Geodesy and Mapping

Purpose: Knowledge of the relative positions of points on the surface of the earth is of military, commercial, and scientific value. How far and in what direction one point is from any other point is a prime requirement for the advancement of civilization. The need for this information was recognized as far back as ancient Greece and Egypt, for it was then that the collection of geodetic and mapping data began.

Definition and Requirement: Geodesy is the science which deals with determining the precise size and shape of the earth and the relative positioning of points on its surface. This knowledge is required so that maps showing topographic features can be constructed with controlled scale and perspective.

Topographic Data: Topographic data is obtained from photographs taken from an aircraft flown over the terrain to be depicted in the map. Special precision cameras are used for this purpose.

Geodetic Data: Various methods are used to obtain geodetic data. Among these are:

Astronomic Observations: Latitude and longitude of points can be obtained from astronomic observations. It is, of course, necessary to occupy the point for which the observations are to be made. Each position determination is an independent observation, the relationship with other positions not being obtained directly. The accuracy of any position relative to any other position is limited due to the deflection of the vertical at the various points; that is, the inability to precisely determine which way is up. The error in the relative positions due to this cause can be highly significant - an error of one mile or more is often found in the distance computed between two such positions.

Triangulation Surveys: For the past several hundred years, triangulation surveys have been used as the primary method of collecting geodetic data. Using an astronomic position as a starting or datum point, triangulation surveys are extended over an area and the relative positions of points precisely determined. A highly accurate, or first order, survey is usually accomplished first, followed by second and third order surveys, and even less accurate position determinations to provide detailed control for mapping. The extent of the area covered by triangulation surveys may be limited by geographical considerations due to an inability to cross large bodies of water and the necessity for occupying the points whose positions are to be determined. The relative position of points included in surveys referenced to different datum points are not accurate. The amount of discrepancy between them will be dependent on the discrepancy between the astronomic positions used as datum points.

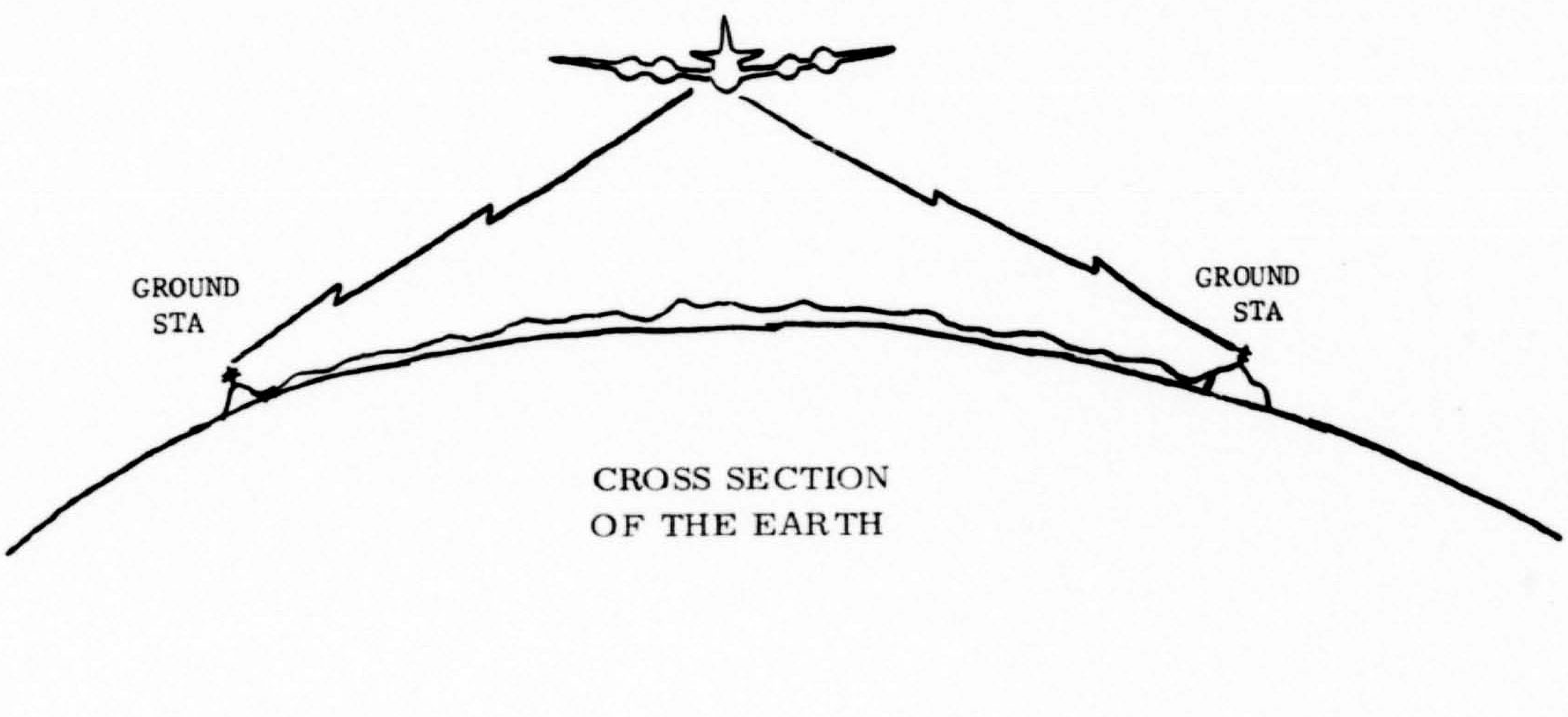
Trilateration Surveys Using Hiran: The long-range distance measuring capability of Hiran permits accurate surveying under conditions which would not allow the use of any other method. Large bodies of water can be crossed and surveys extended across land masses impenetrable to ground survey parties. Local datum systems may be tied together and placed on a common reference. Surveys may not only be extended rapidly but also economically due to the necessity of occupying only a few points on the ground and the fact that weather is no deterrent.

Hiran Electronic System

What Hiran Is: Hiran is a modified Shoran electronic system, operated and maintained with special techniques and auxiliary equipment, 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 distances along the sea level surface of the earth and applied to the science of geodesy.

How Hiran Works: A pulse of radar energy is transmitted by the airborne set to a ground station which receives and retransmits back to the airborne set. The time between transmission and reception at the aircraft is measured and converted to distance. The conversion factor is 0.00001074 second of time to one statute mile of distance. The airborne Hiran equipment makes alternate groups of measurements to two stations. Switching is at a rate which causes the measurements to both stations to appear simultaneous.

HIRAN AIRCRAFT MAKING
DISTANCE MEASUREMENT



Geodetic Surveying: By measuring the distances with Hiran between previously selected ground stations a highly accurate survey net is formed. Computations utilizing these distances yield the latitude and longitude of each ground station relative to each other.

Controlled Photography: By recording the Hiran distances to each of two ground stations at the instant that the aerial mapping film is exposed, the location of the point directly beneath the aircraft can be determined and the photograph placed in its proper spot on the earth's surface.

Hiran's advantages over the other methods of surveying: The Hiran survey can cover great distances rapidly, is not deterred by weather, and can cross large bodies of water and impenetrable areas. Hiran can not only accomplish surveys which cannot be made any other way, but can execute them accurately, rapidly, and economically.

Hiran's tactical uses: With the increased range of present day weapons systems, knowledge of the exact location of both the weapon and the target necessitates accurate surveying spanning oceans to tie the major land masses of the world together. This can and is being done by Hiran surveys.

Hiran's other uses: Hiran surveys are of commercial and scientific value in helping to provide accurate maps, in aiding navigation, in providing information about the earth's surface and the shape and size of the earth, and in determination of the speed of light.

