanding search for natural resources in recent years, however, has focused world attention on mapping problems in these areas.

Components of the Problems

Tropical forests are generally found between 25° N. and 25° S. latitude in areas characterized by high temperatures, constant humidity, and heavy rainfall. Cartographic problems arise from these climatic conditions which combine to generate atmospheric and terrain conditions severely adverse to the mapping process.

These include

- nearly constant cloud cover, which greatly impedes serial photo flights and geodetic operations;
- dense jungle vegetation, which effectively restricts access to the zone while rendering normal stereoscopic map compilation impractical;
- gently sloping topography with few, if any, landmark features for use as control reference points; and
- badly defined drainage patterns, a feature which adversely affects ground surveys and map compilation.

In the past, flat areas have been mapped by laboriously chopping and profiling lines through the jungle (Mott, 1955). This method, besides being slow and very costly, is not adequate in rolling terrain with fairly complex drainage systems such as the Caura Valley in southern Venezuela.

The unfavorable climatic conditions and lack of ground access, which have largely prevented topographic operations, are common to equatorial forests throughout the world. Consequently, any substantial progress in improving or facilitating mapping operations should be regarded as of great importance, an advance which could have significant effects on many of the less developed countries of the world by helping in the search for existing resources.

It now appears feasible to accomplish topographic mapping based on altimetric interpretation of a series of parallel low-altitude flights by using the Laser Airborne Profile Recorder.

The systematic use of the narrow Laser beam to generate profiles of both ground surface and tree canopy has been applied to the mapping of a proposed dam site and reservoir on the Caura River, which the paper describes in detail.

The Specific Case of the Caura Project

Requirements and general information. In 1976, the Government of Venezuela, acting in accordance with priorities of the National Energy Program, authorized preliminary studies of a proposed hydroelectric development on the Caura River in southeastern Venezuela (Figure 1).

The site selected for the diversion dam was at Salto Pará (Figure 2), where the Caura River starts losing a total height of 200 metres within a course of 3 km of rapids. On the basis of limited data, the reservoir was planned to cover approximately 800 sq km between Salto Pará and the junction of the Caura and Erebato Rivers, about 50 kms south of the proposed dam site.

In the Caura area two distinct strata of vegetation are found, the upper intermittent with tree heights to 30 m, and the lower continuous with trees 5 to 20 m in height. In addition, isolated trees rising to 50 m above ground are present throughout the area. No open clearings or savannah areas are found; tree cover is continuous except where broken by the Caura River or its larger tributaries.

Under the trees, topography is characterized by numerous hills which rise to 100 m above average terrain with horizontal dimensions of 200 m or greater.

In mapping water resources developments, the depth of the proposed reservoir is normally the governing factor in setting map criteria. It has generally been accepted that the volume of water impounded and other necessary data may be estimated with acceptable accuracy if the reservoir floods at least ten contours. With a proposed dam height of 40 metres, a five-metre contour interval at 1:25,000 map scale was considered appropriate.

Delivery of maps within five months was an urgent requirement to conform to the overall completion schedule for the design of the project. The Rio Caura project forms an integral part of the Na-

Fig. 1. Areas mapped using Laser-APR for basic height control, and location of the Caura Project (Area 4).

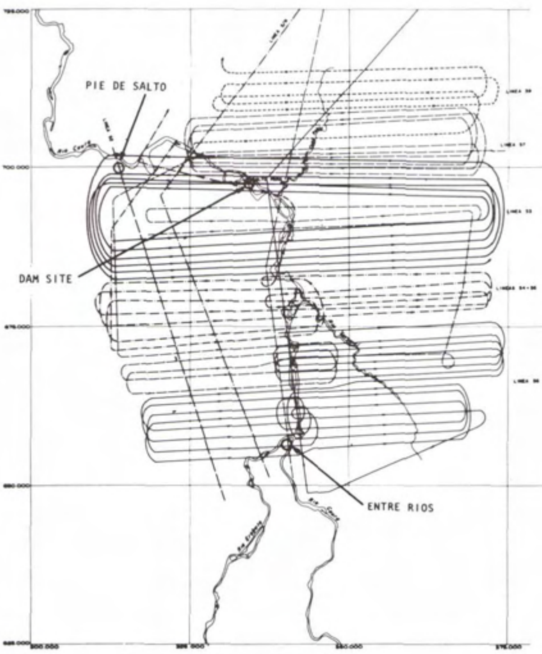

FIG. 2. APR flight lines.

tional Plan for economic and social development of Venezuela during the 1976-80 period.

