PAPER NO. 20.

SURVEYING APPLICATIONS OF THE LASER TERRAIN PROFILER.

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SUMMARY. This paper describes, in general terms, the requirements for a laser terrain profiler and its application to the problem of providing adequate and timely vertical control for 1:100,000 scale mapping in Australia.

1. DEVELOPMENT.

The provision of vertical control for mapping has long posed a problem in arriving at an economic, practical and accurate solution, particularly in respect of medium scale standard mapping in a vast area such as Australia.

The use of photogrammetry has provided a practical solution to the compilation of planimetric 1:250,000 scale maps but with the requirement for contours to be added to the new 1:100,000 map series, considerable demand for vertical control for this purpose has led to the development of airborne methods which can produce the required density and accuracy within a reasonable time scale and without the obstacles imposed by terrain and difficult access.

This development has proceeded through barometric heighting by helicopter and airborne profile recording by radio altimeter to radar profile recording. Barometric heighting and radar profiling are still employed today and each is playing a part in the production of vertical control.

Barometric heighting produces results with a mean square error of approximately ± 2 metres but in order to be an economic proposition, provision of ground control is limited and requires extension by photogrammetric methods to obtain the required density of four vertical control points per photogrammetric model. Radar profile recording can produce results with a mean square error of approximately ± 3 metres and theoretically provide the required density of model control but in practice is limited by lack of resolution and inaccuracies due to the comparatively wide beam of the radar system. This led to investigations of the potential of the laser as a terrain profiler to provide the required accuracy and density of vertical control for systematic mapping at medium scales.

The Division of National Mapping has sponsored the development of a laser terrain profiler through the scientific and research facilities of the Weapons Research Establishment of the Department of Supply. A technical description of the equipment being developed is given in a paper by Mr. G. McQuistan (Paper No.19).

The limitations of radar profiling will be virtually overcome by the use of a laser system which, with a beam of only 10^{-4} radians, will obviate the requirement for extensive datum areas and enable positive ground heights to be obtained even in areas of open timber. One most important aspect of this development is that sponsorship by a surveying and mapping organisation will ensure that a practical field surveying system is produced and not a laboratory type equipment modified for use in an aircraft. Emphasis will be placed on compactness and lightweight rugged construction, facility of field operation and simplicity of field maintenance.

The development of recording methods and ancillary equipment in the laser system will add to the accuracy and simplicity of procedures. As it is being designed as a surveying instrument in the first place, it will have numerous refinements for practical surveying not normally found in the systems developed from modifications to equipment originally designed for other purposes.

Australia is generally a very good country for obtaining vertical control using methods based on barometric height determinations, particularly in the inland where normally fine weather prevails throughout the winter with low isobaric gradients. However, air turbulence is also very prevalent in these areas up to levels of 6000 to 7000 feet. As a stable flying platform is essential to the accuracy of airborne profiling equipment, a unique feature of the equipment being developed for the Division of National Mapping will be its ability to avoid the air turbulence by operating with a high degree of accuracy and resolution at heights of between 7000 to 10,000 feet.

2. USES IN NATIONAL MAPPING.

The Division is currently engaged on a programme to produce 1:100,000 maps of Australia with contours at 20 metre intervals. As this will be the first fully contoured series published in Australia, the provision of accurate and extensive vertical control for contouring is of major importance to the programme.

Superwide angle aerial photography is being used exclusively for the programme and is taken on a basic standard flight pattern of east-west runs with the unit for area coverage being the 1:250,000 map sheet. This involves 8 runs of photography and lends itself ideally to the provision of laser terrain profiles along the side lap of the photographic runs. From these profiles ample vertical control can be obtained to fully control each photogrammetric model.

This will be the major role of the laser terrain profiler in the Division for the duration of the current mapping programme.

The distinct advantage of terrain profiling over other methods of providing vertical control, is the ability to provide individual vertical model control directly from the profiles without further processing or photogrammetric procedures. This advantage is greatest when used in conjunction with analogue methods of establishing horizontal model control. The combination provides full model control for direct use in plotting instruments without the necessity to introduce photogrammetric methods of control intensification or have access to more costly comparator type instruments and electronic computers.

Another role for the Laser Terrain Profiler which may well develop within the Division is the provision of selected terrain profiles for use as an accuracy check on the manuscript map compilation. This will provide a ready means of comparing the terrain profile with its representation on the manuscript map.

3. PROCEDURE.

The equipment has been designed to operate from a light twin-engined aircraft which, apart from very worthwhile economics in aircraft operation, will permit the use of smaller airstrips with the consequent savings in unproductive flying. A combination of strip mosaics from existing photography and the 1:250,000 series maps will be used for navigation by visual flight rules and this will ensure accurate tracking over the prescribed flight lines.

The detailed procedures of operation have yet to be determined after operational testing of the equipment but will probably follow closely those used in radar profiling. This will involve commencing a survey flight over a pre-selected datum, proceeding along the survey line and closing with a further datum run. The continuous strip positioning photography will enable differential stereoscopic transfer of selected points to mapping photography and these points can be simply related to the profile record by common fiducial markers.

A major factor in the operation of radar profiling is the necessity to use large datum surfaces which may be some distance from the survey line and involve expensive flying time, less production, more computation of corrections and inaccuracies due to greater dependence on drift determination of the isobaric gradients.

With the possibility of datum measurements over virtual pinpoint targets with the laser terrain profiler, a multiplicity of datums are available from the national levelling programme and other sources not available to radar profiling. This will mean savings in unproductive flight times between datums and survey lines and less dependence on uncertainties of isobaric gradients over long distances, a factor which is vital to the final accuracy of the profiles.

Additional cross-tie profiles will be run at intervals, again commencing and terminating over a known datum, and these will provide a basis for comparison of the profiles at cross-over points and adjustment, if required.

4. REDUCTION.

The reduction of observed profiles will take the same form as that carried out for radar profiling. This will involve corrections for changes in the isobaric surface as determined from aircraft drift, and latitude corrections combined in the formula:

$$\Delta Z = 0.035 \times \text{Sin Lat.} \times \text{Sin Drift Angle} \times \text{True Air Speed} \times \text{Distance.}$$

The correction ΔZ is applied as negative for port drift and positive for starboard drift.

The deviations of the aircraft from the isobaric surface are corrected automatically on the profile record from hypsometer measurements during the profiling operation. Application of the drift corrections between datum runs will allow a closing error to be determined, which, if acceptable, can be distributed linearly along the survey line.

With the pattern of cross-ties a comparison can be made between reduced profile values at the point of intersection and, where necessary, this procedure lends itself to an adjustment of the network either by simple mathematical adjustment or a more sophisticated least squares solution. It is expected that with the accuracy of the laser terrain profiler this latter type of adjustment will be unnecessary for our requirements which are for control suitable for 20 metre contours.

The final corrections to each profile will normally be drawn as a graph so that the required correction can be read off the graph to coincide with any selected control point.

5. THE FUTURE.

The future uses of the laser terrain profiler are of course a subject for conjecture but in the survey field some that come to mind may be worthy of mention.

The accuracy and resolution of the equipment are the key to its potential which could well include providing vertical control profiles for large scale project mapping or the determination of profiles along proposed high tension transmission line routes and clearance profiles for micro-wave radio links.

A further possible use which may well appeal to the forester is the measurement of tree heights in areas of open timber and even the samples of counting of tree crowns where these are sufficiently definite to be resolved from the profile chart.