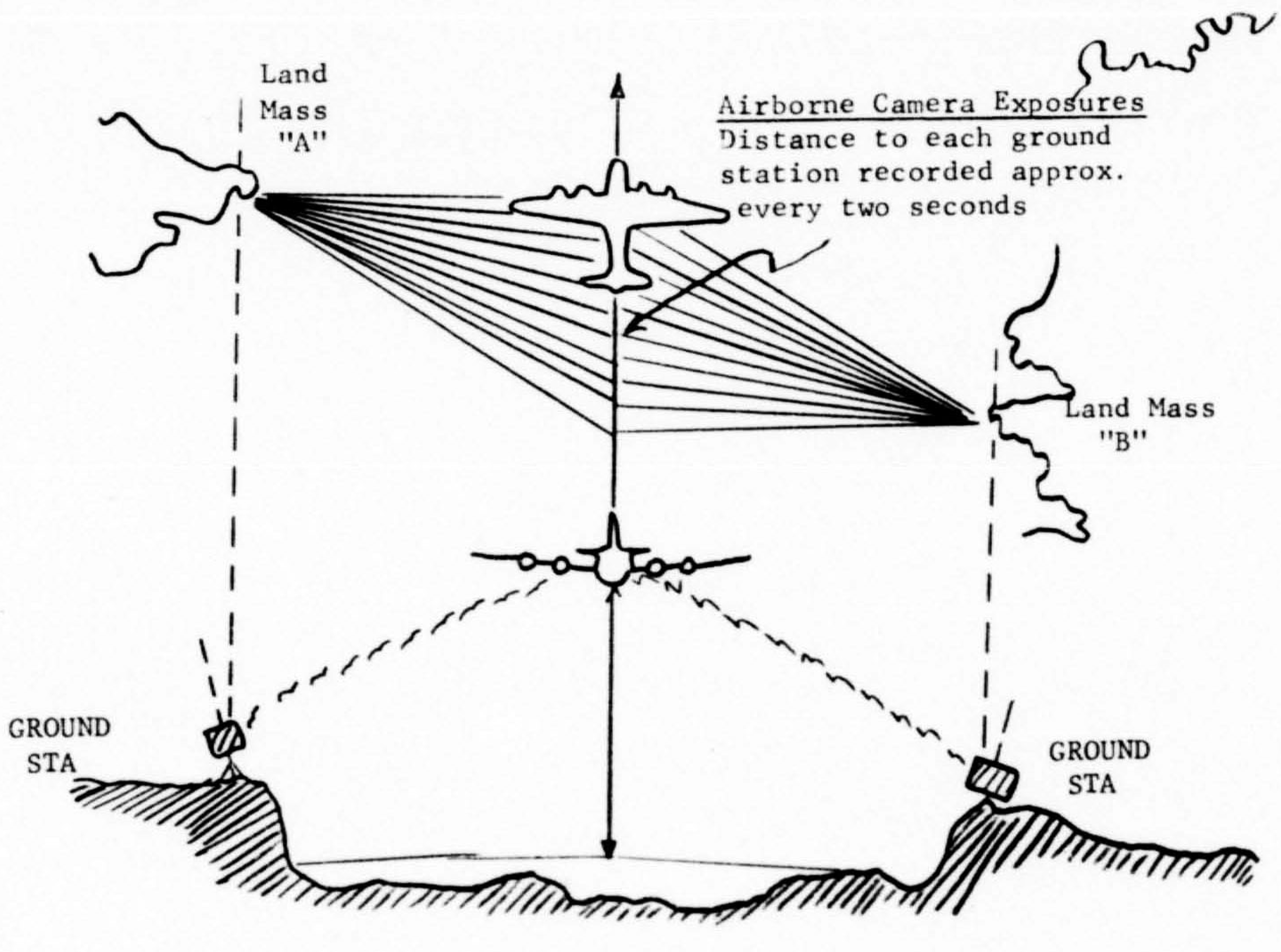
The future of Hiran: The Hiran system will continue to supply much valuable information for improving the world geodetic framework for missiles, rockets, and satellites. It is the basic system that can do much to assure geodetic preparedness so urgent and important to our military weapons of the future.

A new version of Hiran: Equipment is presently being developed for the 1370th Photo-Mapping Wing. This system will employ "Present state of the art" circuitry, provide greater reliability, and speed the collection of geodetic data.

Hiran Geodetic Surveying:

Line Crossing: Flying the aircraft across the imaginary line connecting two ground stations while simultaneously recording the distance to each station is called a line crossing. The recorded distances are then used to mathematically determine the minimum sum distance between the two ground stations via the aircraft. Appropriate corrections to the minimum sum distance produce the distance between the ground stations along the sea level surface of the earth.

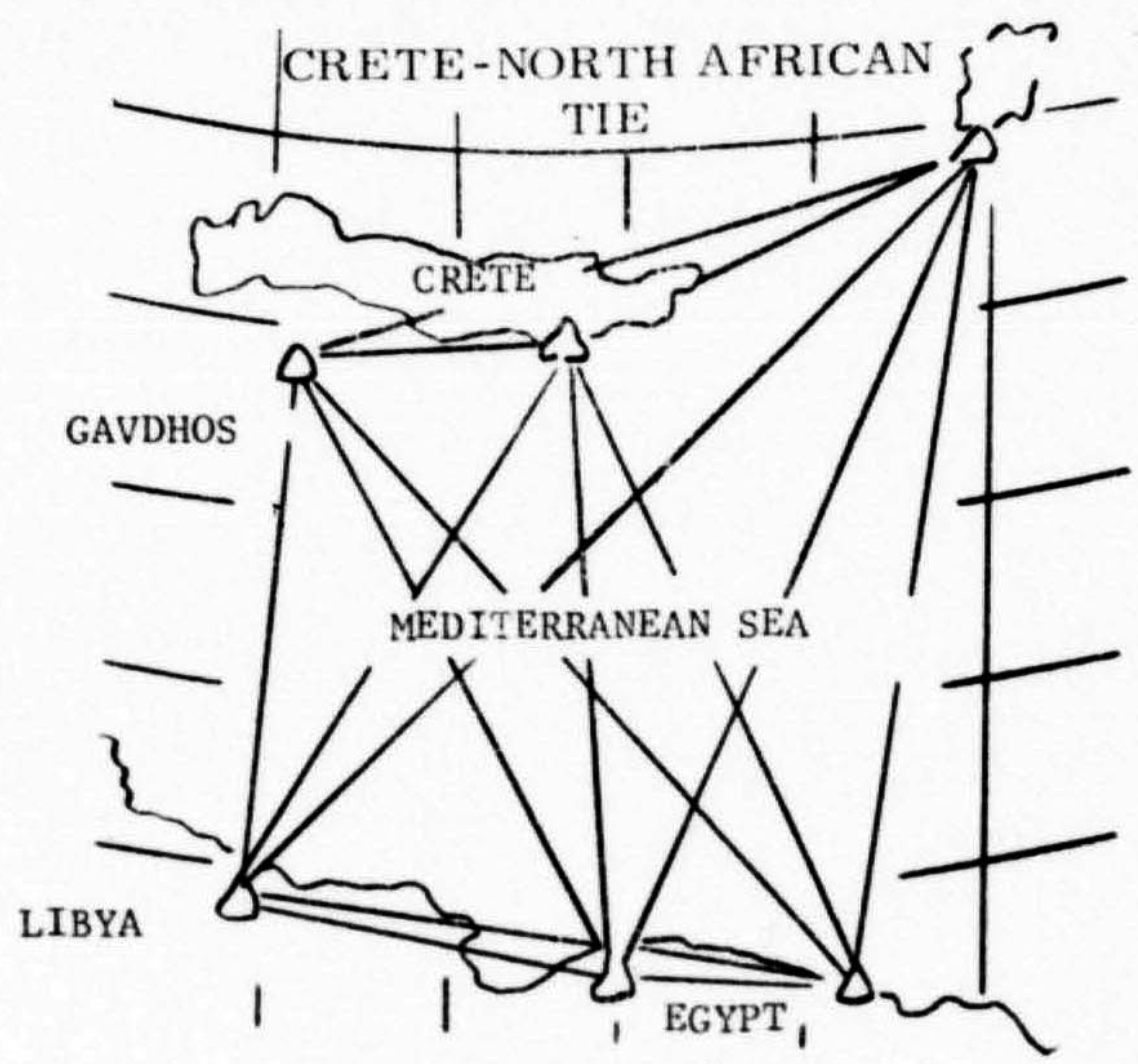
Mission: A Hiran mission consists of twelve line crossings flown in groups of six at each of two altitude levels. The final mission distance between the two stations is thus a mean of twelve crossings usually accomplished in a period of two to three hours. The final result is designated as "S" distance.



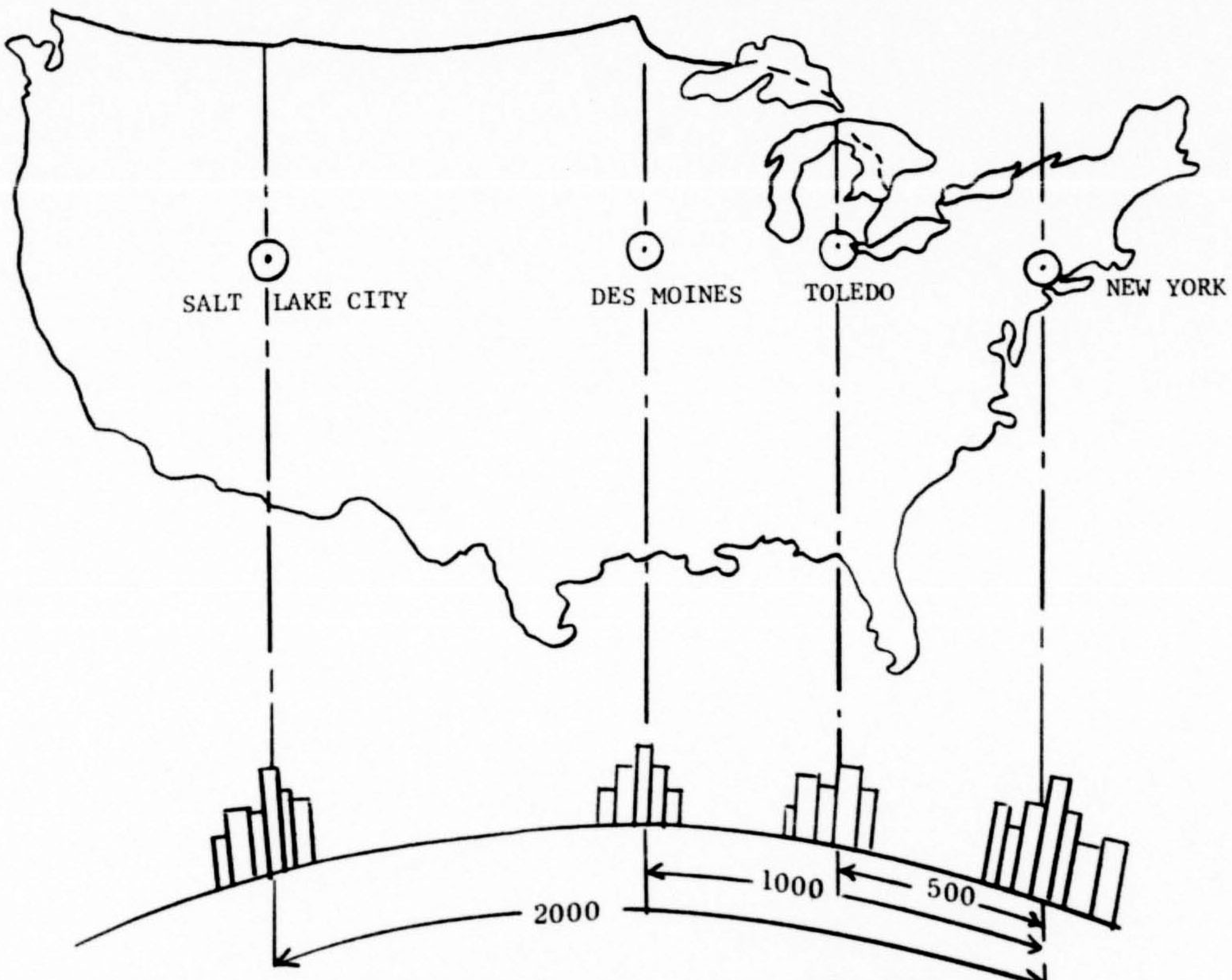
Trilateration Net: The technique of trilateration is used with the Hiran system in the determination of geographic positions of points on the surface of the earth. Networks of measured distances allow the establishment of geographic positions over a distance of thousands of miles. For example, a Hiran net has been accomplished to determine the geographic positions in Europe which are relative to positions in North America.

