BREAK WITH THE PAST

1950 - 1970

By Joseph F Dracup

The golden age of geodetic field operations in the U.S. began shortly after the war ended in 1945 and reached its zenith in the late 1960s. It began to fade in the early 1970s as governmental reorganizations and other factors, including economic conditions, directed funding priorities elsewhere. Despite these factors, after more than 160 years the quality of the work was not affected. If anything it became better, although the productive rate was reduced.

For about 20 years, numerous parties were in the field carrying out mostly triangulation and leveling with smaller units doing triangulation reconnaissance, and astronomic and gravity work. Sub units were assigned to various space and Department of Defense facilities including Cape Canaveral, Vandenberg AFB, Point Mugu and White Sands.

The optimum steel tower party had 3 observing units and about 40 personnel, similar mountain parties about 30 people.

Wild T-3 Replaces Parkhurst

In 1952, Wild T-3 theodolites replaced the Parkhurst, which had been in service for about 25 years. Early fears that these small optical reading theodolites might be unstable proved unfounded. Some observers found the T-3's stubby gunsight pointers inadequate for night work and, to resolve the problem, taped beer can/bottle openers to the top and bottom of the telescopes. Fortunately, this piece of equipment was never in short supply on survey parties. Later illuminated finders, similar to those found on Parkhursts, were added.

Minor details aside, economic benefits were accrued by replacing Parkhursts with T-3s. For the most efficient operation the Parkhurst required a three-person observing unit, an observer, recorder and lightkeeper, who also read the second (B) micrometer. For T-3s the observer makes all the readings and on many occasions the lightkeeper was no longer needed, leaving the slots open for forming more observing units or showing additional lights.

Observation Equations Replace Condition Equations

After the purchase of automatic computing machines in 1948, several test adjustments were made under the overall direction of Charles A. Whitten, Chief of USC&GS Triangulation Branch, to evaluate the method of observation equations (also known as "method of variation of coordinates"), both on the ellipsoid and the plane. By 1953, most

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Wild theodolites (top) gradually replaced the Parkhurst (bottom), but both were commonly used in the 1950s.

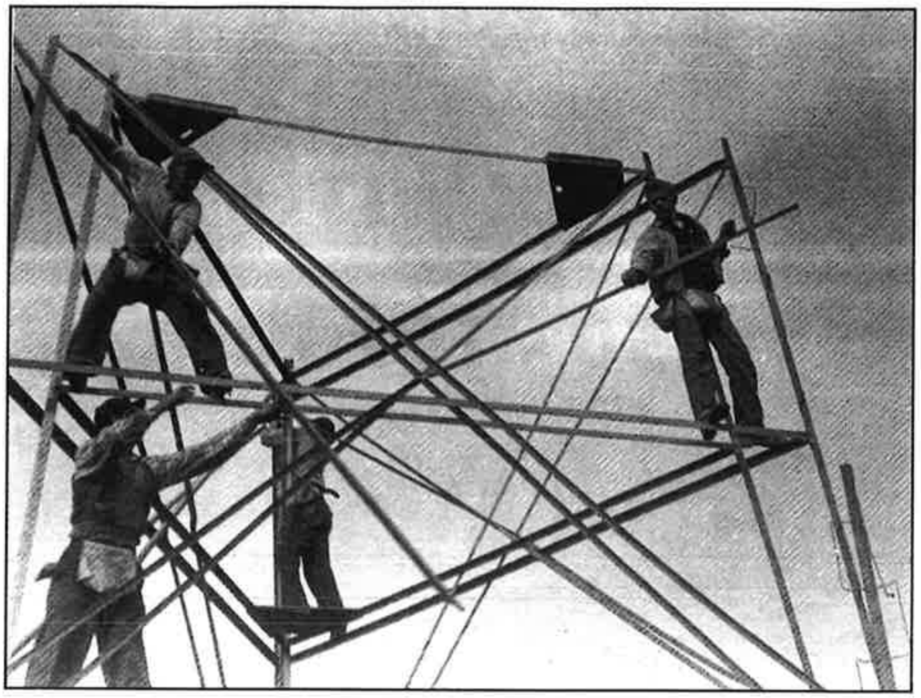
large and many smaller networks were being adjusted using observation equations and few people had any doubt that the long reign of condition equations was about over.

