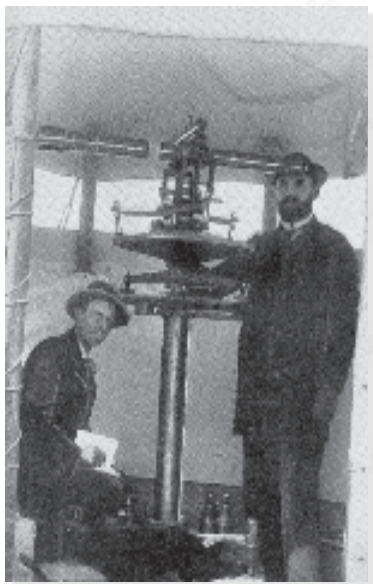


The Transcontinental Arc

— by Captain Charles A. Burroughs, NOAA (Ret.)

Unlike the 1804-06 Corps of Discovery led by Lewis & Clark, which set out to map the little known land along the route of the Missouri River to the northwest part of the country, the U.S. Coast Survey's Transcontinental Triangulation along the 39th parallel was more utilitarian in its purpose. Through painstaking determinations of latitude and longitude of recoverable survey markers along its route, the triangulation would provide a basic framework for all such future works by establishing primary control points for engineers and surveyors alike. Many other government-sponsored scientific expeditions had fanned out across the western reaches of the continent by 1870. Included were those by Zebulon Pike in 1806 which resulted in an 1810 map that served to delineate, to some degree, the landforms and river systems to the southwest of the discoveries made by Lewis and Clark along the main route of the Missouri River and beyond to the Pacific coast. In later years, explorations by Stephen Long and John C. Fremont of the Corps of Topographical Engineers, a unit of the U.S. Army formed in 1818, carried out military engineering surveys for a whole host of purposes. One should also not belittle the fur trappers' contributions to this mapping effort, much less the even more accurate Pacific Railroad Surveys of the 1850s. Then, leading up to and somewhat contemporary with the Survey's Transcontinental Triangulation during that post-Civil War era, were the many topographic and geologic government surveys, including those by Hayden, Wheeler, and King through Colorado, Utah, and Nevada, all of which were, no doubt, consulted in the Survey's efforts to accomplish the task of establishing as precise a horizontal and vertical control network as could be obtained from coast to coast during those times.



Mounting an instrument at a station on Ogden Peak [USC&GS Special Report no. 4]

Here, on the following pages, is the story of the “most extensive piece of geodetic work attempted by any nation in the 19th century...”

The Transcontinental Arc of Triangulation

—by Captain Charles A. Burroughs, NOAA (Ret.)

Long before the days of GPS (c1983), EDM, or even the Invar tape (c1903), scientists and engineers of the U.S. Coast Survey, as the organization was known in 1871, set out to measure, precisely, the distance spanning the American continent from the Atlantic to the Pacific coast.

This work of nearly thirty years resulted in an 871-page document titled “The Transcontinental Triangulation and the American Arc of the Parallel” [Special Publication No. 4 of the U.S. Coast & Geodetic Survey, 1900]. Its author was Asst. Chas. A. Schott, Chief of the Computing Division of that government bureau, then organized within the U. S. Treasury Department.

Quoting from the Foreword:

“... here presented to the scientific world contains the results of the most extensive piece of geodetic work attempted by any nation, a geodetic triangulation across the continent and the resulting arc of the parallel. This work has been conducted with the greatest care, and many improvements in the means of observation have marked its progress.”

The project was designed to connect the triangulation lines that had already been established along the Atlantic and Pacific coasts, as of the close of the Civil War. That geodetic operations needed to be extended became evident as the material development of the young country intensified and the need for measuring it accurately increased.

Thus, by an act of Congress approved March 3, 1871, the U.S. Coast Survey was authorized

to commence operations along the thirty-ninth parallel of latitude. Once completed, some twenty-seven years later, the triangulation served to join the many separate parts of the Survey’s work and make them into one continuous system dependent upon the same geodetic and astronomic data.

