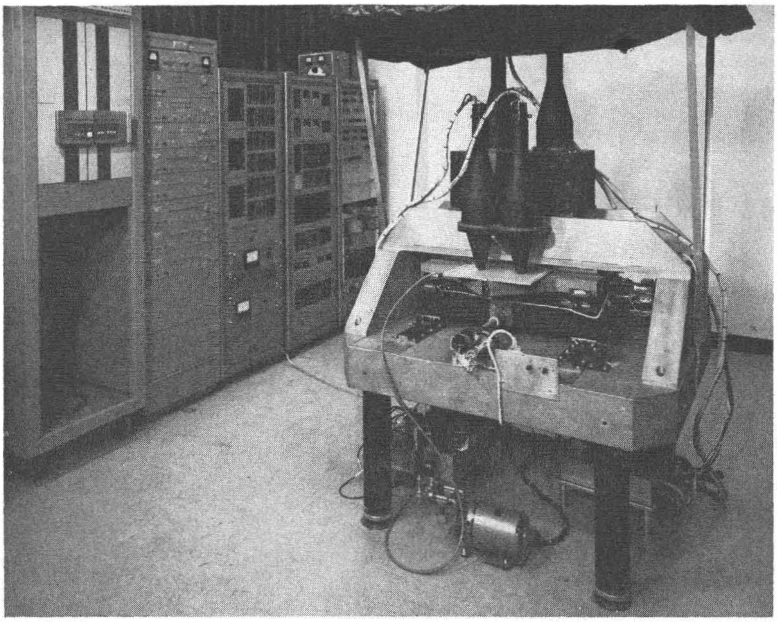

FIG. 9. Automatic map compilation system.

matic map compilation. Much remains to be done with respect to the logic required to bridge difficult terrain such as over water areas, steep cliffs, etc. The answer for now is the availability of a manual intervention facility. As experience is gained with the systems, it is hoped that the logic will improve so that less and less manual intervention will be required. It is believed that the height sensing circuitry will now handle anything a man can handle by direct stereoscopy, but a man does have the ability to interpolate height values into regions that are basically featureless. Several techniques have been suggested to handle these difficult areas and will be incorporated into the system as the work progresses.

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*The AN/USQ-28 Mapping Survey Sub-System**

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BEFORE starting a detailed discussion of the AN/USQ-28 Mapping and Survey Sub-System, I will present some background material which may make possible a better understanding of the operational problems and how the new system will help overcome some of them.

The Air Photographic & Charting Service is the MATS subcommand responsible for meeting USAF requirements for photography

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and precise measurements. Commanded by Maj. General Rees, APCS is currently obtaining these products at 24 permanent locations and dozens of other temporary sites throughout the world.

Some of the units are photographically documenting missile site construction, missile loadings and missile launchings. Others are producing the precise missile-site survey data that go into the missile launch data sheet. However, the APCS unit of particular interest at this meeting—and the unit which will use the equipment that is the subject of this paper—is the 1370th Photo Mapping Wing operating from Turner Air Force Base, Georgia. It is composed of six squadrons and is equipped with turbo-prop RC-130 and piston-engined RB-50 mapping and surveying aircraft. The major missions of this wing are the accomplishment of mapping photography and the establishment of ground-control nets by aerial electronic surveying—commonly referred to as HIRAN trilateration networks. These nets consist of lines which are measured individually by the line-crossing technique. An aircraft carrying a HIRAN transmitter and receiver crosses an imaginary line between two ground transponders. The time between transmission and reception of pulses is read at many points on each of several crossings. These time recordings are converted to distance and the minimum sum of the simultaneous readings is determined. This is the ray path distance. This distance is then converted to ellipsoidal distance between stations.

A good example of a HIRAN net is the current Hawaiian area survey. Hawaii, Johnston and Wake are being tied in, as well as all the intermediate islands. This project is also a fine example of inter-service cooperation. Due to the fact that the net consists mostly of sliver triangles, azimuth as well as range must be determined between points. Army is observing to obtain the HIRAN azimuths by the Sodano method, Coast and Geodetic Survey is doing the intervisible azimuths, Air Force is measuring the distances and Navy is providing surface vessel and helicopter support.