It was obvious from the beginning that the method lent itself extremely well to automatic computers because the formation of the equations follow identical routines for each specific type of observation, such as direction/angle, distance, and azimuth. There was no need to study the network to determine the number and kind of condition equations, nor to form them. Observation equations required only that the identification of the observations and assumed positions be computer-recognizable. Similar requirements applied to the fixed positions, weights, and any conditions placed on the observations.

Until late in the 1960s, it was also necessary to select the normal solution order of the equation to minimize the computer space used. After 1970 this was done automatically by the computer.

About 1957, with the purchase of an IBM 650 electronic computer, the method of observation equations officially replaced the method of condition equations, which had been employed for more than 100 years, however the older method would continue in use for at least another decade. By then, retirement and other forms of attrition had decimated the ranks of those who fully understood condition equations. And, the new generation of geodesists had, at best, only a superficial interest in the method.

In the same time frame, the Cholesky method for solving normal equations was introduced. Its fewer steps made it ideal for use with computers. It had not been employed much previously because the fewer steps required didn't translate into significant savings in time and effort for hand computations when compared with the Gauss-Doolittle procedure used since 1878. Furthermore, Cholesky involved square roots that were not easily attained with mechanical cal-



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Field Work in the Fifties

Top: Building a 64-foot steel tower at triangulation station CAD on February 17, 1953. The station was at the intersection of two state highways, and construction drew a crowd of local people. According to the report on the project, "The speed and team work of the builders so impressed the watchers that they could not believe that the builders were government workers doing a days' work."
Above: Foreman lightkeeper demonstrates a truck battery hookup to get the lights to the correct intensity.
Right: an observing party starting to take cuts on intersection stations from the 64-foot steel tower at station Chilton, August 1953. The city of Chilton is in the background.

culators. Gauss-Doolittle continued to be used for hand computations and remains a viable method for such calculations.

Computer capacity was limited and only the primary scheme was adjusted simultaneously. Supplemental stations, many positioned by single closed triangles, intersection points, and other small jobs, were often adjusted by hand, using condition equations.

About 1962, an IBM 1620 electronic computer, with a larger capacity and higher speed, became the work horse of the bureau. The 1620 lasted for a decade before it was replaced by a still larger and faster computer. As computer capacity improved, the supplemental and intersection points were adjusted in separate computations and eventually entire networks were adjusted in single weighted computations.

Modern Adjustment Theory Becomes Rule

Early in the change-over period, base lines and Laplace azimuths were held fixed in accordance with long practice and the considered opinion that these observations were far more accurate than the angle measurements. However, this rationale changed within a few years, as modern adjustment theory that all observations should receive corrections was accepted. By 1965, accuracy estimates were routinely computed as well. Neither practice was really meaningful, because most of the adjustments of the time were badly constrained. From the beginning, accuracy estimates were expressed in terms of "probable error" and the practice continued until about 1970 when the "standard error" concept, conforming to modern error theory was adopted.

Data sheets containing information, other than descriptions, were all generated by computer by the early 1970s.

Charles A. Whitten - Geodesist

Charles A. Whitten brought geodetic computations into the computer age. His successes with punched card computations (1948-57) provided the catalyst and knowledge needed to adapt the early electronic computers for similar computations. His leadership and interest in adapting computers to geodetic needs didn't end with his retirement in 1972. He was often consulted for his expertise in a wide range of geodetic matters as well, continuing to make significant contributions for the next 20 years.

Whitten was a man of many talents, a superb all-round geodesist who for more than 40 years served in a variety of positions including chief of an astronomic party, Chief, Triangulation Branch and Chief Geodesist. A strong advocate for using geodetic surveys to measure crustal motion, Whitten published numerous papers on the results and was convinced such data would one day contribute to the prediction of seismic events.

He was recognized internationally for his work in adjusting the triangulation of western Europe, the basis for the European Datum 1950 and was President, International Association of Geodesy (IAG) 1960-63. Charles A. Whitten died in 1994, at age 84.