Mission Accuracy: The accuracy of the position determination is dependent on the accuracy of the individual line measurements. Distances measured in Hiran projects are expected to have an average probable error not to exceed ± 12 feet with the maximum error of any distance measured for a Hiran net not to exceed ± 30 feet. These are errors in observed distances. The network adjustment distributes the distance errors in the most probable manner, therefore, the adjusted distances are improved in accuracy.

Position Accuracy: First-order accuracy has been specified for all Hiran projects accomplished. These projects were planned to give an accuracy in position determination equal to the expected accuracy of first-order triangulation surveys of similar extent. The accuracy of the position determination depends on the figure of the net and the accuracy of the Hiran measured distances. Hiran nets are designed with sufficient complexity to produce first-order accuracy with an expected probable error of Hiran measurements of about ± 12 feet. The Crete-North African tie is an example of this. Of course, as the length of a net is extended from known positions, error becomes greater. The accuracy indicated in the illustration on the following page is expected from Hiran surveys.



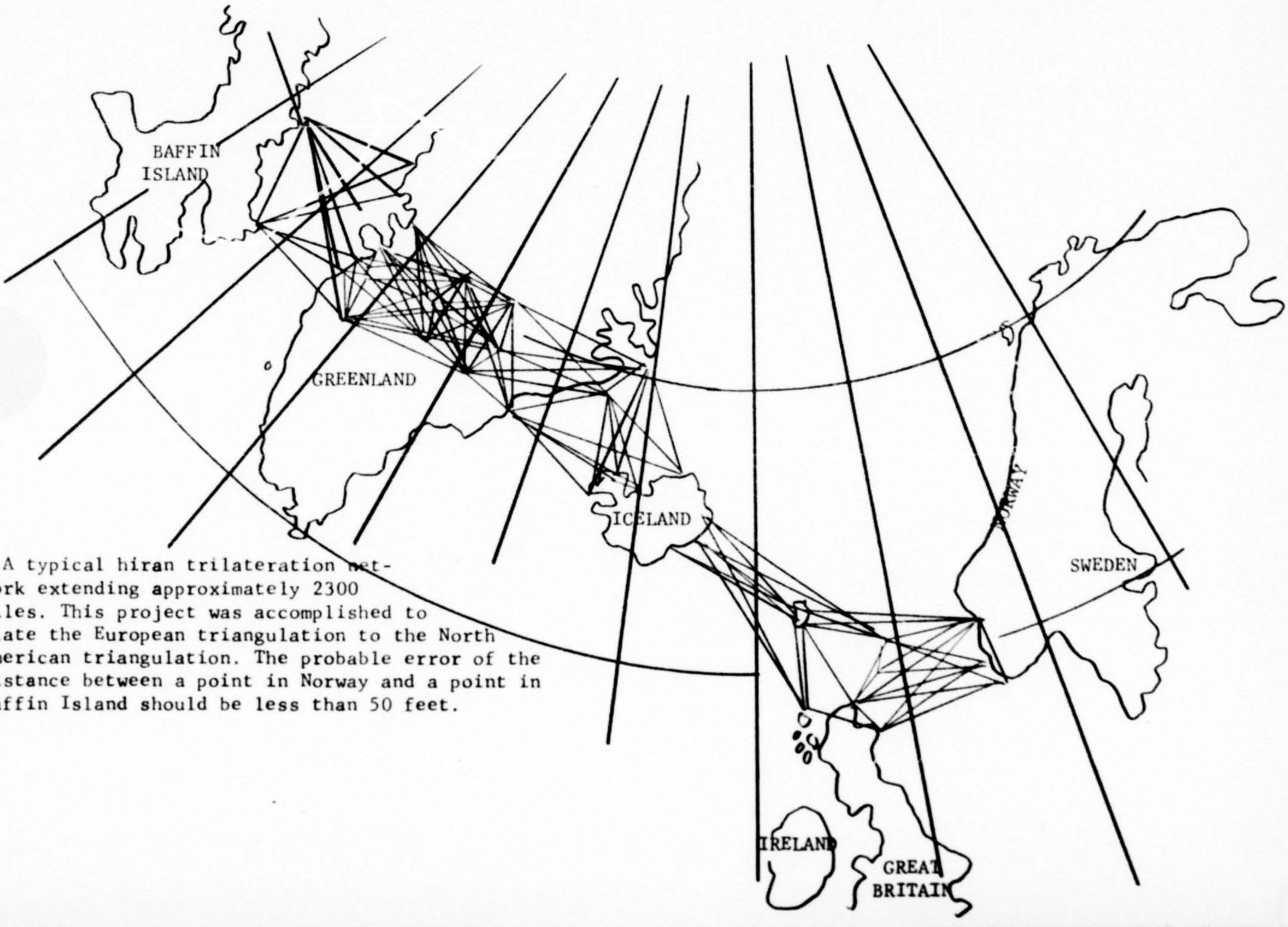
ACCURACY OF HIRAN



IN A HIRAN NETWORK OF INDICATED LENGTH

LENGTH (MILES)	PROBABLE ERROR OF HIRAN POSITION	PROPORTIONAL PART ACCURACY
500	± 15 feet	1:158,000
1000	± 26 feet	1:200,000
2000	± 42 feet	1:252,000

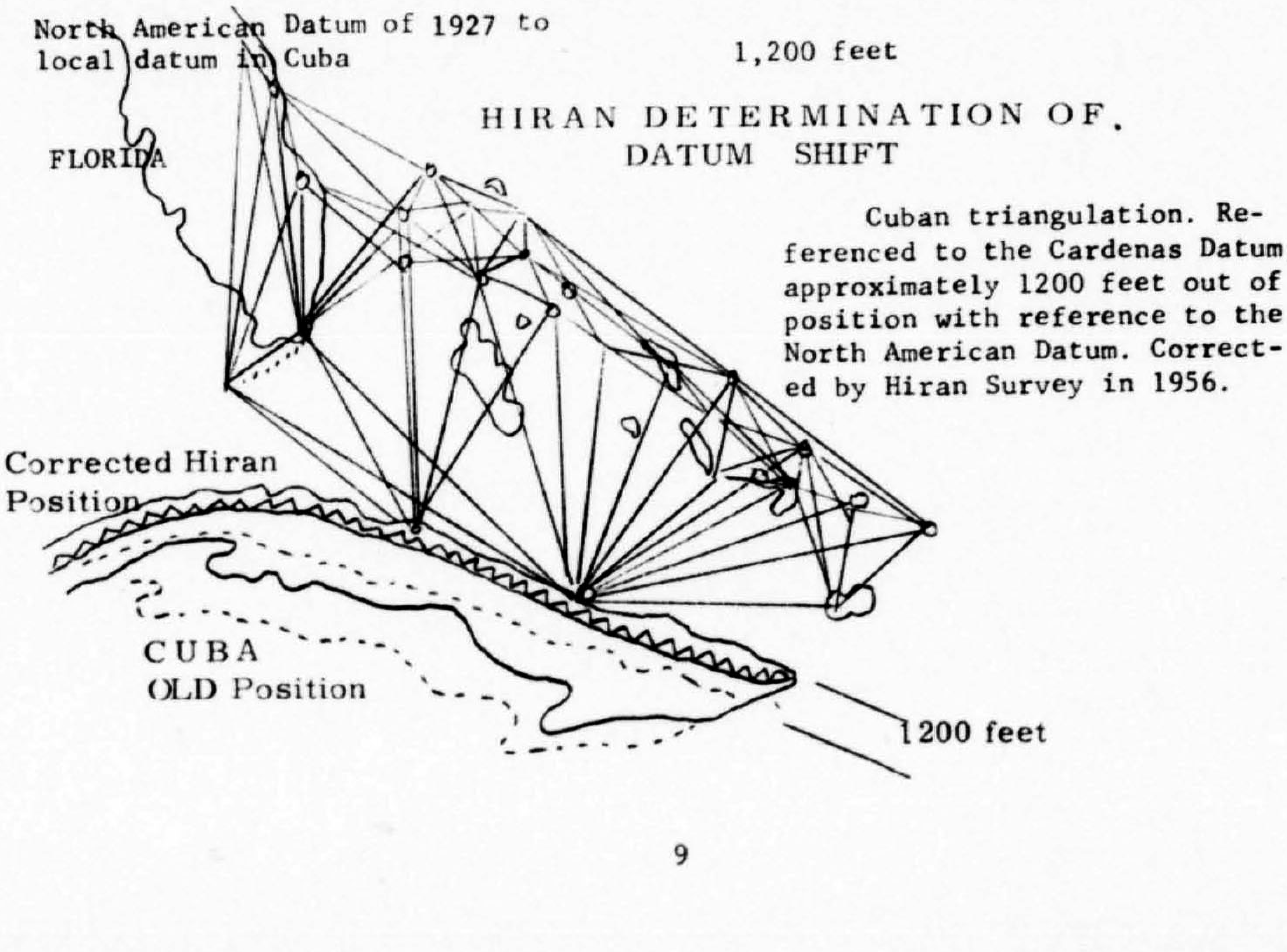
TYPICAL HIRAN TRILATERATION NETWORK



A typical hiran trilateration network extending approximately 2300 miles. This project was accomplished to relate the European triangulation to the North American triangulation. The probable error of the distance between a point in Norway and a point in Baffin Island should be less than 50 feet.