Existing source material. In accordance with standard practice the first phase comprised collection and evaluation of all existing information to avoid possible duplication of effort. Thorough search of all agencies with functions or activities in the region revealed the following:

Cartographic Material.

- The Caura area is partly covered by 1:100,000 planimetric maps which show only the drainage network. The maps were prepared by photo interpretation of existing aerial photography and were used mainly for determining the watershed.
- East of the area modern 1:25,000 maps with contour data exist, prepared under the National Mining Cadastral Program.

Basic Control.

- The nearest first-order triangulation net is found along the Orinoco River, approximately 100 miles north of the project area. These stations form part of the "Cuidad Bolivar-Caicara del Orinoco" net.
- A high-order level line, established by the Cartographia Nacional, exists between these two cities (Figure 3).

Under the Army Map Service program, several precise traverses have been completed between the Caroni River triangulation (upper right, Figure 3) and the previously-mentioned network. Some stations fall within the reservoir area (Figure 4), coordinates for which were obtained from the Cartografia Nacional.

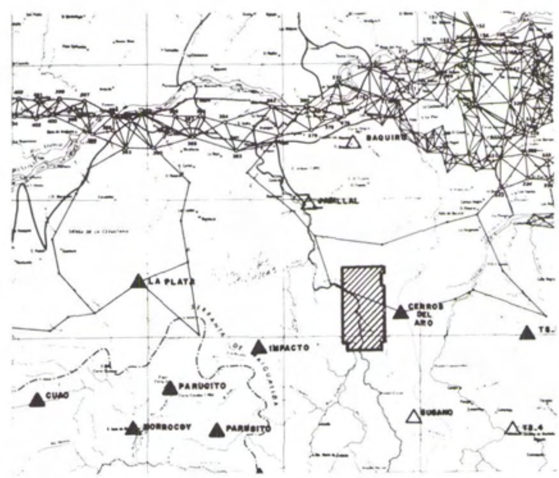

FIG. 3. Existing basic control in the general project area.

Control used in mapping the 1:25,000-scale maps to the east of the area was identified and incorporated into the Caura Project.

In 1972 the Cartografia Nacional began a program of satellite observations for determination of points in the southern part of the country. Several of these points are found within the Caura area (shown by solid triangles, Figure 3).

As a result of this study, more than 20 points of known position and elevation were discovered in the area, each marked on the ground by concrete monuments and plaques carrying the proper inscription.

Aerial Photographic Coverage.

- 1:18,000 scale along the Caura and Erebato Rivers
- 1:50,000 scale, taken in 1960-61 under an AMS-Mission, flown east-west over the area, with a few gaps near Salto Pará.
- 1:125,000 scale photos, flown in 1973, north-south direction, covering the area immediately east of the Project area.

Discussion of alternative methods

Conventional Ground Survey. To map such an area with reasonable completion by ground methods would require cross-sections at rather closely-spaced intervals with a high point density within the sections. In addition, the numerous valleys and stream beds would have to be profiled and cross-sectioned. This work is slow, costly, and often hazardous to ground crews.

Because there have been proposals for employing ground methods, we will mention figures resulting from estimation of the volume of field work which would have been necessary to map the proposed reservoir.

With cross-sections at 100-m intervals, an average distance of 25 m between points within the sections and 4 km of streams per square-kilometer,