The nature of the country traversed by the arc gave rise to new ideas in reconnaissance, signal building, and methods of computing, all of which had an important bearing on all subsequent work of the Survey. During the course of this work, which enlarged the Survey’s functions, the name of the bureau was changed by the act of June 20, 1878, to “U.S. Coast and Geodetic Survey.”

The first such triangulation network conducted by the Survey was that done by its founder, Ferdinand Rudolph Hassler (1770-1843), during the Survey’s formative years, 1816-17. It should be noted that the two baselines measured at this time were an integral part of Hassler’s early field work to the west of New York City, one oriented more or less east-west, the other north-south.

These two baselines, designed to give the network its proper orientation to the surface of the Earth, and to provide the distance factor for the computation of geographic positions, would become the hallmark of all subsequent triangulations extending to the northeast out over Long Island and across the Sound to Connecticut, Massachusetts, and beyond. Extensions to the southeast would be conducted in like manner.

Thus, by 1871, triangulation had been well started that would eventually extend from the Bay of Fundy to the Gulf of Mexico at New Orleans.

This would become known as the “Oblique Arc” by the time it was completed by the end of the 19th century.

The act of 1871 also authorized the extension of aid to states for the survey of their territory whenever provision was made by them for their own topographic and geological surveys.

The far-reaching transcontinental triangulation work was further seen by the leading geodesists of the day as adding significantly to the understanding of the “Figure of the Earth” studies. Triangulation across the continent furnished the area factor, and because one could calculate the curvature factors from the many astronomical measures associated with it, an improved value for the ellipticity of the Earth was contemplated and, eventually, became a reality.

In making the observations and computations, topographic irregularities within four thousand kilometers of each astronomic station were considered, and account was taken of the possible density distribution beneath the surface of the Earth. By studying the station errors (or deflections of the vertical) revealed when the astronomical and geodetic determinations were compared, evidence was brought forth to establish the fact that the condition of isostasy (or equilibrium) exists within the Earth, a fact that proved to be of great value to both geodesy and geology alike.

In stark contrast to how a survey of such a magnitude might be conducted today, the one along the 39th parallel was accomplished by measuring accurate baselines despite working with rather cumbersome instruments. The methods employed

required arduous duty by large numbers of survey personnel and lengthy occupations at survey stations, especially over the higher elevations of mountainous country in Colorado, Utah, Nevada, and California.

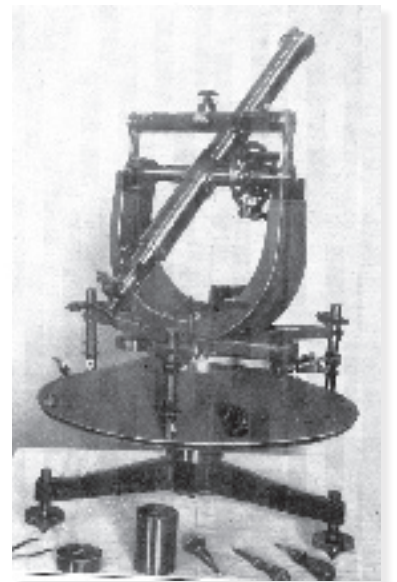
Organizationally, the survey was divided into discrete operations. Ten “Base Nets” of triangulation were established, through time and space, from coast to coast, and each of these included one or more precisely measured baselines:

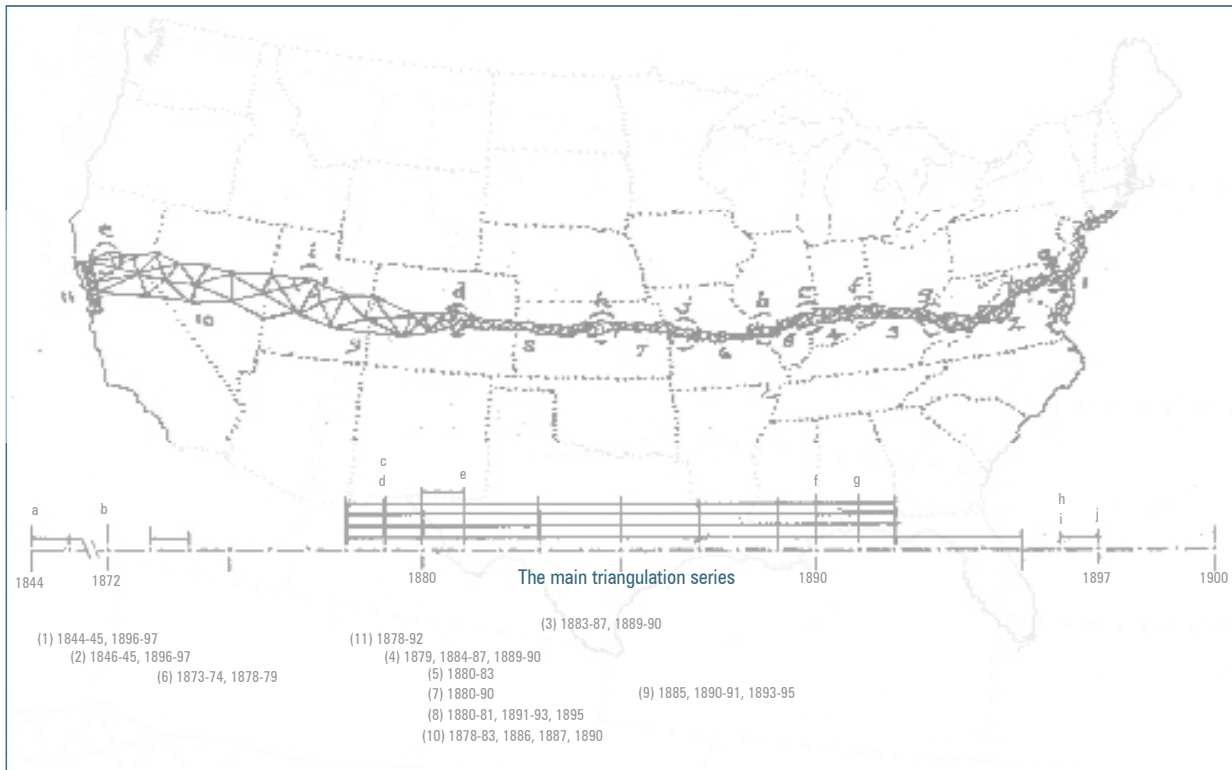
- (a) Kent Island, MD (1844)
- (b) American Bottom, IL (1872)
- (c) Olney, IL (1879)
- (d) El Paso, CO (1879)
- (e) Yolo, CA (1881)
- (f) Holton, IN (1891)
- (g) St. Albans, WV (1892)
- (h) Salina, KS (1896)
- (i) Salt Lake, UT (1896)
- (j) Versailles, MO (1897)

With the exception of two of these (St. Albans and Versailles), all were measured with various types of iron bar and/or contact-slide steel rod base apparatus, a most tedious and time-consuming process. The excepted ones were measured by using 100-metre steel tapes, which were just then (1892-97) coming into accepted practice for such measurements. Through these nets, by gradual expansion, the comparatively short lengths of a base were developed to that of the sides of principal triangles.

