MODERN HIRAN INSTRUMENTATION

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PART I

Introduction

Hiran surveying is a recognized method of providing geodetic control in areas where the procurement of ground control by conventional means has been considered impossible or impractical. In comparison to other media of geodetic-control instrumentation, it is yet fairly new. A number of projects have been completed and results confirm a capability of executing first-order geodetic surveys. The application of Hiran for the nadir-point position in precise aerial mapping is another use. Here, the Hiran proved to be capable of providing control of sufficient accuracy for 1/50 000 scale mapping and under certain conditions could be accurate enough for 1/25 000 scale.

History

First use of the Shoran bombing instrument for geodetic control was envisioned by Carl I. Aslakson, then a Colonel with the Army Air Forces on loan from the United States Coast and Geodetic Survey. Some personnel of that first group are with our Hiran organization today. The first step in the program began with retaining the basic Shoran system and replacement of the bombing computer with a photographic recorder. This feature provided separate recording of precise distances from an aircraft to each of two ground-beacon stations (figure 1). Distances R and D were recorded. Another recorder was added for radio and barometric altitude. In this way we provided altitude and completed the essential instrumentation for Shoran trilateration.

Thus we began with a relatively simple system in early 1946. From then to 1949, we continued on without much change except for the addition of a weather-sampling psychrometer and a determined effort to develop efficient and productive procedures for operation. Some refinement was made to the altitude recorder. A device known as a *straight-line indicator* (SLI) was added, which could allow the navigation a straight course with distance information from the Shoran set. This SLI plus an exposure

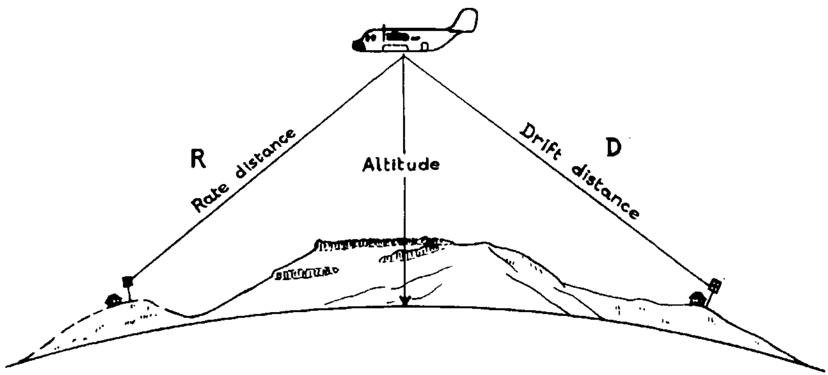

FIG. 1

synchronizer and a T-5 aerial-mapping camera gave us a capability for electronic-controlled mapping. The whole system was crude yet reliable. About this time, investigation was begun to increase the Shoran instrument accuracy. It was established that the Shoran pulse required about 90 feet for buildup time for each of the four received signals (figure 2).

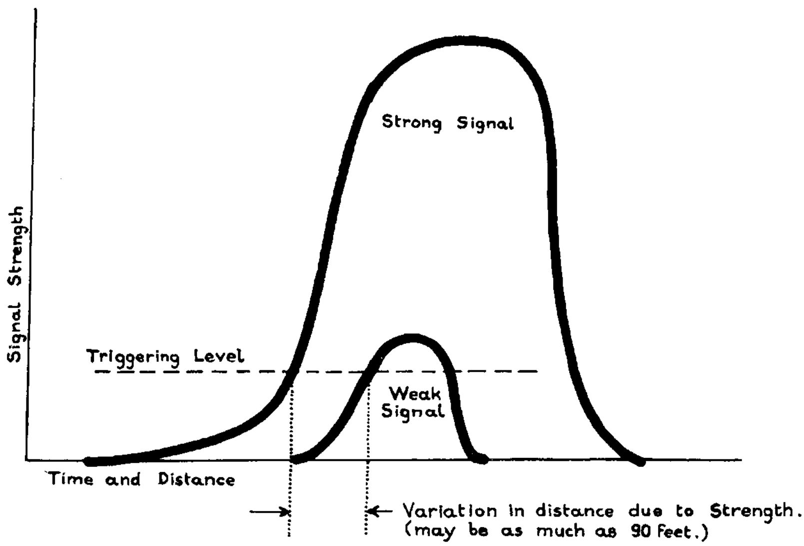

FIG. 2

Total error was possible up to 360 feet. To improve the accuracy, it would be necessary to eliminate or reduce this rather large error. Methods of measuring signal strength and applying empirical corrections were devised, but the method of correlation was unsound and results not reliable. This problem continued without solution.