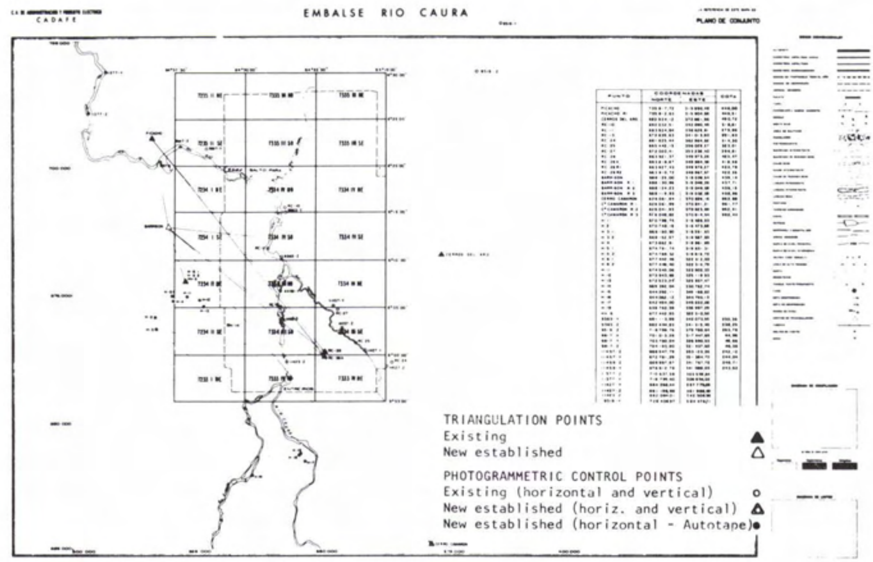

FIG. 4. Ground control

based on surveys in adjacent areas of similar characteristics, the line and water courses would total $800 \times (10 + 4) = 11{,}200$ km. With progress per field party of 1.5 km per day and 220 working days per year it would have taken approximately 34 party-years.

Additional requirements would include provision for field labor, supervising technicians for line cutting, supporting field parties, and supply problems. It is obvious that tacheometric surveys, or any similar method depending primarily on measurements of isolated points, would have been very costly, impractical, and unrealizable within the short time available. In addition this procedure would have resulted in more generalized topography and probable omission of major topographic features.

Photogrammetric Methods. Thus, it was concluded that it was imperative to use photogrammetric methods, which would permit a continuous evaluation. The greatest concern was to resolve the vegetation problem. Aerial photogrammetry has proved useful but has been limited by inability of the stereo compiler to determine tree heights, which are often inconsistent and misleading. On ridges and summits, trees are relatively low in height compared to those in low spots or along drainage courses where ample moisture is present. Along rivers subject to flooding, steep banks may be concealed by overhanging vegetation, thus causing serious errors in ground elevation and configuration of the channel.

If tree heights could be measured, this value could be subtracted from the elevation of the tree crown to obtain the ground elevation.

Fortunately, TRANARG had equipment available which was believed capable of performing this function. This was the Laser Airborne Profile Recorder (APR), Model Geodolite 3A, manufactured by Spectra Physics Company.

This equipment has been used by TRANARG very successfully for elevation control in mapping areas of difficult access and as a substitute for conventional leveling on previous projects (TRANARG, 1974). During these previous uses the high resolution of the equipment, due to the narrow laser beam, had been observed. In some cases tree heights and the heights of man-made features such as buildings had been measured to demonstrate the high resolution of the equipment.

When the Caura Project was planned, where higher contour accuracy was required, these previous experiences suggested the use of the Laser APR not only for establishing vertical control, but additionally for height determination of the vegetation (TRANARG, 1977).

PROPOSED SOLUTION

On the basis of the above considerations the, following solution was proposed:

- To make a photogrammetric survey of the area at 1:25,000 map scale with 5- and 10-metre contours based on the existing 1:50,000 scale photography.
- To determine height of the vegetation, APR profiles would be established every 1.5 kilometres, recorded in continuous graphical form on paper tape. Profiles would be identified on the mapping photography by means of 35-mm photographs exposed every 3 seconds to yield stereoscopic coverage of the ground beneath each APR flight.

DESCRIPTION OF THE EQUIPMENT

The APR equipment. The Laser Airborne Profile Recorder, Model Spectra Physics Geodolite 3A, is a precision distance-measuring instrument that uses an amplitude-modulated, CW helium neon gas laser beam of a wavelength of 6328 Angstrom. Distances are obtained by precise measurement of phase delay between the outgoing and reflected laser signals (Spectra-Physics, no date).

