Sesquicentennial of Coast and Geodetic Survey

SYMPOSIUM

Development and Use of Photogrammetry in the Coast and Geodetic Survey

REAR ADMIRAL H. ARNOLD KARO,
Director, Coast and Geodetic Survey

In 1957 the Coast and Geodetic Survey celebrates its 150th year of service to the Nation. Born of necessity and guided by the farsighted principles laid down by a great public servant—Ferdinand R. Hassler, it was the first technical bureau established in the Federal government. Because of the need of coastal charts in support of waterborne commerce, an Act of Congress passed on February 10, 1807 authorized that a "Survey of the Coast" be made. Upon advice of the American Philosophical Society, after it had examined numerous plans for execution of the work, President Thomas Jefferson appointed Ferdinand Rudolph Hassler, a world-renowned geodesist and engineer of Swiss origin, to superintend and direct the task. Hassler was a fortunate choice since he had the foresight and determination to insist, in the face of an impatient Congress, that the hydrographic and topographic surveys of the coast, and the resulting charts, rest on a firm geodetic base, that is, on astronomic positions connected by precise triangulation to provide an integrated datum; in the beginning for the entire seaboard and finally for the entire nation. Furthermore, Hassler insisted on adequate precision in this work with the result that the early geodetic surveys could be expanded upon and included in the national network without reobserving.

It remained for Hassler's successor, Alexander Dallas Bache, an eminent scientist and great-grandson of Benjamin Franklin, to expand the work and keep pace with the rapidly growing nation. Responsibilities of the Survey were increased many fold with the rapid addition of new territories in the Nineteenth Century; nautical charts were required for commerce in the new territories and surveys had to be expanded rapidly. These included geodetic control, the base for all mapping and resource development, tides and currents observations, magnetic observations, and extensive topographic and hydrographic surveys. The Gulf stream was explored and rapid advances were made in geodetic knowledge as the eastern oblique and trans-continental arcs of triangulation were developed. George Davidson, one of the first assistants of the Survey to be assigned to the west coast, extended geodetic and topographic surveys along the Pacific coast and Alaska. He produced the first coast pilot for that area; it was a model of its day. Davidson was also active in cultural and civic affairs and became the leading scientist on the Pacific coast.

In the Civil War, the Coast Survey's unique facilities were of indispensable aid to the Federal government, and many of its personnel aided in critical war campaigns. Urgent demands were received from theaters of operation for coastal data and geographic information on all sections of the interior where military engagements might be a possibility. The trained personnel of the Survey were able to meet this challenge. Superintendent Bache, surrounded by able and dedicated men, was a chosen advisor to President Lincoln. Declining military honors, Professor Bache devoted himself with almost limitless energy to the duties of vital importance to the union.

A succession of able men followed Bache as heads of the Survey, and notable techniques were developed to meet the growing demand for nautical charts. In addition to civilian assistants, officers from the Army Corps of Engineers and from the Navy were assigned to the Survey; Army officers up until the end of the Civil War and Navy officers to the end of the Spanish American War.

In keeping with Superintendent Hassler's original plan, geodetic control was extended ahead of hydrographic surveys and charting, and connecting arcs were surveyed to provide for adjustment on a common geodetic datum. The eastern oblique arc from the Bay of Fundy to New Orleans was completed in 1889, and the first transcontinental arc in 1895. In 1871 the Survey was given the responsibility of establishing primary geodetic control throughout the interior of the country, and its name was changed by the Act of 1878 from Coast Survey to Coast and Geodetic Survey.

With the acquisition of Alaska from Russia in 1867, work was begun immediately of surveying the treacherous waters and shoreline of that territory. The Philippines became American territory after the Spanish American War, and the great task of surveying and charting these islands was started.

Scientists in the Survey like Charles Schott, John Hayford, and William Bowie, effected stable adjustment of all geodetic data for North America, and developed much scientific information of lasting value. Other scientists, including Rollin Harris, developed precise theories for predicting tides, and developed the Bureau's tide predicting machine, which solves mathematical equations involving up to 37 components.