Datum Ties: Hiran trilateration networks extending across the North Atlantic and from Florida to Trinidad have tied triangulation surveys on local datums to the North American Datum of 1927 and the European Datum, and have tied these two major datums to each other. The discrepancies between datums have been determined. While the discrepancies noted below were caused primarily by inconsistencies in the astronomic positions used on the datum points, the inconsistencies between individual astronomic positions determined with usual accuracy can be considerably larger.

Datum Tie	Discrepancy
European Datum to local Datum in Faeroe Islands	1,600 feet
European Datum to local Datum in Iceland	800 feet
North American Datum of 1927 to local datum in Cuba	1,200 feet

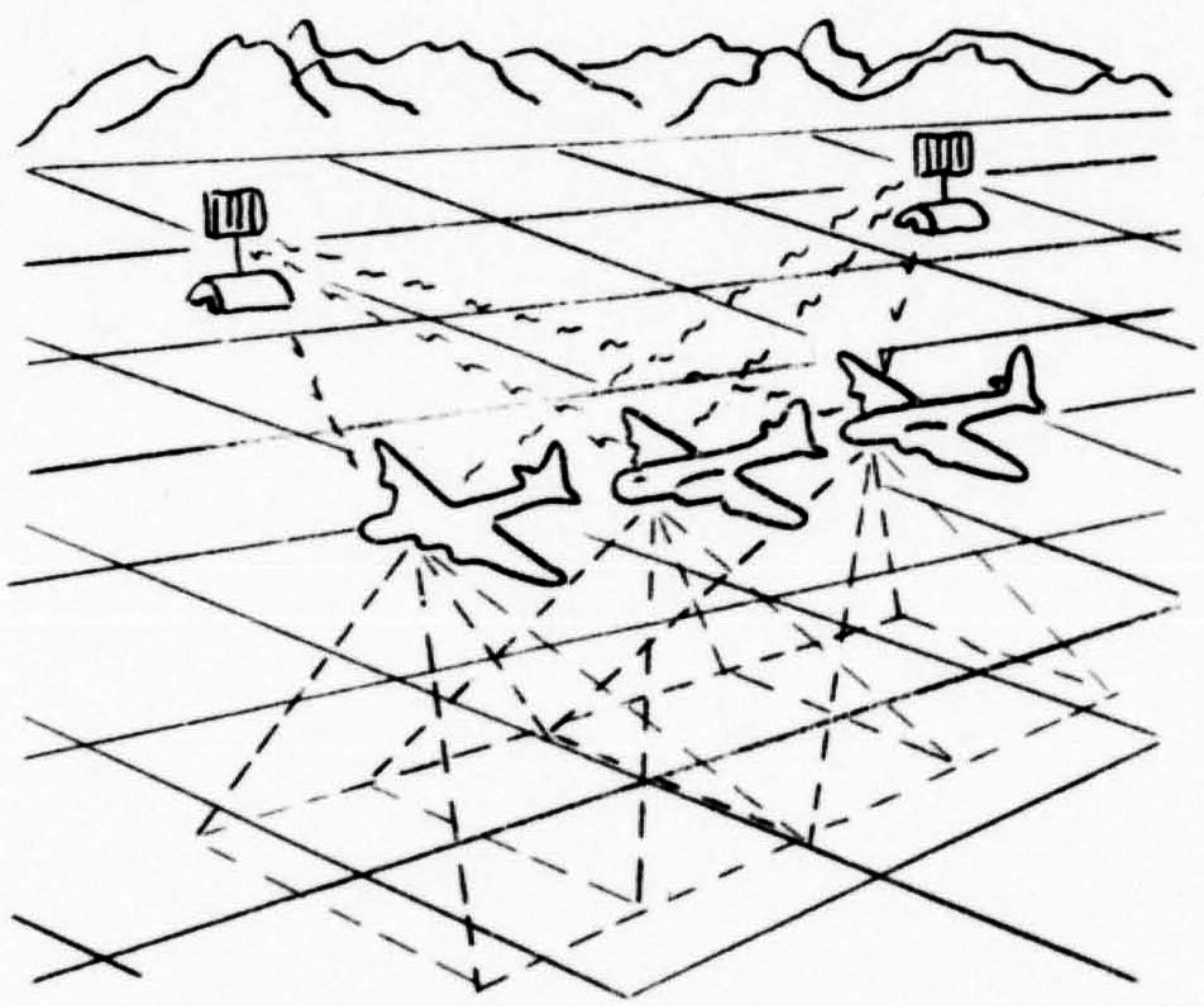


Hiran Controlled Photography

Techniques: Precise mapping requires knowledge of the relative positions of points on the earth's surface for horizontal control. This control can be supplied by utilization of the Hiran controlled photography technique: Distances measured from an aircraft to two ground stations of known geographical position allow the aircraft to be positioned in space; the position of the point on the surace of the earth directly underneath the aircraft can 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. Flight lines of Hiran controlled photography can provide such control points in sufficient quantity and of sufficient quality for precise mapping.

Accuracy: Hiran controlled photography can supply ground control of the accuracy required for 1:50,000 scale mapping and, under optimum conditions, for 1:25,000 scale mapping.