The original generated laser beam of about 25 m-Watts of power is expanded from a few millimetres to 2 cm in diameter and has a divergence angle of less than 1/10,000 radians or about 10 cm/km. At average flying heights of 1200 to 1500 metres above ground, the laser-illuminated spot has a diameter of about 20 cm. A fraction of the laser light, reflected from a natural target, is collected by an 8-inch receiver telescope, focused on a cathode of a photomultiplier, and converted into an electric signal. The voltage output is an analog value of the measured distance. The range depends on the modulation frequency; the available full range steps are 10; 100; 1000; 10,000; and 100,000 feet.

Results are recorded on a Varian strip chart recorder which has a resolution of one percent, so the precision of measurements is 1/100 of the range, or about 0.3 m when operating in the 100-foot channel.

Since the Laser APR is only measuring the distance from the aircraft to the target, variations in the height of the aircraft have to be measured to determine relative elevations. These variations are measured with great accuracy (0.3 m) with a statoscope, a highly sensitive, differential barometric-pressure altimeter, which relates the pressure differences to an isobaric reference surface (Arp, 1976).

Autotape. The Autotape used on the Caura Project was specifically manufactured by Cubic Corporation for TRANARG and included a third channel for distance measurement in place of two channels as normally used.

This remarkable device, mounted in a helicopter, automatically measures and records on paper tape distances to three remote stations with a precision of 0.5 metre. This permits determination of the Autotape position by intersection of distances, with excellent results consistent with the accuracy of position of the three remote stations.

Aerotriangulation Equipment

Wild PUG-4. Used to mark on the diapositives the position of the pass points, horizontal-vertical control, and all other points to be measured and calculated in the aerotriangulation phase. This device drills holes 60 micrometres in diameter through the emulsion with a precision of about 10 micrometres.

Bausch & Lomb Zoom Transfer Scope. Used for stereoscopic study of photographs of different origin by means of individual magnification of each photograph. This device facilitated transfer of APR points from the 35-mm photos to the mapping photography.

Kern MK-2 Monocomparator. Used for precise measurement of image coordinates of points marked on the diapositives for subsequent use in analytical triangulation.

Ackermann Program. A computer program considered an indispensable element for the photogrammetric proceedings on this project (Ackermann et al., 1973). This program transfers in a very rigorous form, by the least-square method, model coordinates to field coordinates. Excellent results may be obtained even with horizontal control reduced to the perimeter of the area only. Its principal characteristic is the fact that the program uses all ties between aerial photographs, both longitudinally and laterally, to position the entire block of photographs to the ground control.

Wang 2000 VP Computer. Available in-house and comparable in speed and operational capacity with the IBM 360/40, the Wang 2200 VP was used for processing basic data (field observations, comparator measurements, etc.) as well as for transcription of the data in the computing process, thus increasing the security, quality, accuracy, and speed of execution of the work.

EXECUTION OF THE MAPPING OPERATIONS

Field Work. APR Flight. The APR surveys were made during August 1976, with equipment installed in a B-25 aircraft, which had a cruising range of 7 hours.

Flight lines were laid out on a photomosaic basically in the east-west direction at intervals of 1.5 kilometres. North-south flights for elevation ties were also planned over the center and borders of the survey area.

The dense vegetation and uniform appearance of the terrain made navigation difficult; to help overcome this problem, all flights began over the Caura River, the only ground reference of easy location (Figure 2).

Each flight also crossed one of the two landing fields (either Entre Rios or Pie de Salto), which provided reference points for measurements on different days. Water levels of the Caura River, obtained by the Ministry of Public Works, furnished additional reference points for the APR flights.

The Varian Recorder was set at a chart speed of 2 cm/second, and the Geodolite was operated in the 1000-foot channel. The horizontal and vertical scales were 1:5,000 and 1:3,050, respectively.

Basic Control. The network of basic control points consisted of the vertices of AMS precise triangulation in the vicinity. To furnish additional photogrammetric control in the Southwest part of the reservoir area, the AMS net was expanded by establishing three new stations, which also served as remote stations for APR weather observations.

Establishment of the new ground stations was performed in three stages: (1) reconnaissance, (2) site preparation, and (3) measurement of angles and distances.

In the reconnaissance phase observers made a general check of the proposed site and verified line of sight to adjacent stations. Then clearing parties, who descended by ladder from helicopters, cleared the site for helicopter landing and opened lines for observation by removing trees. Vertices were then monumented and measurements were begun, using the Wild T2 theodolites for angular observation and Electrotape electronic distance measurement (EDM) equipment for distance measurements (Figure 4).