The HIRAN equipment will be replaced in the AN/USQ-28 system by SHIRAN—the S added since the operating frequency will be in the S-band. This frequency change from the 3–400 to the 3000 megacycle band was made at the request of the Federal Communications Commission, and is one of the primary reasons for developing new distance measuring equipment. The SHIRAN ground equipment will offer a much higher degree of portability than the HIRAN equipment. Along with more portability, achievement of much higher reliability, greater accuracy and more operational flexibility is expected. The reliability and portability factors are natural by-products of the advances in the state-of-the-art of the electronics industry over the past twenty years. That period is given because todays HIRAN equipment is of the same basic design as SHORAN, which was used extensively in World War II. The accuracy and reliability factors will be covered more fully later.

Now a word about the aircraft chosen as the vehicle in which to configure the USQ-28 and the reasons for this choice. The RB-50 presently assigned to the 1370th which are used for the high-altitude long-range missions are in the same category as the HIRAN gear. Although the maintenance people must be given a great deal of credit for maintaining a high degree of reliability on these aircraft, the fact remains that this reliability is bought only with a great deal of effort. The obvious way to reduce this maintenance problem is to change to jet-powered aircraft. This, though, is only one of the advantages of jets; the real pay-off, particularly for the mapping mission, is the tremendous gain in stability and reduction in vibration amplitudes. Last but not least is the requirement for speed, range and altitude. At first glance, speed may not seem too important in a mapping vehicle, but it helps a great deal to be able to get in and get photo coverage in a hurry in areas where marginal weather conditions prevail. Range is a great asset in a world-wide military operation since it can eliminate a great deal of the necessity for staging. Altitude extends the coverage for both the photo and the electronic survey missions. The aircraft that appears to best meet all these requirements is a four-engine jet-type aircraft especially modified to meet the military requirements.

Naturally, along with the new vehicle and the SHIRAN equipment, the USQ-28 sub-system will offer a number of other improvements. Some offer only increased reliability while others may open the door to completely new surveying and mapping concepts. The goal in selecting the various equipments and their integration is to give the Department of Defense the best possible end product, and to do this in the most expeditious and least expensive way possible.

Before describing the details of the USQ-28 components, it should be stated that the R & D project officer responsible for selecting and integrating equipment to meet the APCS requirements is Mr. Carmen diCarlo. He and his team at the Aeronautical Systems Division of Air Force Systems Command have been most enthusiastically working to provide the best equipment available. The following list of components shows that quantitatively an all inclusive system is being planned.

AN/USQ-28 SUB-SYSTEM COMPONENTS

1. Photographic Equipment
2. Distance Measuring Equipment
3. Terrain Profile Sensor
4. Meterological Data Sensors
5. Navigation Equipment
6. Digital Computer
7. Digital Recorder
8. Azimuth Lights
9. Ground Support Equipment

The cameras may be located in the rear of the aircraft. Although the center of gravity has always been the favored position for cameras, stabilization tests made on jet-transport aircraft indicate no appreciable difference in pitch and roll amplitude between the center of gravity and rear positions. These tests also show that in this type of aircraft the airframe itself may serve as the stable platform, so additional mount stabilization may not be required. Further stability tests are being conducted.

PHOTOGRAPHIC EQUIPMENT

1. *Prime Vertical*
   KC-1 (x) 6″ F.L. 9″×9″ Format
   Shutter Synchronized to SHIRAN
   Platen Reseau
   Remote Controlled Variable Aperture
   Digital Record on Film of Tip-Tilt-Azimuth—Position—Etc.
   KC-(x) Electromagnetic Shutter—IMC—Automatic Exposure Control Plus Above Features
   KC-4 GEOCON I Lens
   KC-3 Super Avigon Lens (3.45″ 120°)
2. *Supplemental*
   Panoramic—12″ F.L. Film
3. *Spotting*
   Frame 35mm—APR Correlation
4. *V/H Sensor*
   Electro-Optical
   Same Field of View
   As Prime Vertical

Two prime vertical, one supplemental and one spotting camera will make up the photo sensor package.