HIRAN CONTROLLED PHOTO FLIGHT LINE

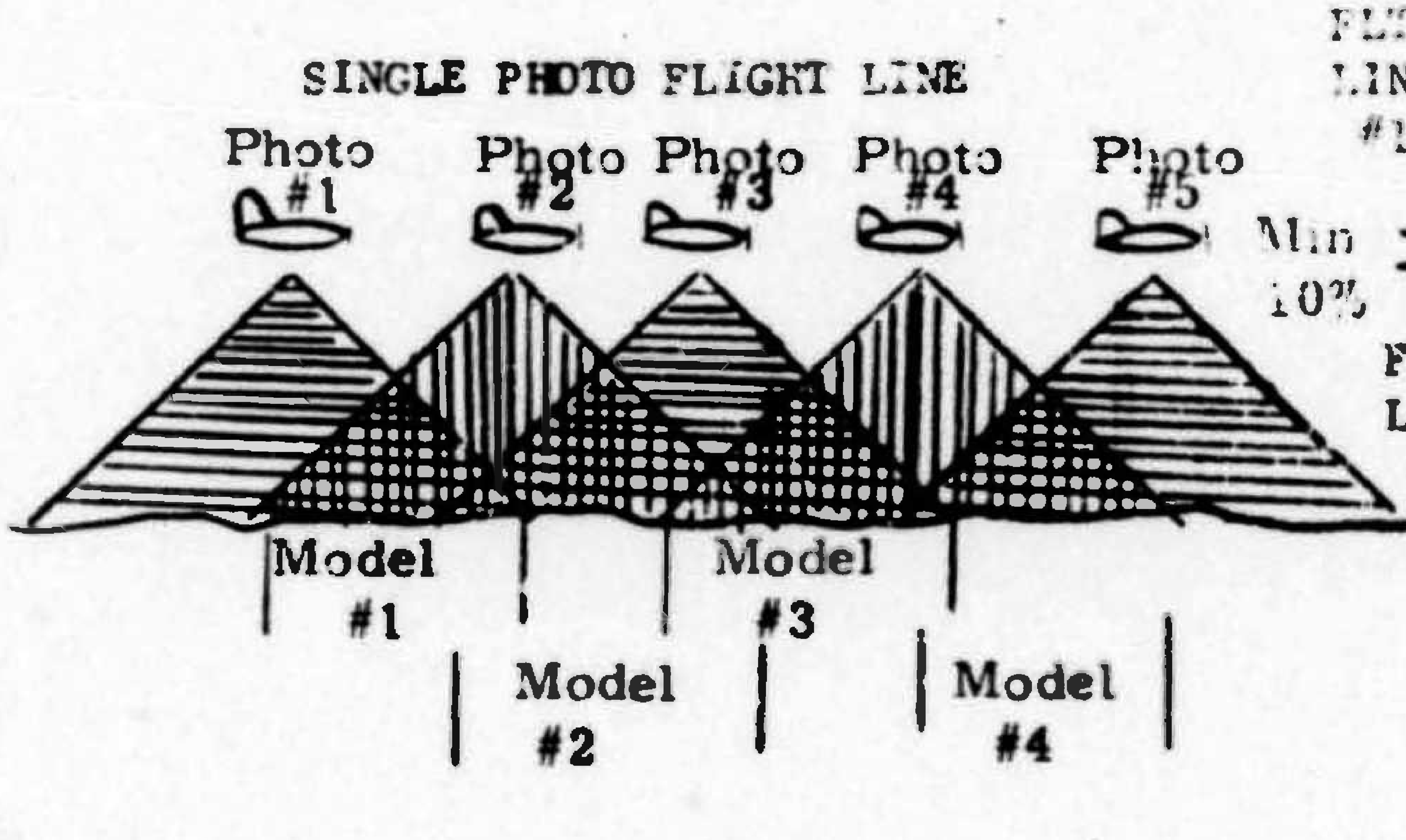


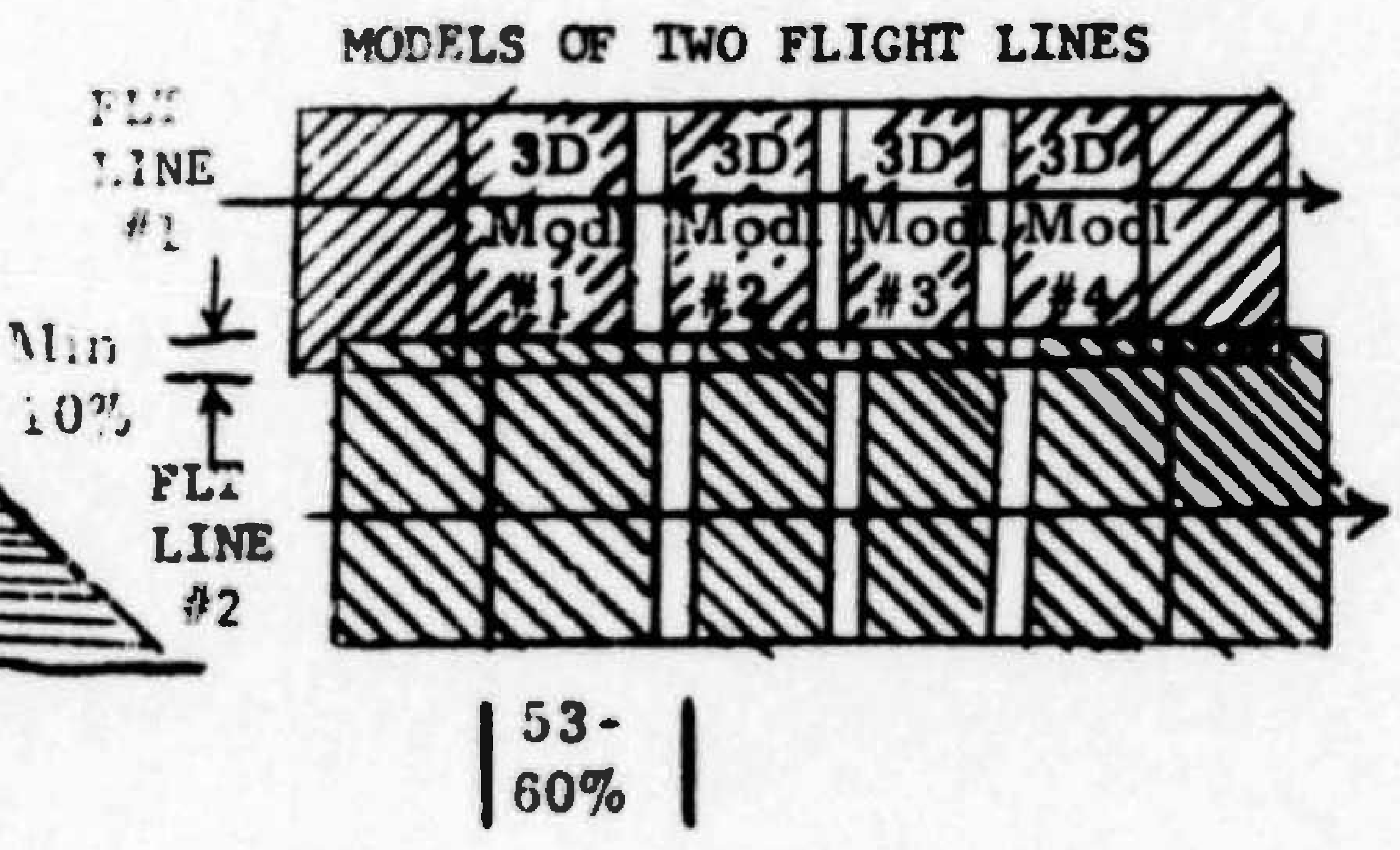
DISTANCE TO EACH GROUND STATION RECORDED IN AIRCRAFT AT THE INSTANT OF EACH CAMERA EXPOSURE

Precision Aerial Mapping Photography

Purpose: Precision aerial photographs obtained by the 1370th Photo-Mapping Wing play a major role in the art of modern map making. Reproductions of the photographs, called diapositives, are inserted into stereoscopic projection instruments. The projection causes a three dimensional view and creates the illusion that the map maker is viewing a relief model of the terrain depicted by the photographs. To be a true replica, the projection must be matched with points of known distances and azimuths. These points, established by survey or Hiran control, and points of known elevation control the scale, orientation and elevations in the final map production. Hundreds of these models, to provide stereo coverage of the entire area, are generally required to complete a typical photo-mapping project.

Technique: A precision mapping camera, gyro stabilized, is borne in an aircraft which flies at a constant altitude along pre-selected straight flight lines. Photographs are taken at intervals which will cause one photograph to overlap the next, in the forward direction, by 53 to 60 percent. Adjacent flight lines are parallel and so spaced to provide a minimum of 10 percent side lap. To be acceptable, the photographs must be taken during days when atmospheric, light, and terrain conditions are such that clear, well defined negatives of normal detail can be produced.





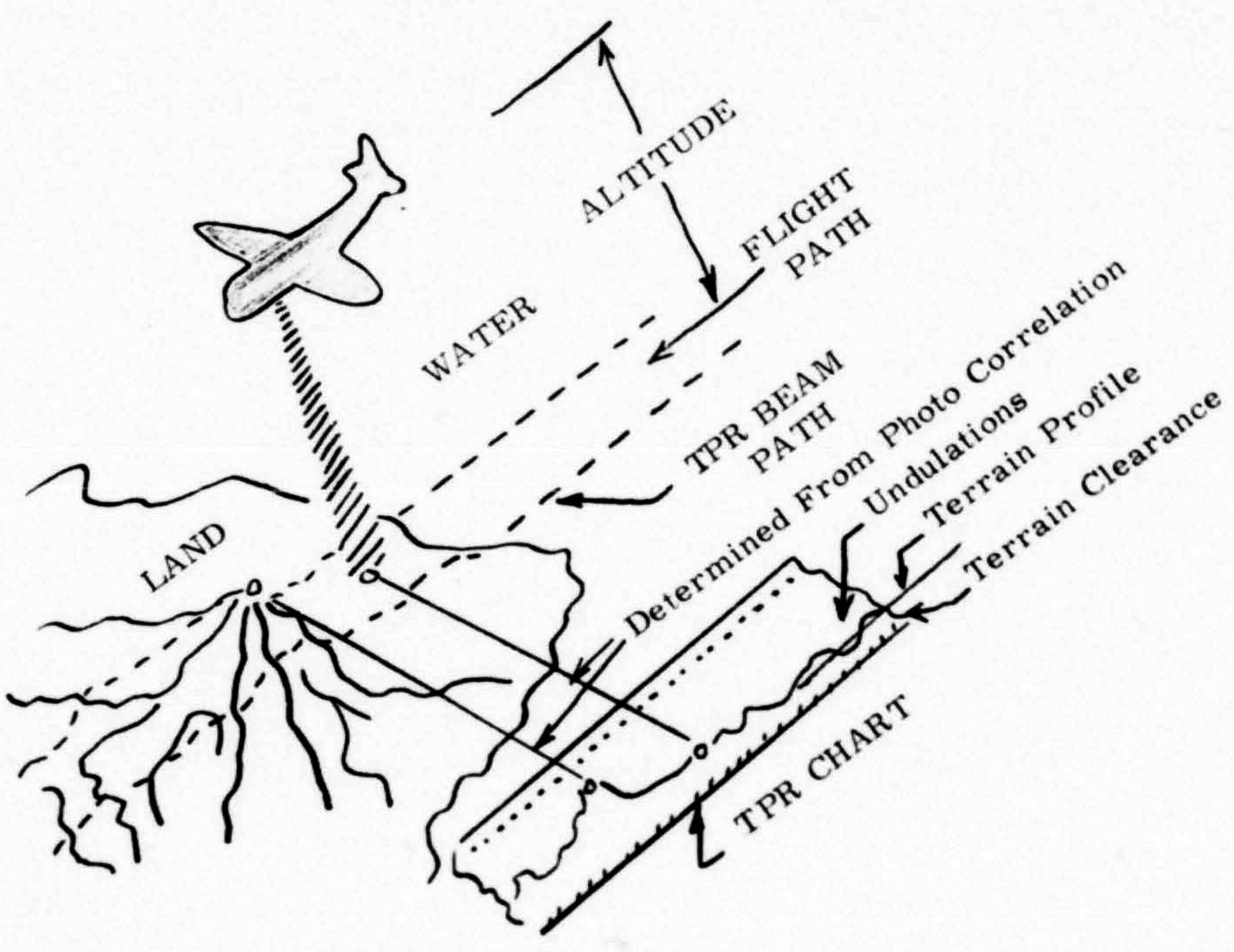
Terrain Profile Recorder (TPR)

Purpose: Accurate map production requires a knowledge of the various elevations of the terrain to be mapped. This knowledge, relative to mean sea level is called vertical control. Also needed is the precise scale of the mapping photographs to be used. Obtaining this information by ground survey methods is time consuming and often impractical in undeveloped areas of the world. When required, elevation and scale information can be obtained with the Terrain Profile Recorder electronic system (TPR). This system is installed in a number of the aircraft in the 1370th Photo-Mapping Wing.