Early Geodimeters

The C&GS obtained its first electronic distance measuring instrument (EDMI) a Model 1 Geodimeter, in 1953, and the second, a Model 2 Geodimeter, in 1956. In the period 1953 to 1958, 84 triangulation lines were measured, the first between stations KILLIAN and THERESA in eastern Wisconsin, a distance of about 2.25 miles. Four previously taped base lines were included in the total.

Each line was observed on at least two separate nights, except for 4 lines in Arizona where only one measurement was made. A measurement consisted of six observations, spread over 75 to 90 minutes. The longest line observed was 26 miles, the shortest 0.7 mile and the average 10 miles. All new lines were satisfactorily included in the adjustments of the triangulation.

Both models weighed in excess of 300 lbs. and while good results were obtained from 12 ft. wooden towers, those from a 103 ft. Bilby tower were not, primarily because of stability problems. The problem was resolved in short order. C&GS field personnel were highly skilled in adapting equipment to fit any need.

As a result of these tests, a first-order base line was specified as resulting from 12 complete observations, six on one night and six on the second.

The most obvious conclusion drawn was that the 140-year period of measuring base lines with various mechanical apparatus had ended. The last regular taped base line was measured at Bristol, Illinois, west of Chicago in 1956. Base lines specifically measured to test EDMI were taped at Beltsville, Maryland, in 1964 and near Culpeper, Virginia (MITCHELL Base) in 1965, with a highly accurate remeasurement in 1967. The first was slightly more than a mile in length, the second about 5.6 miles.

Lasers Give Longer Range

New model Geodimeters were considerably lighter than early versions. Longer range, especially in daylight and haze, was desired. To achieve this, George B. Lesley modified a Model 4D Geodimeter with a 2 milliwatt laser as the light source in 1965. Tests showed conclusively that the desired results were obtained. Ten mile lines were easily measured in bright daylight and at night, with a stronger light return at all times. Furthermore, successful measurements under adverse weather conditions were the rule. On the basis of these tests, AGA (a Geodimeter manufacturer.) was contracted to convert about 15 Model 4D Geodimeters, then in use in the U.S., to laser instruments.

In the 1970's, Lesley replaced the 2 milliwatt laser in an instrument with a 10 milliwatt one. This extensively modified Model 4D, known as "Big Red," routinely measured distances in excess of 50 miles in daylight. AGA and other firms produced laser instruments in the late 1960s.

Tellurometers and Other Microwaves

EDMI using microwave as a measuring source appeared about 1957. Tellurometer was the first, developed by T. L. Wadley of the South African Research Council. These instruments were lightweight, operated in daylight, had long-range capability and were less expensive than electro-optical instruments. These features attracted many surveyors. However, the observations were seriously affected by humidity, especially on longer lines and by a condition known as ground swing. The latter could be corrected, but was not always recognized. During the interstate highway program many surveys, including most by the C&GS, were microwave measured traverses and could only be classified as second-order class II (1:20,000) for this reason. Had electro-optical instruments been employed, these surveys would have rated at the next higher accuracy class.

First 1:1,000,000 Survey

As space and missile programs began expanding, it was recognized that a super accurate nationwide horizontal network was needed. It was readily apparent that the recently-invented EDMI would play an important role and that the simplest solution would be to weave an electro-optical traverse through the existing network, utilizing the original monuments wherever possible. Lansing G. Simmons, the Chief Geodesist, devised a scheme that amounted to parallel traverses, by using diamond shaped figures created by setting an auxiliary point, about 25 meters distant from every other station and connected to it. All observations were to be made at least 25 ft. above the ground, on two nights, including astronomic azimuths at the terminals of the diamond figures. Astronomic positions were observed by a special unit.

When longer range EDMI became available, sliver triangles and even single line configurations were permitted, in some instances, under controlled circumstances. Early on, taking mid-point temperatures was required, using balloons to hoist thermistors to the line height. This requirement was dropped in the later stages, except in the mountains or on long lines. Airplanes carrying thermistors on their wings were used on a few occasions to fly such lines to obtain average temperatures.