Photogrammetric control. Because of the sparse distribution of existing control, it was necessary to obtain additional image points for model control. This presented a serious problem in this area totally lacking in accessible points of positive identification.

A new technique was introduced to overcome this problem. This consisted of the following:

After the zone where a horizontal point was needed had been outlined, the procedure consisted of three steps: (1) selecting a detail, (2) measuring the position, and (3) identification.

In most cases the only outstanding ground feature as seen from the helicopter was an individual tree, which stood out because of some characteristic such as shape, size of crown, or location on high ground.

The helicopter was maintained "floating" over the point while measurements were made with a three-channel Autotape to three remote stations, with an accuracy of 0.5 m, which permitted computation of coordinates of the selected image point by intersection of distances. The problem remained to develop a positive means of identifying the detail point on the 1:50,000-scale mapping photography. This was done by taking a series of 35-mm exposures vertically over the point as the helicopter ascended to about 500 feet, at which point an area of 90 by 120 m was covered. These successive photographs were used to locate the general zone of the detail measured, and then locate the selected point itself on 1:50,000 photographs.

In some cases the general zone was determined by means of approximate coordinates obtained by preliminary block adjustment.

All stations of the newly established network and some of the existing ones were signalized and photographed with the aerial camera from a low altitude (approximately 3500 feet above ground)

Office Operations. APR Evaluation. The first phase consisted of location of the APR flights on the mapping photography (Figure 5). To do this the photos were enlarged to 1:25,000 scale, which coincided with the scale of the 35-mm APR tracking photography. Detail was matched by superimposition; if this proved difficult, the APR photos, which had been exposed with 50 percent endlap, were studied stereoscopically, which assisted greatly in the task.

FIG. 5. Identification of APR flight paths on the aerial photography.

A line index was prepared at 1:100,000 scale showing location of APR flights and the photo centers of the mapping photography for use by the map compilers (Figure 6).

A cross-reference was also prepared to show the

FIG. 6. Identification and location of the tracking camera photographs of the APR flights.

relationship between mapping photography, APR flights, and identified APR 35-mm photographs.

Selected east-west and north-south APR lines were used for the elevation adjustment of the aero-triangulation. Points were selected in areas where horizontal shifts had little effect on elevation. These consisted mainly of

- river crossings and flat areas with uniform vegetation, or
- transverse crossing of level ridges.

In the first case the water level or ground in the clearing was measured and in the second points were picked at the average altitude of the upper stratum of the vegetation.

About 140 points were established in this manner, which provided a solid base for height adjustment of the aerotriangulation. In addition, about 470 APR points similar to those described above were used to refine the vertical model orientation in the compilation phase.

Preparation of APR Reference Sheets. Monographs were prepared consisting of Xerox copies of the APR recordings and enlargements of the corresponding APR photos used in the aerotriangulation computations (Figure 7).

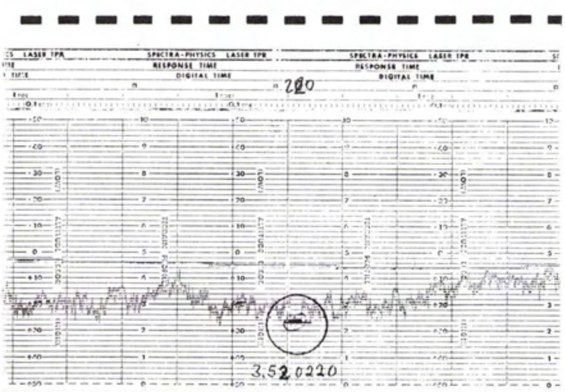

FIG. 7. An APR monograph, consisting of an APR record and corresponding enlarged 35-mm photograph of the tracking camera. The circled point (in profile and photograph) constitutes an identified vertical control point.

The numerical evaluation the APR data consisted in the following:

(a) for each APR point identified the following information was compiled, based on the APR register:
- Number of the APR Photo
- Time of measurement (day-hour-minute)
- APR Measurement (Distance Aircraft-point)
- Statoscope readings (departure of aircraft from the isobaric surface)
- Measuring channel (100-1000′)
- Sensitivity of the statoscope readings

(b) computation of the APR data to bring all observations to the same datum.