TPR System: The TPR system comprises two channels of circuitry. One is a narrow beam radar altimeter which measures the aircraft height relative to the earth's surface. The other contains a hypsometer unit which determines exact deviation of the aircraft from a pre-selected atmospheric pressure level. Both channels combine to provide a chart type recording of terrain profile which will be accurate if the selected atmospheric pressure level remains constant relative to height above the earth's mean sea level surface. Otherwise, appropriate corrections must be applied. Radar attitude without hypsometer correction is recorded on the same chart and is called terrain clearance. This recording and the focal length of the mapping camera can be used for photographic scale determination if camera verticality can be established.

Spotting Camera: A camera is included with the TPR installation which enables correlation of the information in the chart recordings to the mapping photographs. Known as the spotting or positioning camera, its optical axis is locked to the axis of the radar beam and their relationship is known to within five minutes of a degree. Therefore, points of terrain which were struck by the radar beam can be identified on the photographs obtained. Each photograph is time correlated with the chart recording. Thus, terrain elevation and clearance information can be accurately transferred from the chart to the mapping photography.

Data Collection: Accomplishment of TPR flight lines is preceded by hypsometer adjustment while over a flat surface of known elevation. An ocean, lake or river is ideal for this purpose. Here, the aircraft is purposely undulated above and below the selected pressure level while the hypsometer sensitivity is adjusted to cause a chart record of constant elevation in terrain profile. Next, the true height of the selected atmospheric pressure level above the mean sea level is determined. Surface elevation, known, plus height above the surface, terrain clearance, equals height above mean sea level. Then, the TPR and spotting camera are flown along the path where profile and clearance information is required. It is preferable to have the mapping camera and Hiran control to function at the same time. During this mission, aircraft deviations from the selected atmospheric pressure level must not exceed the hypsometer correction limits. As the mission progresses, a continuous chart recording of terrain profile and clearance is obtained. A fiducial mark appears on the chart to show the time of each spotting camera correlation photograph. The profile and clearance recorders are caused to deflect each time a mapping photograph is obtained. At intervals along the line, drift angle, air speed, latitude and distance flown are hand recorded. This is to determine any change in atmospheric pressure level relative to height above mean sea level at specified intervals along the line. After termination, the true height of the selected pressure level is again measured over a flat surface of known elevation to determine the true pressure level change. This provides a check over the accumulated pressure changes determined by computation from hand recorded data.



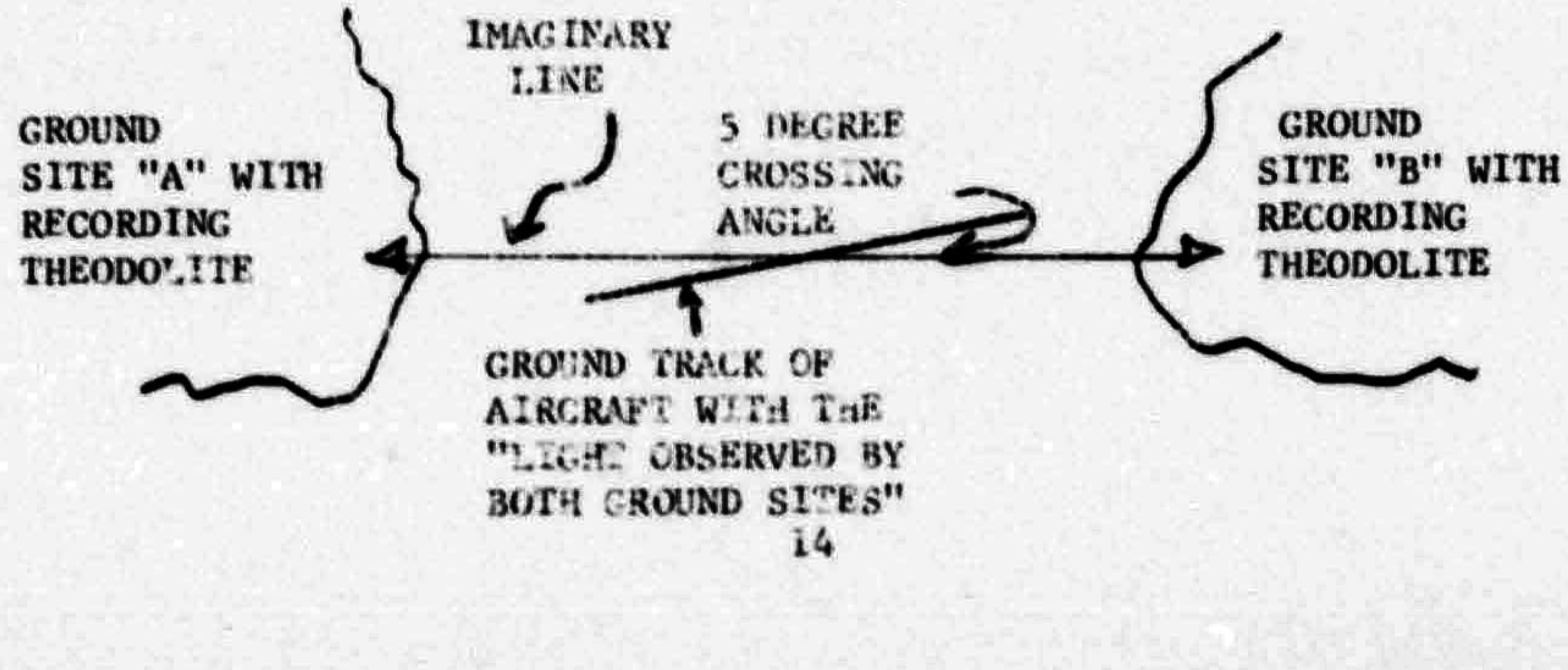
Long Line Azimuth Measurement

Purpose: Ground surveys are not always available in remote areas to provide azimuth for oreitnation of a Hiran survey network. In these cases, azimuths can be determined with a process known as LOLA (LOng Line Azimuth) measurement using the Sodano technique. The feature of this process is that azimuths can be measured to within one second of arc accuracy for distances longer than visual line of sight. It is especially useful when establishing an independent geodetic datum and also to maintain orientation in a long arc of Hiran survey. To date, LOLA measurements have been successful to determine the azimuths of lines as long as 240 miles.

Technique: A constant light source, mounted on an aircraft, is borne across the imaginary line connecting the two ground stations. The crossing angle, relative to the line, is purposely kept very small, approximately five degrees, to cause the lateral movement of the light, as viewed from the ground sites, to be relatively slow. Tracking becomes possible and precision azimuth measurements are obtained.

As the line is crossed, azimuths to the light are observed with two photo recording theodolites, one located at each of the two ground sites. To be useful, recordings at the two sites must be made simultaneously. This is accomplished by tripping both theodolite recording cameras at the same time with pulses sent by radio from the aircraft. Data thus obtained during the crossing are entered into a mathematical equation for solution of the reciprocal azimuths from the two stations. Twelve crossings are required for each line. These are averaged to determine the most probable reciprocal azimuths for the imaginary line connecting the two stations.

Time Requirement: The time required to accomplish a complete LOLA measurement is dependent on weather conditions. Many flights are generally necessary to obtain twelve acceptable crossings since simultaneous optical view is required between the ground sites and the airborne light.



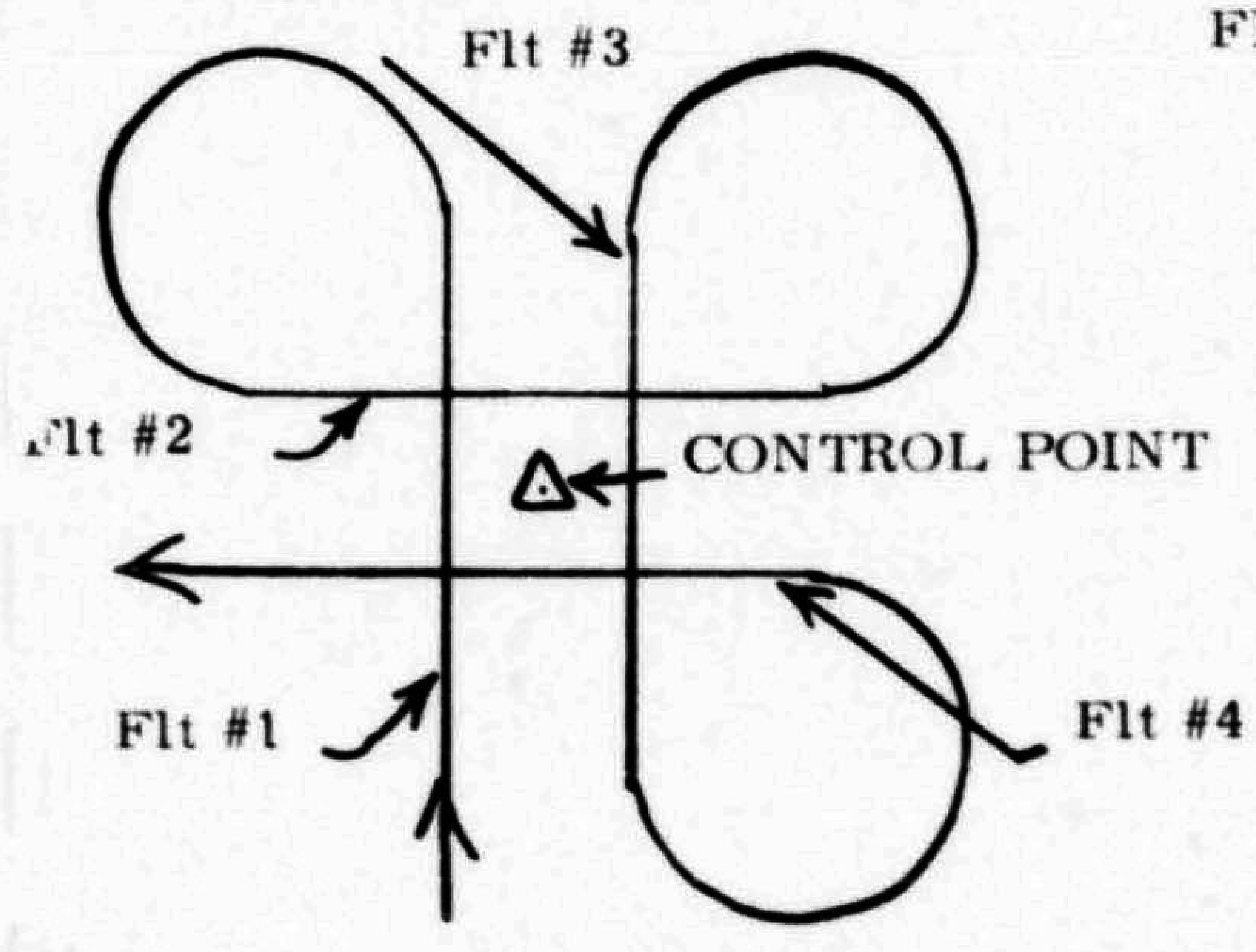
Secondary Control Point Photography (SCP)