The survey began in 1961, in Florida, was completed in Michigan in 1976, and is known as the High-Precision Transcontinental Traverse (TCT). It has an accuracy of one part in a million or better, the most accurate survey ever made using conventional methods. About 2,750 stations were included in the

13,660-mile traverse that passed through 44 states. A section originally proposed from Maine to Michigan via Canada was abandoned because space and satellite technology gave good promise for even higher accuracy nets. In addition to assistance in measuring several legs, the Department of Defense provided much of the funding..

Cooperative Surveys

About 1960, the C&GS began emphasizing cooperative arrangements for establishing control in urban, county, and even statewide areas. Such undertakings were not new. Even in the early 1900s, Congress ordered a survey of greater New York City. More recently (about 1950) the East Bay Cities network was surveyed.

From 1960 to 1980, about 50 such projects were observed. Many were truly cooperative, as local surveyors worked side by side with C&GS/NGS personnel in positioning points selected to control proposed local traverses.

Mark Preservation and State Advisors

From a modest beginning about 1950, the mark preservation program came to full bloom in the early 1970s, saving thousands of stations and benchmarks along the way. Unfortunately, the work, skills and dedication of the "mark dusters" was neither understood nor appreciated in high places and they are no more. Their loss is everyone's loss: once a monument is gone, it's gone forever.

State advisors appeared later in this time frame, as states began making geodetic quality surveys for highway construction and other purposes. Fortunately, the program continues and with that, the hope that a volunteer mark preservation plan will be developed. Where once instructing in geodetic surveying was the primary purpose, it now appears advising in cadastral matters is the principal function of the job.

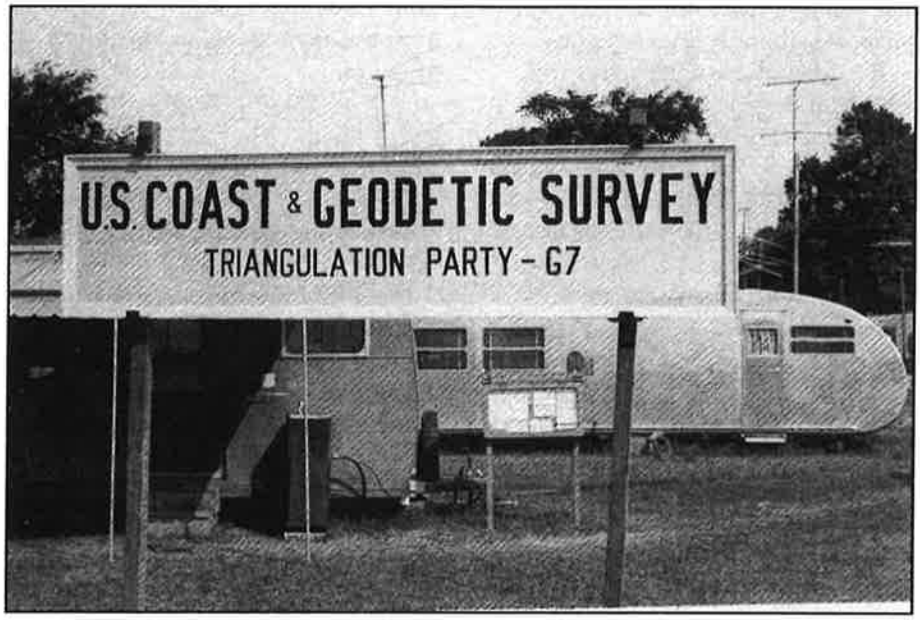
First Worldwide Network

Between 1966 and 1973, a 45 station worldwide satellite triangulation network was observed under the technical supervision of the C&GS. The communist bloc countries did not participate in the effort, creating a hole in the net to the north. The lack of even the smallest island in the South Pacific Ocean to use as a ground station created another.

Captain James Cook on his 18th century voyage to the south Pacific region had reported a least depth, at an acceptable location, that could conceivably hold a platform. One thought among the C&GS was to sink an old ship as the base for the observations. The spot, however, couldn't be found.