In this phase variations in atmospheric conditions were compensated by recording the altitude of the aircraft, as shown by the precise altimeter, at each river crossing. When the observed altitude was compared with the true altitude as determined by adding the Laser APR vertical distance to the known river elevation, the correction, if any, was applied to points along the APR profile in direct proportion to the amount of elapsed time since the previous calibration.

As it was not feasible to determine atmospheric conditions at the 3000-foot altitude at the ends of the APR flight lines (30 km from the river), it was necessary to assume that atmospheric conditions were uniform throughout the area, subject to updating at each river crossing at about 15-minute intervals.

This assumption apparently was valid as the APR supplemental elevations used in the block adjustment were in quite close agreement with the field surveyed elevations.

Control Computations. In this phase conventional methods of data reduction were applied as data consisted of horizontal and vertical angle observations with Wild T2 theodolites and distances measured with EDM equipment. Once these data were reduced, coordinates were computed, using special programs which achieve optimum results by adjusting measurements by the least-square method.

Adjustment of the Autotape data required a special procedure as the register did not indicate multiples of 10 kilometres. This ambiguity was readily resolved by plotting the approximate location of the measured points on a 1:100,000-scale map.

Aerotriangulation and Block-Adjustment. Two Wild PUG-4s and the B & L Zoom Transfer Scope were used in the preparation for aerotriangulation.

Measurements on the diapositives were made with the Kern MK-2 Monocomparator. Model formation was performed using special computer programs. Photogrammetric block-adjustment utilized the method of independent models, according to Ackermann.

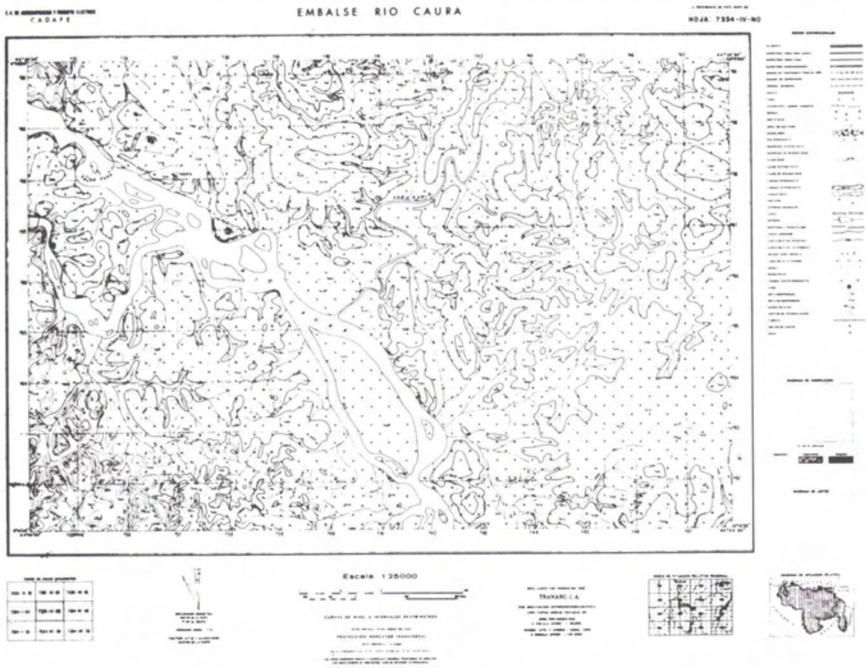

FIG. 8. Sample of 1:25,000-scale map sheet produced by the project.

Stereocompilation. Compilation followed these steps for each photogrammetric model:

- Estimation of tree heights based on APR profiles in the model.
- Contour drawing taking said height into account.
- Interpretation of the ground points of the APR profile and its inclusion in the compilation by photo interpretation.
- Final adjustment of contours.

Drafting. Drafting was performed in black ink on stable-base plastic film, using the format and sheet layout at 1:25,000 scale prescribed by the National Cartografic Office (Figure 8).

Evaluation and Discussion of Results

Three main aspects have to be discussed:

- The horizontal and vertical accuracy of the block adjustment,
- The altimetric accuracy of the APR points, and
- The determination of tree and vegetation heights by means of APR profiles.

