

## A NEW TECHNIQUE FOR

### AERIAL MAPPING

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by

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## A NEW TECHNIQUE FOR AERIAL MAPPING

A new aerial mapping system is presently under development in the U. S. Map data acquisition is a time consuming laborious job which is plagued by the tedious difficulties of acquiring dense networks of ground control in all types of terrain. Aerial mapping aircraft are also faced with the problem of finding cloud free areas. The aerial photographer knows that on the rare day that he is able to arrive in the project area and finds clear weather that he must accomplish the maximum aerial photography possible.

All these problems were given serious consideration when a new mapping and survey aircraft was to be developed. Could the new aircraft do more in survey data acquisition? Could it accomplish more when it found a clear area? Could the clear areas be located and if they were, would the aircraft have the range speed and endurance to take maximum advantage of the situation.

Answers to some of the questions were found in the Boeing RC-135, an aircraft very similar to the well known commercial jet airliner the 707.

The high speed jet aircraft will provide an extremely stable platform for the most intricate and sophisticated system ever developed for aerial surveying and cartographic mapping.

This new aircraft will reach an altitude greater than 50,000 feet. At a true air speed of about 600 miles per hour plus its long endurance will result in exceptionally high mission accomplishments.

The mapping and surveying system being developed will consist of a new 6" focal length mapping camera, an inertial platform so precise that it will record the true vertical of each exposure to less than 30" of arc, and a new electronic surveying system that will give instantaneous ranging of distance from the aircraft to as many as four widely separated ground stations. These plus many other innovations will be incorporated in this new system. The result expected from the new system is to secure in addition to the mapping photography, most of the control data required for large scale maps (1/50,000).

The article attempts to explain some of the intricacies of this sophisticated system and then gives the views of the author on an operational concept to rapidly acquire data to meet the map deficiencies that face the world today.



## A NEW CONCEPT FOR AERIAL MAPPING

Map making is no small task. In the U. S. the combined efforts of the Army, Navy, Air Force, U. S. Geological Survey, USC&GS, Department of Agriculture, plus civilian contractors coordinate their talents in the massive efforts of accurately portraying the minute details of the earth's surface.

Map detail is derived from data collected by the ground surveyors, who obtain horizontal and vertical control, and the aerial photographers who obtain the precise mapping photography. National map accuracy standards prescribe the details that appear on the maps published by cartographic agencies.

There have been some advanced developments in the ground surveyor's tools. The Telurometer and Geodimeter for horizontal measurements have to a large extent replaced the steel tape and chain. The Ground Elevation Meter is being used in some areas to acquire low order leveling.

The aerial photographer, too, has been developing a highly sophisticated airborne system which is the purpose of this paper.

To start with let me briefly review our present system. Aerial electronic surveying (known by its coined name of Hiran) was developed as a first order surveying tool after World War II. The Hiran System can precisely measure great distances using a high altitude aircraft between two ground stations. Measurements can be made over short distances and up to distances of about 570 miles with a probable error of 12 feet. Hiran has accurately surveyed the Atlantic and Pacific missile ranges and made the historic and first precise geodetic connection between the continents of North America and Europe. This survey, over 2,000 miles long, between the North American continent and Europe achieved an accuracy of 1/314,000 with a probable error of 34 feet.

Mapping of an area by a combination of aerial photography and the aerial electronic survey technique would permit adjustment of photo positions (provided complete area coverage of the area is obtained) to within 25 to 30 meters for horizontal control. This method we have called Hiran Controlled Photography. A terrain profile is charted by a narrow beam ( $1^\circ$ ) radar signal sent vertically from the aircraft which is modified with hypsometer corrections. This device is known as an Airborne Profile Recorder (APR). Aerial profile readings have been obtained and interpolated to six (6) feet in moderate terrain.

Although Hiran Controlled Photography seems to be a logical answer to the acquisition of aerial mapping photography with horizontal control data, it is in many areas operationally uneconomical. The necessity for clear



weather in the limited area sustained by the ground stations ties the hands of the operating units until suitable photo weather occurs. Months of waiting can make this procedure exceedingly costly.