Helmut H. Schmid directed the overall operation of the satellite triangulation network. The project was managed by L. W. Swanson (C&GS). Moving heavy equipment and personnel to so many remote places was a huge and complicated task. Dealing with representatives of foreign countries was an entirely different and more delicate one. Funding for this multi-nation effort was provided primarily by Defense Department.

The basis for the net was a series of directions, determined photogrammetricly from photographic plates, showing the trace of a balloon satellite against a star background. The plates are the end-product of simultaneous observations, obtained by very accurate ballistic cameras, from at least two stations.



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Geodetic Surveyors Move To Dickson Early Next Week

A triangulation party of the U. S. Coast and Geodetic Survey will move its headquarters to Dickson the first part of next week and set up a base camp at the fair grounds.

There are approximately eighty persons, including families, moving with the party. Most of the group live in house trailers at the camp.

The party comes here from Hopkinsville, Ky., having spent two months in making surveys in that area. Previously to that the

C&GS survey parties worked hard at good public relations. Their efforts included large signs at the camps and articles in the local newspapers. One report gave one big reason: "It is a distinct help to the Field Foreman in getting permission to build towers and establish marks on private property if an article concerning the work is published in the local paper at about the time a party moves into the area."

The method provided geometry and orientation, but not scale, which was introduced by seven long base lines measured in the U.S., Europe, Africa and Australia. The shortest was 743 miles long and the longest 2,166 miles. Positional accuracies were on the order of five meters. A proposed North America densification net was dropped as more accurate and less expensive positioning systems became operational.

Measuring Crustal Motion

Geodetic surveys are excellent tools for measuring the amount of horizontal and vertical movement due to seismic and other events. These procedures were not employed much until the 1940s because of the cost and a lack of previous surveys. They were needed for comparison purposes in many affected areas.

Resurveys were made after the 1906 San Francisco earthquake in California. The primary arc from Lake Tahoe to San Francisco, south to Santa Barbara Channel and east to the Imperial Valley, was reobserved from 1922 to 1924, but little else was done. One short arc was reobserved and some releveling in the 1930s. A plan was made in this decade to reobserve and relevel selected nets at specific intervals and to carry out resurveys, following major earthquakes, as soon as practical.

In the next three decades, a number of these nets and lines were observed as planned and several were reobserved as scheduled. One of the first resurveys, made following an earthquake, was the Imperial Valley triangulation in 1941 after a major seismic event in 1940. Other resurveys included the Dixie Valley triangulation, near Fallon, Nevada, following a large earthquake in 1954; and much of the existing work within a 150 mile radius of Anchorage, Alaska, after the Prince William Sound seismic event in 1964.

To measure the slippage along the San Andreas Fault, 30 small nets straddling the fault, with sides 200 to 600 meters in length, containing six to eight stations and independently scaled and oriented, were established between 1964 and 1967, in cooperation with the California Department of Water Resources. All but one were resurveyed at least once before 1970.

Charles A. Whitten and Buford K. Meade wrote numerous scientific papers dealing with the results of the surveys. With the transfer of seismology functions to the USGS about 1970, in-house interest began to wane, coming almost to a stop in the 1980s.

Special Purpose Surveys

Special purpose surveys made in the 1940 - 1980 period included those for:

- David Taylor Model Basin, Maryland;
- Straits of Mackinac Bridge, Michigan;
- Triangulation and leveling networks for the Blue Nile River Basin, Ethiopia;
- Several linear and circular accelerators in New York and California;
- Astronomic observations at Thor missile sites in England, at the time of the Cuban crisis;
- Arizona-California boundary, where the actual boundary, the center of the Colorado River, is defined by positions determined photogrammetrically from shore line control;
- Super-precise alignment and measurement of the Holloman AFB rocket sled track;
- Resurveys of the north-south Mason-Dixon line between Delaware and Maryland and the east-west line between the two states, originally surveyed by colonial surveyors;
- Extension of Louisiana triangulation to locate oil drilling rig platforms, 50 miles in the Gulf of Mexico utilizing Bilby towers anchored on the platforms;
- Astronomic positions observed at about 30 km (18 mi.) intervals to determine the astro-geodetic profile along the 35th parallel;
- Position and azimuth determinations at Polaris submarine servicing facilities;
- Surveys to delineate the U.S.-Mexico boundary at the mouth of the Rio Grande River and its extension to the Pacific Ocean, south of San Diego;
- Astro-geodetic deflections for use in correcting the observed angles included in NAD83, observed at about 100 stations, mostly base line points involved with steep lines.
- Observations to upgrade the national net on Fishers Island, NY for U.S. Navy Underwater Sound Laboratory.
- Astronomic positions to verify the California-Nevada boundary at Lake Tahoe.
- Surveys at Goldstone (near Barstow, California) and MacDonald (Davis Mtns., Texas) observatories, the latter to study any motion relative to the LURE observatory on Mt. Haleakala, Maui, Hawaii.
- Nuclear test sites;
- Subsidence studies at the White House.
- Locations of numerous missile sites.