Horizontal and Vertical Accuracy of the Block Adjustment

In the last decade accuracy aspects of bundle and model block-adjustments have been studied. It has been proven that the root-mean-square (RMS) values of the residual values of the used control points are good indicators of the absolute precision of the aerotriangulation.

The results of the aerotriangulation of the Caura Project yielded accuracies of 2 m in position and elevation for all control points. The RMS values of the model points were 2 m in position and elevation and of the projection centers 3 m in position and 1.5 m in elevation. The latter values give an idea how models fit together.

The Altimetric Accuracy of the APR Points

The final accuracy of 140 used APR points was 2.6 m. This could be interpreted by a critical observer as an internal or relative accuracy of the used method. Due to the fact that APR observations are derived from observation originally referred to an isobaric surface of unknown shape and slope, accuracies consequently depend on how well these values can be determined. Different corrections and field and computation procedures have been applied to get optimum results.

- Daily periodical variations in atmospheric pressures, which can change pressure altitude by as much as 50 m, have been taken into account by measuring pressure and temperature at several ground stations during the APR flights.
- At several ground stations during the APR flights along the main rivers several control points, established by the AMS-Mission, permitted calculation of the absolute elevation of the isobaric surface.
- River gradients have been considered.

- APR lines are relatively short between check points. All lines started and ended on well-defined reference surfaces such as landing strips and the rivers crossing the area.
- APR elevations have been adjusted by block adjustment, taking advantage of the PAT-M-43 program of Prof. Ackermann, with additional parameters for vertical control derived from APR observations.
- APR points were selected in areas where horizontal shifts had little effect on elevation.

INTERPRETATION OF APR-PROFILES AND EVALUATION OF RESULTS

The profiles shown in Figures 9, 10, and 11 can be considered as representative for the main landscape and vegetation cover types of the mapping area. In each of these profiles the deep penetration of the laser beam in the vegetation cover can be observed.

Measuring in the 1000-foot channel, differences between lowest and highest points can be determined with a precision of about 3 metres and may be interpreted as the height of the vegetation cover.

Figure 9 represents a typical profile of hilly terrain with continuous and homogeneous forest cover and with an average height of 35 to 40 m in the less inclined areas and 25 to 30 m in the steepest slopes.

Figure 10 shows an evident example of a multistrata tree cover where the medium stratum is very rarely penetrated by the laser beam, which indicates high density in the vegetation. The whole profile concerns a rather flat and gently undulating topography.

Figure 11 as well as the corresponding serial photograph (Figure 12) establish a visible and explicit correlation between the profile and the real aspect of terrain. General topography is flat or very gently undulating. Starting from point A, which shows a swampy area with low grassy and bushy vegetation cover (4 to 5 m), one can identify several very different landscape and vegetation cover types: Point C, medium or low dense forest; and point B, low bushy forest.

It is convenient to emphasize that, in addition to a satisfactory altimetric accuracy, the profile interpretation may bring very valuable and detailed information about geomorphological and geographical features of usually unexplored and badly studied regions.

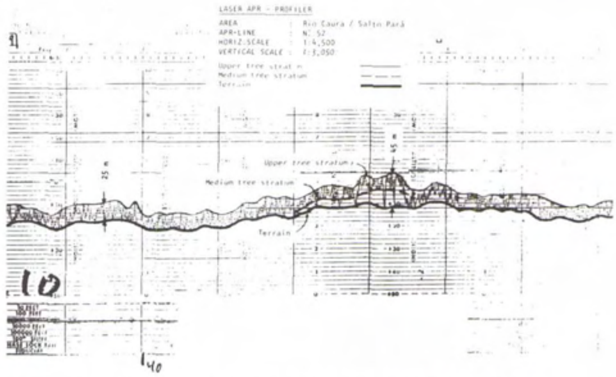

FIG. 10. The central part of the APR profile shows a very illustrative example of two well defined strata within a tropical rain forest: The upper strata with medium height of 40 to 45 m and the medium strata between 25 and 30 m.