It appears that a variety of choices is open on cameras for the prime vertical station. Basically, there are only two choices—modification of KC-1B or KC-4 to incorporate the listed features, or development of the KC-(x). The KC-3 must await the verdict of the mapping agencies since the use of this ultra-wide angle lens would require rather drastic changes in map compilation equipment. There is close cooperation with the Corps of Engineers in evaluating available cameras and on design criteria for new models.

To digress a moment and explain why the decisions on cameras and other equipment haven't been firmed up yet. We are still in the initial stages of the configuration program. Certain cost and feasibility studies must be completed before hardware choices can be made firm.

One of the most promising developments planned for inclusion in the system is the panoramic supplemental camera. From an installation point of view, this is a considerable improvement over the multiple K-38 array in the present system. The reduction in the number of photographs that must be handled should also be a boon to the map compiler.

SHIRAN DISTANCE MEASURING EQUIPMENT

1. S-Band
2. Distance Observations Accurate to Ten Feet Over 900mm Range (Conditional)
3. Digital Readout
4. Four-Station Interrogation

The resolution capability of the SHIRAN equipment will be about ten centimeters. Total accuracy though will, of course, be limited to the accuracy with which we can determine and correct for atmospheric anomalies and multipath effects. Attempt is being made to keep the root mean square of these errors to less than ten feet.

The digital readout feature will mean a tremendous savings in data reduction time and effort.

The four-station interrogation capability, as opposed to the existing two-station capability, will permit increasing the area of effective coverage in the controlled photo mission and to increase the accuracy through better geometry.

NAVIGATION EQUIPMENT

1. *Inertial Platform*
   (Doppler Damped-Stellar Monitored)
   Azimuth Data—3 Minutes
   Verticality Data—30 Seconds
   Positional Data—1/5000
   Guidance—Autopilot Tie In
   Velocity Input For V/H Computation
   Mission Pre-Programming
2. *Optical Viewfinder*
   Positional Data
   Computer Link
3. *Radar*
   Positional Data
   Computer Link
   Weather Avoidance

The heart of the AN/USQ-28 Sub-System is the navigation gear. At the moment it has not been decided whether the navigation equipment will consist basically of a doppler damped-stellar monitored-inertial guidance system, doppler damped-inertial, or just plain pure inertial. Each has its advantages and disadvantages. Our primary navigation problem is to be able to get proper sidelap in areas where visual fixing is difficult or impossible. There are, of course, other things a system of this calibre can do. For instance, azimuth of photographs can be determined to an accuracy of ± 3 minutes; verticality of the camera optical axis can be read out to an accuracy of thirty seconds; and positional accuracy should approach one part in 5000 of distance traveled. Thus the accuracy of the basic navigation equipment alone will be close to third-order ground survey accuracy. This takes the system out of the realm of ordinary navigation equipment and places it in the category of a surveying instrument. Compared to HIRAN or SHIRAN, this positional accuracy is crude, but it is one step nearer the ultimate goal of a completely independent self-contained first-order airborne surveying tool.

The optical viewfinder will serve to monitor the inertial system and provide a back-up method for photo flight line navigation in case of malfunction of the prime system.

Both the optical sight and the radar set will have the cross hairs tied to the computer for automatic position fixing.

SUPPORTING COMPONENTS

1. *Terrain Profile Sensor*
   Digital and Analog Outputs
   Height Data For V/H Computation
2. *Digital Computer*
   Position Comp. From Inertial Data
   Position Comp. From SHIRAN Data
   Position Comp. From Optical Data
   Position Comp. From Radar Data
   V/H Comp.
3. *Recorder*
   Digital—On Mag Tape
4. *Metrological Sensors*
   Digital Output
5. *Azimuth Lights*
   Continuous—for Sodano Method
   Strobe-For Ballistic Camera Method
6. *Ground Support Equipment*
   Data Processing
   Maintenance
   Training

The profile sensor will be very much like present airborne profile recording equipment except that a digital output will be added.