Not All Plane Surveying

In 1965, a Tellurometer traverse was measured by a U.S.- Canadian field party connecting the Alcan Highway triangulation and the coastal surveys at Yakutat Bay, Alaska, linking the recently named Mt. Kennedy. While the connection is of minor importance, the experience of the observing unit atop Mt. Kennedy is an outstanding example of the adage, when things go wrong, they go very wrong.

Several days after the crew set up a camp in a saddle just below the summit, an unexpected storm struck, destroying their tents and a protective snow block wall. This major disaster forced the men to spend 14 hours to dig an ice cave, 9 ft. by 10 ft. and 5 ft. high, where they lived for eight days with 100 m.p.h. winds and - 40°F temperatures outside.

Special projects done in the 1950s: Ethiopia geodetic surveys (left) ; Leveling of the White House (right); marker from the original survey of the Mason-Dixon line, resurveyed in the 1950s (below right).

After a short break, another storm struck and it was five more days in the cave. More problems were still to come. A helicopter, sent to bring the unit back became disabled, requiring a larger Canadian Air Force helicopter to bring the men and disabled machine to Whitehorse. A few days later, the observer Paul H. Swift returned with two new assistants and they completed the observations on the first day. The story doesn't end there.

Another storm hit and they had to spend three days in the cave, making it 16 days of cave time for Swift. To him it was just another C&GS work assignment. Some were good and some not as good. This one fell in the "not-as-good" category.

New Standards of Accuracy

New standards of accuracy and specifications were issued in 1957, replacing those used since 1933. For the first time, the classic first- and second-order standards for triangulation were subdivided into classes, recognizing the need for higher accuracy surveys, as well as the need to establish a national standard for area triangulation.

Other Significant Contributors

Other organizations made significant contributions to the national networks during the period. Among the most notable are: The U.S. Geological Survey, a number of State Departments of Transportation, especially California and Minnesota, and the unique North Carolina Geodetic Survey organized in the early 1960s. It has established thousands of points statewide in the interim. Another unique group exists within the Los Angeles County Engineer's Office, which routinely carries out first-order horizontal and vertical surveys. All other contributions were second-order. The South Carolina Geodetic Survey, last of several such county and state agencies to be formed, began operations in the late 1970s and continues today.

Geodetic Leveling

The vertical control network grew from 45,000 miles in 1929 to about 260,000 miles in 1940 and more than 420,000 miles by 1970, with little fanfare. Geodetic leveling has none of the glamour or adventure associated with triangulation, and receives little publicity about its operations. There are no high mountains to climb or tall towers to build, no 100 mile-long sights, nor 15-mile base lines to measure, only endless hours walking along railroad tracks and roads day after day, making observations every 400 ft. Yet, the work gets done and to a high accuracy. And, so it was for the period from 1940 to 1970. About the only changes were the replacement of Fischer level, in use since 1899, and the invar rods, designed by C&GS in 1916. Both were replaced in 1967 by equipment of European design and manufacture.

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With the Fischer level retired, no longer could one view a C&GS level operator lift the Fischer tripod, instrument attached, kick the forward leg up and out, spread the others, then ride the apparatus into the ground, bring it to level and ready to observe, all in what seemed like one, single smooth motion. Modern levels can't be handled in that fashion.

Thus ended the last decade of the old era...only we didn't know it at the time, nor just how good we had it.