Filling the gaps between these base networks were schematic

The 20-inch theodolite, used at the primary stations in the Rocky Mountain Region. [USC&GS Special Report no. 4]





The base nets and the main triangulation series [after NOAA Professional Paper no. 2, pp. 17-18.]

arcs of triangulation known as “Sub-divisions” and names were given for each chain (Series), as follows:

1. Atlantic Coast to Kent Island [Eastern Shore; 1844-45, 1896-97]
2. Kent Island to St. Albans [Allegheny; 1846-50, 1868-80]
3. St. Albans to Holton [Ohio; 1883-87, 1889-90]
4. Holton to Olney [Indiana; 1879, 1884-87, 1889-90]
5. Olney to American Bottom [Illinois; 1880-83]
6. American Bottom to Versailles [Missouri; 1873-74, 1878-79]
7. Versailles to Salina [Missouri-Kansas; 1880-90]
8. Salina to El Paso [Kansas to Colorado; 1880-81, 1891-93, 1895]
9. El Paso to Salt Lake [Rocky Mountain; 1885, 1890-91, 1893-95]
10. Salt Lake to Yolo [Nevada; 1878-83, 1885, 1887, 1890]
11. Yolo to Pacific Coast [Western or Coast Range; 1878-92]

Before proceeding with more of the details of certain aspects of this survey, it might be advisable to reflect upon the procedures of those times as compared with the “advances” that had been made some thirty years after the conclusion of this work. The theodolites for angular measurements were large and cumbersome, each provided with three micrometer micro-

scopes for use in reading the seconds of arc, and one more for reading the degrees and minutes.

Such instruments yielded excellent results but were slow in operation and very difficult to carry to mountain stations. All observations were made during daylight hours on poles, targets or, in the case of mountain stations, heliotropes. It was very difficult to see, except under the best conditions, a pole or target over distances in excess of 12 miles. Heliotope work in mountainous country was uncertain in that one could only be used during times of sunshine with the observation period constrained to early morning or late afternoon hours after the atmosphere became steady. Taking these factors into consideration, it was very difficult to complete the observations at one station in less than four hours. The means of transportation were horses, mules, wagons and pack trains, thus making the movement from one station to another rather slow. Observers took great pride in securing the greatest accuracy with the smallest possible errors. There was also the fear that a record book might be lost, which resulted in a great degree of copying of records and the duplication of abstracts, which served to sap the energy and was very time consuming for the members of a triangulation party.

Contrast such conditions with those in practice by 1930. The 8-inch direction theodolites

had become compact and comparatively light, and could be read with only two micrometer microscopes. The first-order angle observations at each of a number of stations could be completed in less than one hour of observing. During the intervening years, various types of signal lamps had been developed that made night observations possible. This eventually led to lines in excess of 100 miles becoming inter-visible. For even longer lines, up to 150 miles in length, two such lamps were sometimes stacked one upon the other and were battery-powered. Add to this the advent of motorized travel and improved roadways and it is easy to realize how much this improved the transport of men and materials to station sites.

By 1927, the development of the Bilby steel triangulation tower essentially replaced the need for wooden towers in flat and heavily wooded terrain. Such towers, whether constructed of wood or steel, were double structures, the inner tower supporting the theodolite, the outer supporting the observer. Many of these towers were built to a height of well in excess of 100 feet, but for normal operations, towers of 77 feet, 90 feet, or 103 feet sufficed.

Another important facet of triangulation surveys, whether they were done for the Transcontinental Arc or for more modern surveys, was the need for reconnaissance to select the stations. When wooden towers were used, the selection of stations had to be done with the greatest of care so as to minimize the cost of lumber and the building of the towers. An error of 15 feet in height would mean, if the height was estimated too low, an obstructed line; if it were estimated too high, it would mean a waste of lumber and time by the building party.

Advances were also made in the field of astronomical observations for the determination of astronomic latitude, longitude, and azimuth at selected stations throughout the triangulation networks. During the implementation of the transcontinental arc, astronomic longitude had to be determined without the benefit of radio time signals; instead, telegraphic signals were used.

Because of the complexity of observations for triangulation, it was not uncommon for a difference of longitude to require observations in excess of 21 days.

[Editor's note: The rigors of geodetic surveying during the latter quarter of the 19th century are the topic of another chapter. Look for Part Two in the following issue.]