About 1949, three new Shoran sets, experimental in nature, were built under contract by RCA. They used part of the old system but incorporated advantages of goniometers with error compensators, better receivers, improved crystal timing circuitry, and a five times faster scale for the operator to view the pulses. This promised a real improvement in accuracy. The 90-foot signal-rise-time error was controlled by a method called *Gain*

Riding. A small test project followed, with results of great promise. Two airborne sets plus new ground stations were obtained, and a production project begun. Results of this project confirmed first-order accuracy. During 1952, a later model set was obtained and on a test project proved sufficiently accurate for 1/50 000-scale mapping and under certain conditions could be used for 1/25 000-scale application. These later models contained improvements in the goniometer system permitting greater accuracy in the 50-100-mile, and multiples thereof, range. Production quantities of the latest type were received in early 1953, and it is this same set, known as the AN/APN-84, that is used today. Because of its higher precision than Shoran, it soon was designated as Hiran.

General electronic considerations

The basic concept of measurement is by electrical goniometers. The application is relatively simple. A sinusoidal wave is used to excite the stator of a resolver. The rotor of this resolver may be turned anywhere in its 360-degree rotation. The output is again a sinusoidal wave, but with a change in phase angle directly dependent on angular position. Hence, 90° rotation is exactly $\frac{1}{4}$ mile, 270° rotation is exactly $\frac{3}{4}$ mile. The accuracy of the input sinusoidal wave is mission calibrated to 10^{-5} and the angular position (physical) of the rotor versus phase shift (electrical) is periodically calibrated to within $\pm$ 2.5 feet. In the electronic consideration, the sinusoidal wave output is combined with 10- and 100-mile equivalent waves, and at coincidence the Hiran transmitter is triggered. Hiran, like the older model Shoran, uses one airborne interrogator and two ground-beacon transponders.

Operating procedures have been greatly refined throughout the years. The first method for completion of a mission was to fly four measurements at three distinct altitudes. Today we fly six measurements at two altitudes, which give about the same product, but with less effort. Mission sequence today calls for at least one hour, preferably two, for warmup and stabilization of the equipment. Complete zeroing (six measurements), second zeroing (six more measurements) and third final zero constitute one complete mission. With no difficulties, the sequence requires less than one hour.

Past projects have indicated a probable error of a single mission to be about ten (10) feet. Contributing to this uncertainty are factors due to the Hiran equipment, operational errors, aircraft-altitude determination, and recovery of the propagation velocity. The first step in a Hiran project is to calibrate and provide acceptance of the equipment. Each airborne set must be flown against a known distance as measured by ground triangulation. This measurement must agree within fifteen (15) feet on several complete missions. Occasional measurements which deviate from this figure are allowed, but for the most part, the equipment must display reasonable consistency.

PART II (*)

New Aircraft program

(*) This part is not being reproduced here owing to its special technical nature.

PART III

Additional areas of modernization

Simultaneously with the new C-130 program, we are also engaged in other programs intended to increase our accuracy and efficiency.

A new antenna system and mast for the ground stations are being developed. This should provide at least 3 times better Hiran signals, and is remotely controlled in both height and direction. While observing the signal quality at the Hiran set, we will be able to make adjustments in height and azimuth for the best signals. This system also contains the VHF troposcatter radio antenna.

An error recorder for post-mission analysis of airborne data is being fabricated. It will eliminate the ambiguity problem which sometimes occurs in Hiran-controlled photomissions. This feature is made possible through automatic stepping of the scale from 100-10-1-mile intervals. Display of gain riding levels and signal strength are also being considered.

Improvement in the Hiran receiver with a three (3) times better sensitivity, more uniform bandwidth and with a panoramic display for precise tuning is being considered. Reasons for errors which sometimes occur on Hiran missions have been difficult if not impossible to resolve. One thing we do know is that off-tuning of the receiver causes error. Consider then that the transmitter can also drift off frequency and cause the same error. Presently we have no way of detecting such drift and resulting magnitude or direction of error. This drift is further complicated by the fact that it can occur any time during the mission; for example, between altitude groups. The panoramic presentation provides continuous monitoring throughout the mission, and thus should eliminate errors due to off-tuning.

Automatic gain riding for the ground stations will be tested in the near future. This instrument is similar to that in the C-130.

A new power unit type PU-377 will soon be used at the ground stations. It is a five-kilowatt unit.

A new frequency standard for use in the aircraft with the AN/APN-84 is under study. This should improve our accuracy and speed up the mission.

Electronic computers and tape recording of airborne data are under study. This is yet too premature to discuss.