The computer will be the real work horse of the system. All information required by the flight crew to maintain proper flight conditions will be computed and displayed in real time.

These flight conditions plus the raw data from the prime mission sensors will be recorded in digital form on magnetic tape.

Several R & D projects are underway for meterological data sensing equipment, so considerable improvement over present methods is expected.

The lights are simply an aid to azimuth determination and are not integrated into any of the rest of the system. The data recording for both the Sodano and the ballistic camera techniques is done on the ground.

The ground support equipment is self explanatory and is listed here only to show that the USQ-28 sub-system includes all the bits and pieces necessary to make it work successfully.

Now to answer the question that may have arisen—what will the USQ-28 system do that the present systems won't do? First examine the increased capability for the straight photo-mapping mission.

The present reject rate for improper sidelap and overlap is averaging about 20%. This may seem a little high to commercial mapping people, but if there is consideration that most projects are carried out in places that present the worst possible conditions, it is a pretty fair record. However, we hope the navigation system and the new overlap control device will practically eliminate this cause for rejected photography.

The speed and altitude capability of a jet aircraft will permit producing over twice the square miles of photography produced per hour in our present aircraft. Also, it is expected that the aircraft utilization rate will increase from 50 to at least 75 hours per month. This all adds up to about a 400% increase in photo productivity.

Distance measurements by the line crossing method will be done more efficiently for a variety of reasons. It now takes twelve crossings of each line to get enough redundancy to guarantee the required first order accuracy. We hope to cut this down to three.

Also, improvements in the meterological data sensing equipment will permit eliminating the need for flying along the ray path to get index of refraction data.

In all, the present average of 17 total flying hours per line should be reduced to about 5.

There also will be benefit from the greater altitude capability through being able to extend our maximum line length from 500 miles to about 900.

Data reduction time will also be drastically reduced. Presently read and hand logged are at least 30 sets of two goniometer readings for each of 12 crossings. That's almost 1,000 readings that must be reduced to 12 minimum readings before one can go to the computer for final reduction. By recording these readings plus the other pertinent data on mag tape, one can go directly to the computer and get the answer in a matter of minutes.

Since the controlled photo mission is a combination of the two missions just covered, every benefit accruing to the others is applicable here. In addition, the four station interrogation feature will permit maintaining the geometry necessary to consistently yield an air position good to 24 feet or less. The verticality data will then provide the necessary link to tie the air position to the ground so that the nadir point position can be determined almost as precisely as the air position. Preliminary studies show that SHIRAN controlled photography can be used for the compilation ot 1:25,000 scale maps.

Secondary-control point photography is a variation of the controlled photo operation just covered. This is a new concept and is realistic only if the planned USQ-28 system accuracies can be obtained. The basic difference between controlled photo as previously discussed and this variation is the amount of cloud cover that can be tolerated. Secondary-control photography could be of greatest use in areas where periods of good visual photo weather are infrequent.

The operation will proceed like this: SHIRAN ground stations positions will be determined by regular line crossing methods. The area will then be overflown as in a regular controlled photo mission except that only spot photographs will be exposed through holes in the cloud cover. The ground stations can then be withdrawn since each identifiable point on the photography becomes a control point. Straight visual mapping photography would be obtained later when proper weather conditions prevailed. Secondary-control points photographed on the first mission plus the trilateration net furnish the necessary control for compilation from the photography taken on the visual photo mission.

As the need for increased accuracy brings forth new equipment design, in turn the resulting accuracy makes possible newer and better methods of utilization. Many of the concepts presented here are the products of the fertile minds of Colonel Humbrecht and his staff at the 1370th Photo Mapping Wing. Undoubtedly, operational experience with the USQ-28 system will bring forth many more innovations in the methods of producing mapping data.

This paper has pretty well covered the benefits that data collectors expect to receive from this new system. Another subject of equal if not greater importance is the exploitation of these data. Since not in the compilation business one cannot presume to suggest how these data are to be used. It is firmly believed, though, that the accuracy and completeness of the data has the potential for greatly reducing time and cost factors in map compilation. Devising means of fully utilizing this potential offers a real challenge to the photogrammetric community.