Purpose: The primary use of Secondary Control Point Photography (SCP) is to horizontally position a point of interest such as a small island, or a landmark, relative to geodetic positions, without installing a Hiran ground station at the point. A combination of Hiran measurements and aerial photographs is used to provide position coordinates to an accuracy of within ± 50 feet.

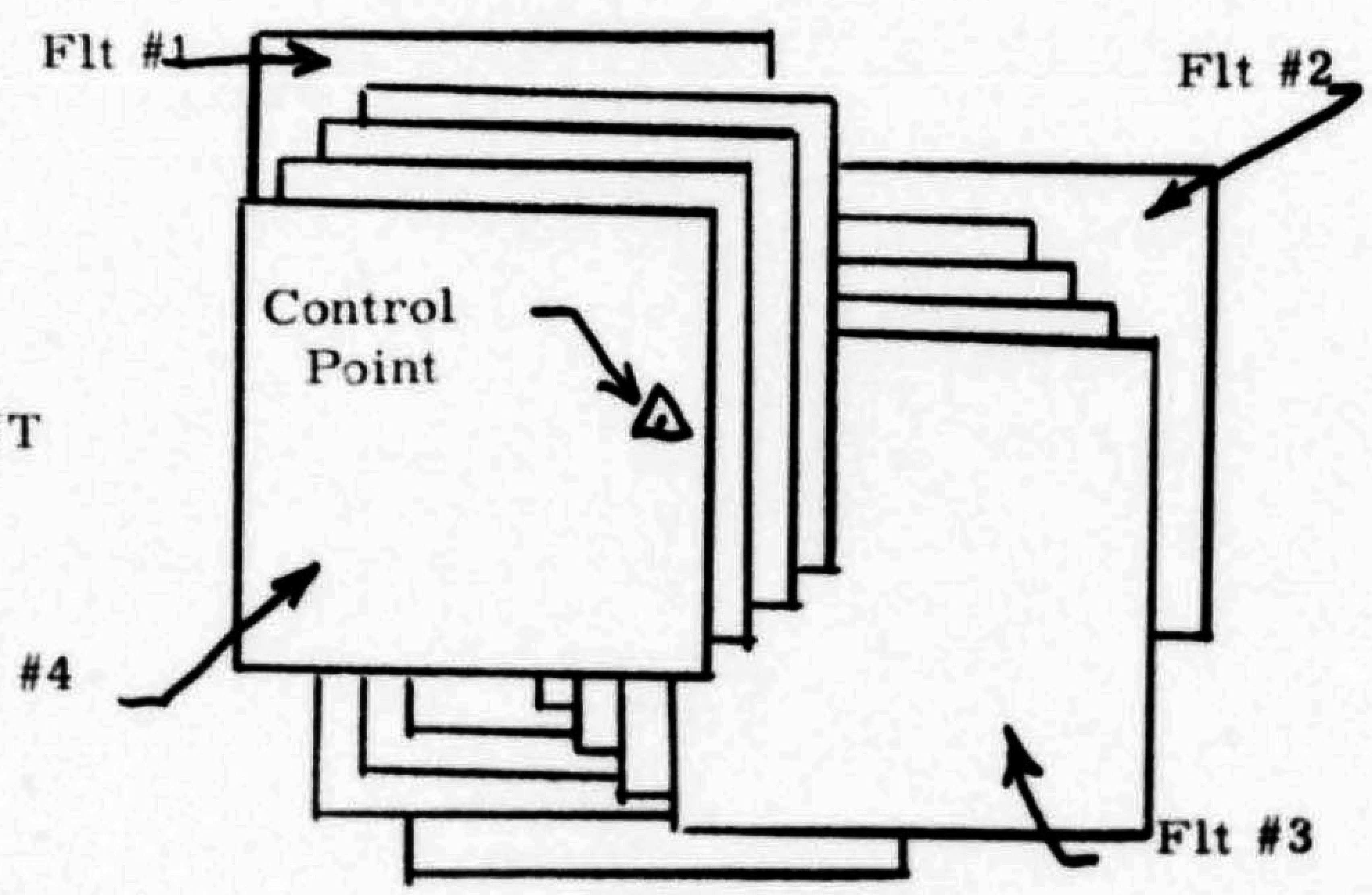
Technique: The flight pattern is a clover leaf form with the point to be positioned located beneath the center. The result is four cardinal flight lines flown over the point. Flight altitude is kept as low as possible to minimize the effects of camera tip and tilt and also to provide maximum photo detail. Reception of Hiran signals and image motion are the altitude determining factors. Camera exposures, synchronized with the Hiran distance recordings, are started as the point to be positioned enters the camera view. Exposure interval is kept as short as possible to obtain the maximum number of photographs which contain the point. It is desired to obtain a minimum of thirteen such photographs during each of the four flight lines. Six as the aircraft approaches the point, one over and six after. This totals to 52 photographs, each controlled by Hiran distances.

Appropriate corrections are applied to the distance data and mathematically reduced to sea level. These reduced distances provide the necessary information for geodetic computations for each nadir point. Finally, photogrammetric measurements are used to produce the average or most probable geodetic position for the point of interest. Averaging minimizes random Hiran distance errors and the effects of tip and tilt.