Currently under study is the modification to the airborne Hiran set to eliminate the restricted high-error-distance zone which occurs about 100 miles per channel. Consideration is being given to changing the set from 100-mile to 300-mile cyclic measuring ability. This would eliminate the problem since it would not occur at 100 or 200 miles. This change requires 3-to-1 gear (mechanical) and 3:1 divider (electronic) modifications. A breadboard divider has already been worked up. The gear ratio which is actually now 100:1 must be changed to 300:1, and there is some difficulty in space for the new gearing. This problem is being pursued presently. We have prepared a study for a new geodetic system to replace the present Hiran set. Of interest is the accuracy requirement which has been stated as :

(1) *Trilateration.*

The various types of errors in a new geodetic survey system should be completely random in nature so that the measurements of different observed distances or the same observed distance at different days or times should follow the laws of probability. The system should not show a

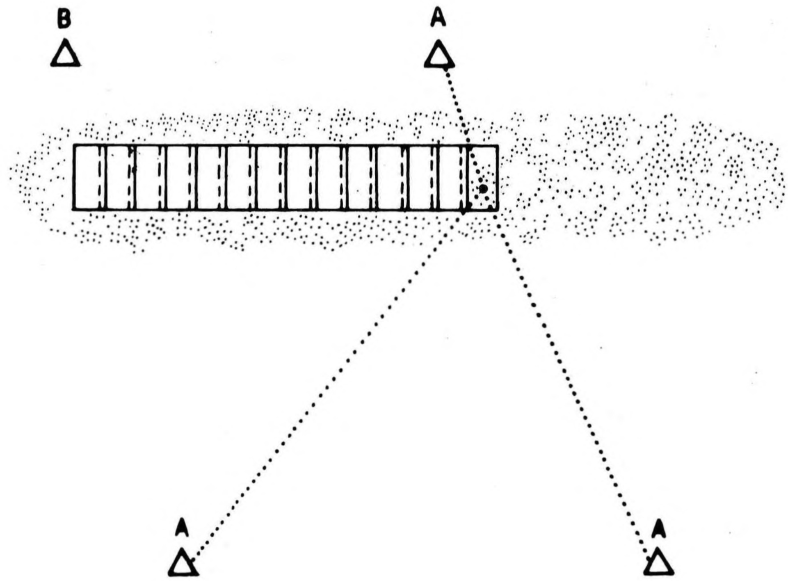

FIG. 3*a*. — Controlled Photo Mapping.
A = In use. B = Finished. C = Ready.

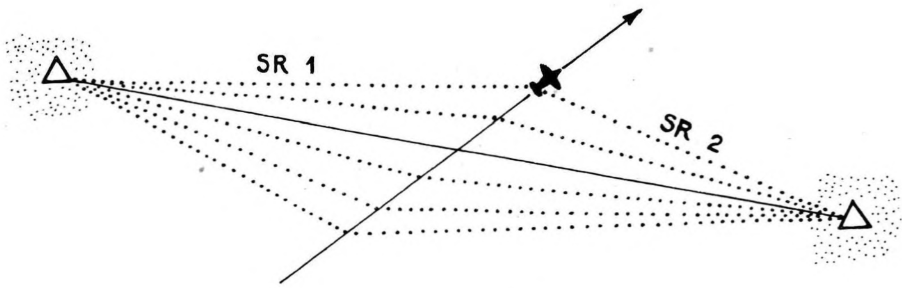

FIG. 3*b*. — Trilateration.
Two channels for SR_1 } Combinations are switched
Two channels for SR_2 } for successive measurements.

systematic or constant error. The practical maximum limit of accumulated error in any line measurement should not exceed ± .0058 statute mile, and the probable error of a single observed distance should be less than ± .0020 statute mile. This means that at least one half of the measurement should be in error by no more than ± .0020 statute mile, two thirds of the measurements should be in error by no more than ± .0030 statute mile, and no more than one measurement in twenty should exceed the limit of ± .0058 statute mile.

(2) *Hiran-Controlled Photography*

The total average error existing in the instantaneous, reduced rate and drift measurements should not exceed ± 0.0047 statute mile, and the individual error should follow the laws of probability. The practical maximum limit of accumulated error in any single-leg measurement should not exceed ± 0.0116 statute mile, and the probable error of a single measurement should be less than ± .0040 statute mile. This means that at least one half of the measurements should be in error by no more than ± 0.0040 statute mile, two thirds of the measurements should be in error by no more than ± 0.0059 statute mile, and no more than one measurement in twenty should exceed the limit of ± 0.0116 statute mile.

One new idea in the system is that of using four channels. Three of these are in use at one time to provide control for photomapping. This eliminates the 60° to 130° station-angle restriction we now have. The fourth channel is for switching to a new station along the flight path. In figure 3 we see three active channels. The fourth is being readied for the next station.

Electronic considerations for a new system are manifold. The Hiran of today is plagued with interference to and by other activities. Another spectrum, such as 1 000 megacycles, or somewhere in the present UHF TV band (this is contingent on reallocation of the present UHF band which has been determined as unsatisfactory), should prove satisfactory. Use of about 1 000 megacycles would permit high-performance parabolic antennas, passive reflectors, R/T unit on top of mast, and sharper rise-time signals through wider bandwidth. Propagation of signals is down 9 decibels at 1 000 megacycles, and 18 decibels at 2 000 megacycles, as compared with 300 megacycles. This should be overcome with higher-gain antenna systems.

Use of Maser circuits, voltage-adjustable capacitors, magnetic amplifiers, new high-power transmitting tubes and many other new innovations are promising with regard to a new system to replace Hiran.