The Survey was re-organized in 1917 under the leadership of Superintendent E. Lester Jones to provide and maintain a corps of highly qualified field engineers to command survey ships and survey parties. On 22 May 1917, Congress empowered the President to transfer vessels, equipment, and personnel of the Survey to the War and Navy Departments during periods of emergency, but subject to return to the Department of Commerce after the emergency. In keeping with this arrangement, field engineers of this Bureau were given commission status with ranks relative to those in the Navy. This organization proved highly effective and is used today. The Director of the Bureau holds the rank of Rear Admiral and other officers hold ranks ranging from Ensign to Rear Admiral comparable to those in the Navy. The commissioned corps is supported by civilian scientists and technicians who constitute the bulk of the Bureau's personnel.

During both World War I and World War II, the Survey demonstrated its ability to mobilize quickly and effectively for the national defense, and its technical services were devoted largely to support of military operations. In World War II, six of the Bureau's nine major ships were ordered to duty with the Navy. Of the 171 commissioned officers subject to military assignment, 94 were transferred to the military service—48 to the Army and 46 to the Navy. The remaining officers were retained by the Bureau for assignment to duties related to wartime activities. Those transferred to the Army served primarily in the Air Force, the Artillery, and the Corps of Engineers. The majority of those transferred to the Navy served on the transferred Survey ships and other Naval survey Ships as Commanding Officers, Executive Officers, and Survey Officers.

Close correlation with and support of military projects continues in time of peace: Commissioned officers are assigned to the Inter-American Geodetic Survey; The Armed Forces Staff College; The Artillery School; Board No. 1, Continental Army Command; Joint Long Range Proving Ground; Department of Observation, The Artillery and Guided Missile School; Naval Amphibious Training Unit concerned with amphibious training operations. In addition, technical services, particularly geodetic services, are provided for research and other projects. The Survey provided a nucleus of trained personnel and technical advice to the Corps of Engineers for organization of the highly successful Inter-American Geodetic Survey, and continues to have an officer assigned to that survey. Since the war the Survey has contributed greatly to the strategic mapping of Alaska by mapping the coastline of northern and western Alaska, and the Aleutian Islands, and by making basic geodetic surveys throughout the interior of Alaska in cooperation with the Army Map Service.

When the Coast Survey was organized in 1807 surveying and cartographic techniques were virtually unknown in the United States. Superintendent Hassler brought the first theodolites and other precision instruments from Europe in 1816, and since that time the Survey has made many notable technical contributions to the art and science of surveying and mapping. In the first century of operation up to about 1915, principal developments included the sounding machine, the wire drag, the automatic tide gage, the tide predicting machine, invar tapes for base measurement, signal lamps (acetylene, and later electric) for triangulation observations, improved theodolites, etc. In more recent years it has pioneered in the development of echo sounding and radio acoustic ranging for position fixing out of sight of land. The latest developments include electronic devices such as the electronic position indicator, portable steel towers for triangulation, portable tide gages, and the radio current meter for tidal current observations. One of the most significant developments is the application of photogrammetry for coastal surveys and the development of the nine-lens aerial camera and related equipment.

In this, its 150th year, the Survey continues its mapping and charting, engineering, and scientific services to the nation; its jurisdiction has been increased by the acquisition of territories to include more than 90,000 miles of tidal shoreline and more than 2½ million square miles of coastal and offshore waters bordering the coastline of continental United States, Alaska, Guam, Hawaiian Islands, Puerto Rico, the Canal Zone and the Virgin Islands. Over the years the scientific functions and responsibilities of the Survey have been broadened, and the several separate pieces of substantive legislation enacted at different times since the passage of the organic Act of 1807 have been brought together under one head in the Act of August 6, 1947.