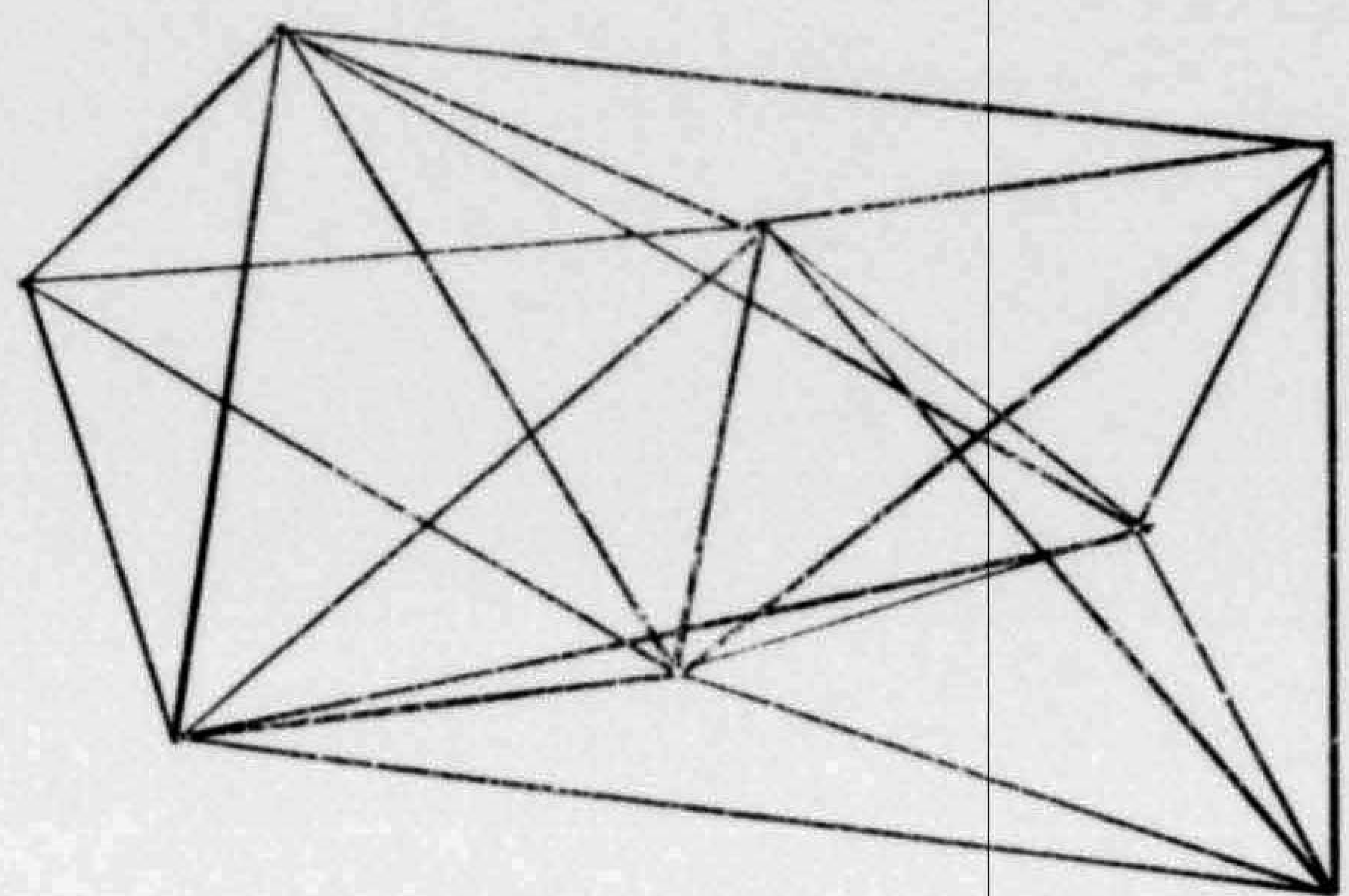
FLIGHT PATTERN



52 HIRAN CONTROLLED PHOTO'S

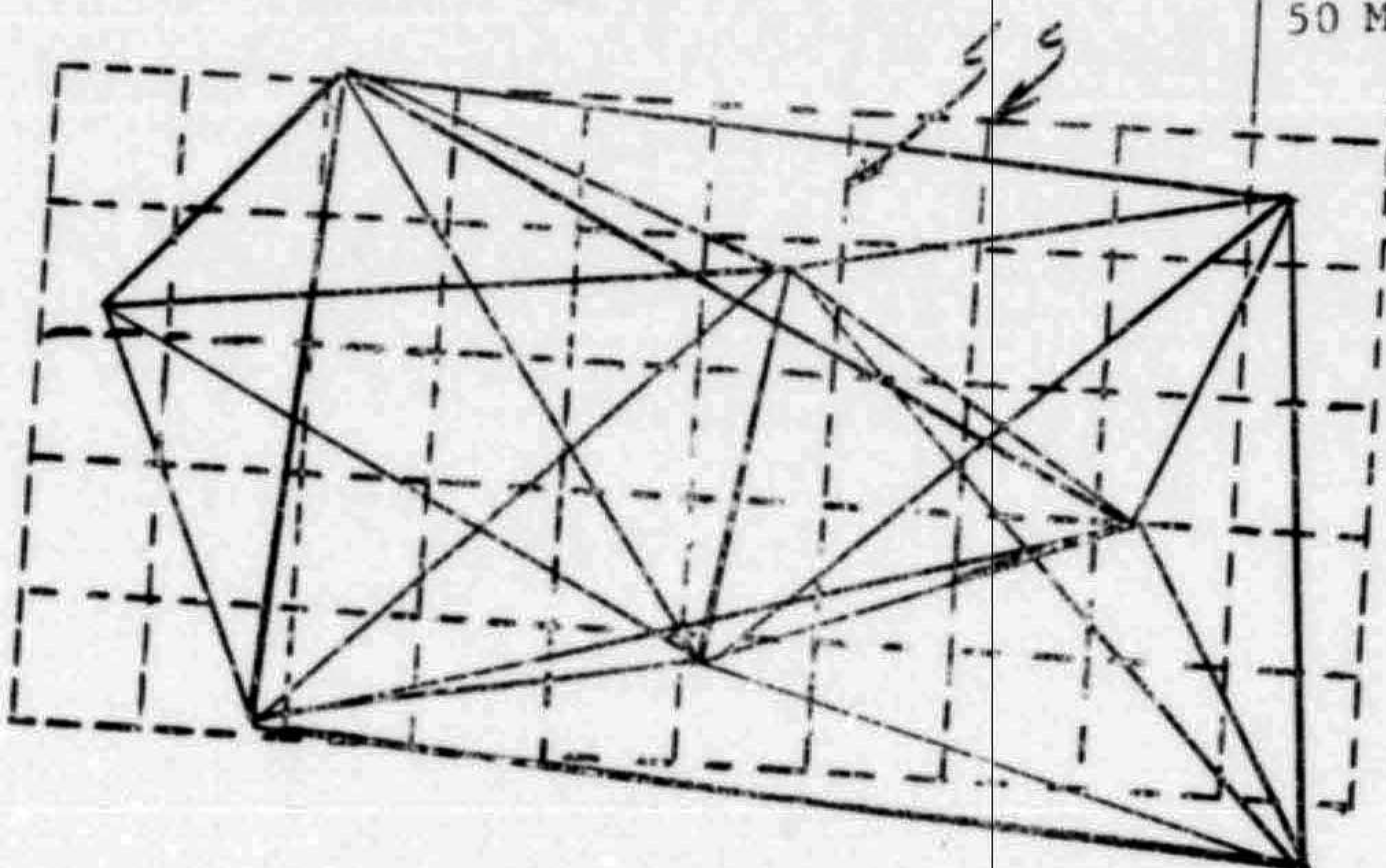


HIRAN TPR, LOLA, AND MAPPING PHOTOGRAPHY
PROVING ALL DATA NECESSARY TO MAKE ACCURATE MAPS



STEP 1:
<u>Primary Control</u>: First-order horizontal control accomplished by Hiran trilateration survey. LOLA measurements can provide azimuths.

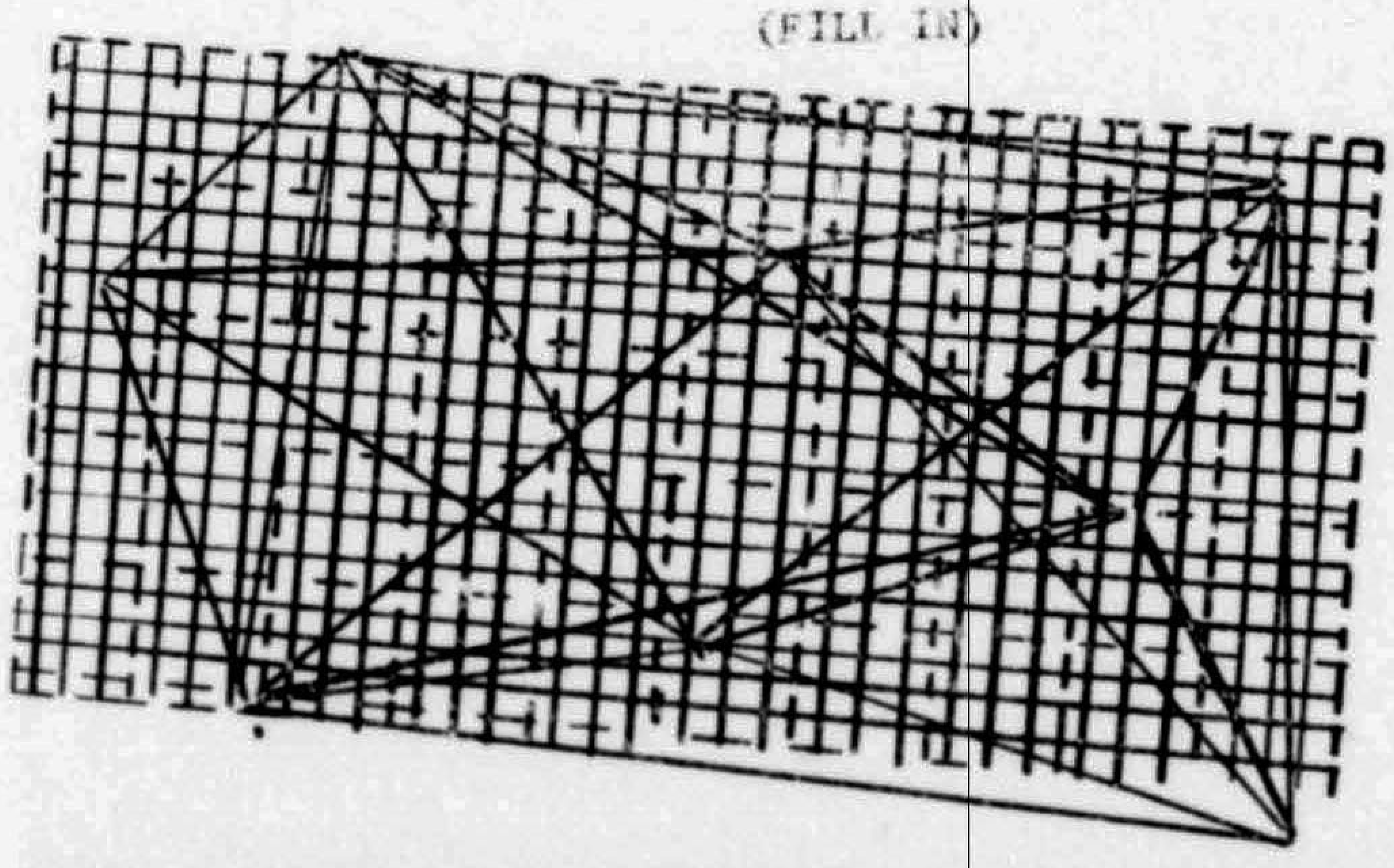
FLIGHT LINE (GRID)



STEP 2:
<u>Secondary Control</u>: Grid system of Hiran controlled aerial mapping photography Each photograph accurately positioned at instant of exposure and referenced to horizontal control established in Step 1. Elevations provided by Terrain Profile Recorder operated during each flight line.

FLIGHT LINE

(FILL IN)



STEP 3:
<u>Complete Coverage (Mosaic)</u>:
Each grid block filled in with flight lines of aerial mapping photography.
1:25,000 scale mapping can be produced if fill in lines are Hiran controlled. Accuracy is somewhat reduced if fill in lines are not horizontally controlled by Hiran