In this paper I will explain a new approach to the problems of aerial mapping which has been developed into a new streamlined operational concept and by which horizontal and vertical control data can be obtained by the aircraft rapidly and efficiently. This concept was first envisioned using a highly stable aerial platform which is worthy of explanation.

The Boeing KC-135 aircraft was conceived and designed as a high speed, high altitude stable platform for air refueling missions. To maintain its high altitude, high speed stability while rapidly discharging its many tons of fuel was solved by retaining its center of gravity throughout the refueling operation. The aircraft was also designed to consume its internal fuel (including tanker fuel), for maximum range or ferry operations. All of its tanker fuel is below the cargo floor. Above this floor an area the size of a bowling alley will accommodate multiple cameras, electronic survey equipment, etc.

The skilled engineering of the auto pilot compliments the stability characteristics of the aircraft and maintains it rigidly in space as a firm stable platform ideal for the aerial mapping mission.

Before proceeding with our discussion on the aircraft development, I would like to relate my views of the task of the photogrammetrist. This skilled technician receives the geometrically perfect (less than 10 micron distortion) aerial photographs which were taken by the mapping aircraft. The camera, if cradled in our present stabilized mount, is pointing almost vertically when the aerial photographs are taken. But which way that first photo was tilted and how much cannot be determined without the aid of ground control. Accurately surveyed ground positions which can be identified or plotted on the mapping photograph must be correlated with the aerial exposure to correct it to its true vertical. When one photograph has been properly oriented to the ground survey control data, then overlapping stereo photographs can be leveled and the control extended by aero triangulation. Aero triangulation works fine over a short distance, but accuracy gradually deteriorates as it is cantilevered from the first model or bridged between two separate models. Approximately seven successive stereo photographs are generally considered to be the maximum extension possible for first order aero triangulation.

In summary, it would seem reasonable to conclude that it would be a very major benefit to the photogrammetrist when he can rapidly determine the true vertical axis of the mapping camera in our new aerial mapping system. The vertical readout of the inertial platform optically recorded and synchronized with the aerial exposure to less than 30 arc seconds will greatly enhance the photogrammetric accuracy of extensions by cantilever and bridging.



I mentioned earlier that Hiran Controlled Photography was not operationally feasible except in the very good weather areas, but there is another technique used with the present Hiran system that has been successful which is called Secondary Control Photography (SCP). It is used to locate a pinpoint target such as an off shore island or an inaccessible point when first order accuracy is not required. The SCP technique does not require a large clear weather area, only the pinpoint target need be unobstructed by clouds.

Secondary Control Photography is obtained in the following manner. While the aircraft is accurately and continuously positioned in space in relation to two ground stations, a series of photographs are taken on each of four flight paths. The operational flight pattern is designed to cross the target (SCP) in an X pattern of each of the four cardinal compass headings. A minimum of 13 aerial mapping photographs are taken on each flight path. The combined total of 52 exposures is centered on the (SCP) target. This large number of photographs are then analyzed for the most probable position by relating the distances measured on each of the four flight paths. The final computed position of the secondary control point (SCP) would have an expected accuracy of better than 50 feet.

This current SCP technique can be radically upgraded in accuracy with incorporation of the 30" vertical in the new mapping and survey systems under development and is called Control Point Photography rather than Secondary Control Point Photography.

The past and present method of map compilation from aerial photographs has depended to a large degree upon the ground surveyor's accomplishments. The ground surveyor's task is slow and laborious, and in addition, he is unable to traverse much of the world's primitive and impenetrable areas. A system that relies solely on the ground surveyor's accomplishments to compliment aerial photography will not satisfy todays mapping requirements.

A new aerial electronic surveying system called Shiran has been developed and tested in the U. S. Performance specifications required a precision measuring capability of 6' accuracy for measurements up to 450 miles line of sight distance from each ground station. Development specifications dictated that a high order of reliability be built into this system. The results to be recorded on digitized tape and compatible with out electronic computers. The new system will also permit the aircraft to record four channel measurements simultaneously from widely separated ground stations which will greatly strengthen its potential as an airborne surveying tool.