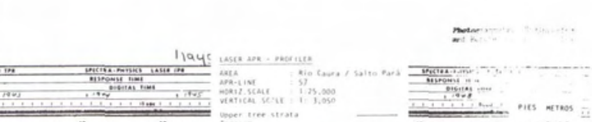

FIG. 9. This profile shows the evident structural characteristics of a tropical rain-forest vegetation cover, with a medium tree height of 35 to 40 m, and with outstanding trees reaching heights up to 55 m.

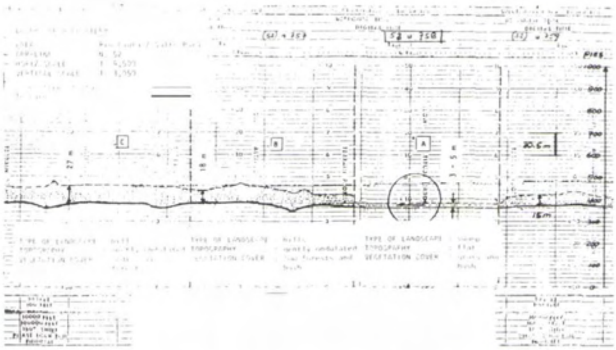

FIG. 11. This profile shows very evidently a swamp with flat topography covered with bush and grass (maximum height between 3 and 5 m), causing dense and short APR reflections. The low forest associated with bush vegetation shows variation of about 18 m in the APR profile, which corresponds to the real characteristics of that kind of vegetation. The medium forest shows reflection up to 27 m. The points A, B, and C marked on the APR profile are identified and located on Figure 12.

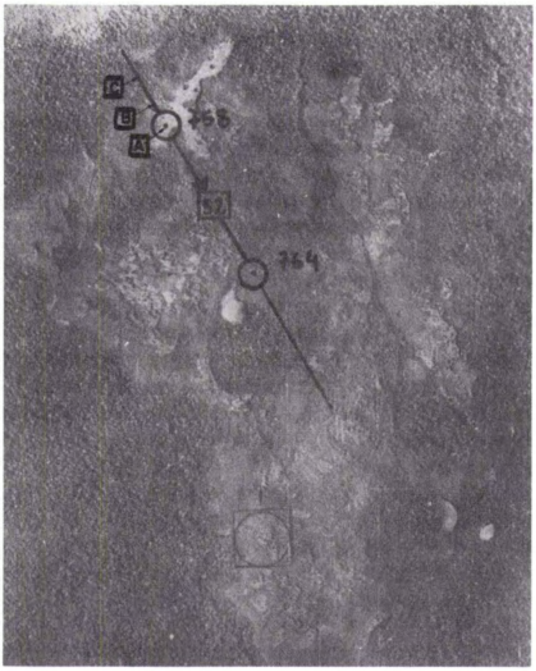

FIG. 12. Aerial photograph with identified APR points (see Figure 11).

SUMMARY AND CONCLUSIONS

The procedure and instrumentation described in this paper appear to offer a rapid, economical, and satisfactory solution to the problem of topographic mapping for preliminary engineering studies in tropical forest areas. Such maps are generally used for determining if a proposed project is technically and economically feasible; the latter factor assumes costs may be estimated within an accuracy of 15 to 20 percent.

It is recognized that later more precise maps may be needed for planning dams, powerhouse, transmission lines, roadways, or canals; these require clearing and subsequent large-scale surveys.

Formal map accuracy tests on the Caura River Project by closed traverses and profiles would be very costly as monumented control is mainly on summits and widely separated. Realizing this, a strong effort was made to control quality throughout by careful monitoring of technical procedures and by taking full advantage of every opportunity to verify results by comparing stream gradients, profiles from cross flights, residual errors, and map profiles versus APR profiles. Based on these internal checks, the resulting maps are believed wholly satisfactory for the intended purpose.

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Workshop
Aerial Photography/Aerial Photo Interpretation

University of Idaho
8-12 February 1982

The Workshop, sponsored by the College of Forestry, Wildlife and Range Sciences and Office of Continuing Education, University of Idaho, is for those land resource managers who have not had or who need a refresher on such topics as obtaining aerial photography; small format camera systems; preparing and viewing aerial photos stereoscopically; determining scale, distances, heights, slopes, and area; making simple maps; and interpreting vegetation and landform.

For more information please contact

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