When this system becomes operational, a trilateration network of aerial electronic measurements, with ground stations separated 100 to 500 miles, will provide a basic geodetic framework of 1st order horizontal control. This density for the geodetic framework is, of course, inadequate



for large scale (1/50,000) map compilation. However, the new surveying system will have the ability for instantaneous distance recording from any or all of the four ground stations. This feature is a key element of the new concept which makes possible the accomplishment of what I termed "Control Point Photography". Control Point Photography can be obtained by recording the simultaneous airborne distance measurements from three or four ground stations encircling the aircraft which will pinpoint it for a strong geometric fix. The geometric fix synchronized with the mapping camera exposure along with its vertical deflection of less than 30" arc (3 sigma) will permit each photo nadir to be plotted to a probable error or 15' within the trilateration net.

From an operational standpoint, control point photography is a very desirable technique since scattered to broken cloud conditions would be no hindrance to the aerial surveyor. Since 3/10 to 5/10 cloud cover is the normal weather condition that can be expected 90% of the time in the majority of areas of the world, a dense network of stereo, control point photos could be easily obtained where the ground is not obstructed by scattered or broken clouds.

The operational procedure would call first on the ground stations to be installed in an appropriate network pattern. As soon as the ground stations are installed a trilateration net can be flown. While these ground stations are in place a dense network of Control Point Photography can be acquired which will precisely locate the nadir of each of the stereophotos throughout the project area.

Compilation to satisfy horizontal control criteria for the required 1/50,000 scale maps should be possible with approximately 50% area coverage by means of Control Point Photography. In addition to the trilateration net and Control Point Photography of the project area, a terrain profile will be obtained by the aircraft's Airborne Profile Recorder (APR) for vertical control. The high precision inertial platform will also assist in the vertical determinations as it will be possible to record the air station base line between successive aerial photos with a probable error of 5 feet. The air station base line distance, the precise vertical deflection and the hypsometer recordings of the profile recorder will provide the raw data and geometry for contouring stereo photographs. Complete visual aerial mapping of each project area will be obtained when good photo weather prevails. The visual photo operational phase will not normally be accomplished during the same period in which the trilateration net and the control point photography is accomplished.\* This procedure is more fully explained in the next section entitled "An Operational Concept for Map Data Acquisition."

\*Note: Flight line navigation will be guided by the high precision inertial platform and updated as required by the versatile optical view finder.



## AN OPERATIONAL CONCEPT FOR MAP DATA ACQUISITION

The new U. S. aerial mapping and survey system will be one of the most complete and sophisticated systems ever developed. It will be able to acquire data at great speed which can be used to translate into accurate maps and charts. Its work, however, must be planned to take full advantage of its mammoth capacity.

Trilateration networks can be accomplished with our regard to the weather. Control Point Photography to satisfy the needs for horizontal control, can be acquired with as much as 50% cloud coverage in the area. The airborne or terrain profile recorder for elevation profiles are not dependent upon the electronic ground stations so this phase of the mission can be accomplished when the visual photography is taken.

This new system will eliminate much of the drudgery and time required for acquisition of map control data. However, there is still a huge obstacle confronting the aerial mapper. Visual mapping requires cloud free areas to complete this phase of the mission. To complicate the problem for the aerial mapper, weather reporting is practically non-existent in many parts of the world today.

Needless to say, the business of map making is largely dependent upon the acquisition of aerial photography. I would, therefore, like to direct your thoughts to the aerial mapper and see how he goes about the business of fulfilling this task.

You may well know that the aerial mapping organizations do not welcome jobs in an area where clouds would make it a highly speculative venture.

Just how does the aerial mapper go about his business of betting on enough clear cloudless days to make his profession pay?

Meteorological records in developed nations have been officially kept since 1664. These records provide statistical data of selected areas and reports are obtainable which indicate the average number of days per month that completely clear skies should prevail.

For example, in the U. S., Phoenix, Arizona, lists 210 possible photo days a year. If all photo projects were in areas such as Arizona, the aerial mapper's job would be simple.

The usual report of expected weather for a certain month indicates that in the best photo season you can expect a few clear days suitable for aerial photography. These figures are a statistical average and the current or succeeding years may or may not repeat the normal average.



This system of using weather records thus has obvious drawbacks for planning aerial mapping operations.

A solution of this problem is possible by combining the long range high speed capabilities of the new mapping aircraft with instantaneous data obtainable from the U. S. weather satellites.

The new Tiros weather satellites are now in continuous service. The polar orbit of this satellite, the new Automatic Picture Transmission (APT) camera and the simple transportable ground receivers that can be used in any location world-wide makes it possible to pinpoint clear areas for the photo aircraft. With a high speed jet aircraft and instantaneous weather reporting it will be possible to overcome one of the major problems in aerial mapping.

Aerial electronic surveying will be independent of visual photo missions. The field support unit, consisting of ten ground stations, will call upon the operational unit only when its ground stations are installed and on the air. Operational mission aircraft will then be sent to the area to accomplish the aerial trilateration surveying and control point photography. The long range RC-135 aircraft will either fly round robin survey missions from its home base or stage at a suitable airfield. In any event, concentrated flights will rapidly acquire the aerial survey measurements and the control point photography for the 10 operational ground stations in a maximum of a few days. The aircraft will return to its operating base where the collected data will be evaluated. The RC-135 aircraft are freed then for other operational missions while evaluation adjustment and ground movements take place.

An ideal operating unit for extensive areas coverage\*, would have two RC-135 aircraft. Two helicopters would support the ground station movements. The RC-130 aircraft would accomplish the smaller requirements: visual photography, station photo, etc. In effect, under this operating concept, the long range aircraft will be called upon for bulk accomplishments, for which it is best suited, and the RC-130 aircraft will acquire the diversified individual tasks for which it is best suited.

If visualized properly, this operational concept permits a continuous productive effort. Visual aerial mapping pursued daily in the good weather areas, and the ground stations for aerial surveying, either moving or in place and calling upon the operational unit for a trilateration survey or control point photography.

Although the operational concept envisions the aircraft capable of obtaining vertical and horizontal control as well as visual photography, there is no intent to conclude or infer that the ground surveyor is

\*Note: For small areas one RC-135 a/c could be deployed.



obsolete. Instead, the planning of over-all operational accomplishments will include project requirements that can be most efficiently obtained by ground survey parties.

It is important to note that the operational area encompassed by the ground stations will not necessarily coincide with the visual photo area. The trilateration net and control point photography will be acquired on a priority basis where ground stations can be installed. Visual mapping photo and APR will be acquired in the clear weather area regardless of priority.

In conclusion, I can state that the sophisticated survey and mapping system presently under development, combined with this operational concept, will rapidly gather high quality, precise data for large scale maps.

To further substantiate the basis for this concept, I refer you to a report on the value of 30 second vertical photography which was compiled by the Ohio State University Research Foundation and published in May 1962.

The noted photogrammetrist, Dr. Brandenberger, states in his conclusions that "One of the greatest advantages of vertical photography lies probably in a very simplified procedure of determining secondary ground control." A savings of as much as 80% in ground control data would be realized by combining the precise vertical photography with the electronic surveying system (Control Point Photography). The DoD is also convinced that the new aircraft with its unique innovations will greatly accelerate the process of map data acquisition. It is anticipated that compilation of data acquired by this new system will result in a significant savings in time, manpower and dollars. Time and experience will determine the full extent of these savings.

In summary then, this new mapping concept will "jet propel" the surveyors laborious process of data acquisition by acquiring most of the control needed by the map maker along with the aerial photography. The precise vertical photography will also provide a short cut to map compilation which will elevate it to a new height of efficiency and production.