The full scope of the Survey's work today embraces the hydrographic and topographic surveys of the coasts of the United States and its possessions to insure safe navigation of coastal and intracoastal waters; the determination of geographic positions and elevations in the interior of the country in order to coordinate the coastal surveys and to provide a framework for mapping and other engineering work; the observation, analysis, and the prediction of tides and currents to furnish datum planes to engineers and tide and current tables to mariners; the compilation, publication, and distribution of nautical charts to meet the needs of marine commerce; the compilation, publication, and distribution of aeronautical charts for use in air navigation; observations of the earth's magnetism in all parts of the country to provide magnetic information essential to the mariner, aviator, land surveyor, radio engineer, and others; and seismological observations and investigations to supply data required in designing structures to reduce the earthquake hazard.

The operating divisions of the Survey are organized along functional lines and the purpose of the Photogrammetry Division is primarily to supply the large-scale surveys and maps required to produce and maintain aeronautical and nautical charts. Nautical charts must show the features of the adjacent land as a guide to the mariner. Consequently, topographic surveys of the coastline have always accompanied or preceded inshore hydrography for chart construction and revision. Until the advent of photogrammetry, this work was done by planetable as a combined field operation with the hydrography, and the first planetable survey, still on record in the Bureau Archives, was made on Long Island in 1832.

Similarly, an aeronautical chart is a special map on which aeronautical information is overprinted on a topographic base. Topographic maps of the Geological Survey and other agencies supply a large part of the information for the topographic base for these charts, but special surveys are required by the Bureau in many instances, as for example, for the preparation of instrument approach and landing charts and airport obstruction plans.

Photogrammetry is essentially a method of surveying, and with its rapid development since World War II has become an extremely effective method for large-scale surveying and mapping. The scope of this modern mapping technique is ever broadening with increasing application to special problems and requirements. For example, it is now being used in conjunction with geodetic surveys for the location of aeronautical aids to navigation; in addition to the regular mapping for the construction of nautical charts, it provides a most effective means of revising and maintaining up-to-date land information on those charts. The following papers in this series provide detailed information about the application of photogrammetry to nautical and aeronautical charting and about the detailed photogrammetric methods and equipment in use.

Although the Survey was quite aware of the possibilities of photogrammetry as a surveying tool, it did not find its wide application practicable until the development of the airplane and aerial photography after World War I. As early as 1872 an employee of the Survey studied the possiblity of using balloons for this purpose, but found it inadvisable. It was recognized that some mapping of this sort had been done during the Civil War, and that more had been done even prior to that time in Europe.

On a limited scale the Survey had participated in terrestrial photogrammetry in connection with work on the Alaska-Canada boundary as early as 1894. One of the early books in the country written on the subject was by J. A. Flemmer, an Assistant in the Survey, who participated in terrestrial photogrammetric work on the Alaska-Canada boundary survey in 1894, and later was assigned by the Bureau to study photogrammetric methods in Europe. In 1919 the Survey used single-lens photographs for the revision of a chart of Atlantic City, and in 1921–22 for mapping the Mississippi Delta. However, it was the advent of multiple-lens cameras that opened the door for wide application of this method to coastal work; in 1928 the Ten Thousand Islands of Florida were mapped with three and four lens photographs, and until the Bureau completed its own nine-lens camera in 1937 a considerable amount of coastal mapping was done with four and five lens photographs in the early 1930s.

Participation by the Bureau in professional societies and other efforts for promoting photogrammetry as a field is well known. Captain O. S. Reading and others from the Survey were instrumental in the formation of the American Society of Photogrammetry. The Bureau's Topographic Manual is an important source of information about photogrammetric techniques. Many of the Bureau's personnel have been active in the International Society of Photogrammetry, and in 1948–52 Captain Reading was President of that organization. Other participation and cooperative efforts included work done for the National Geographic Society for use in their expedition to the North Pole in 1953. Mr. G. C. Tewinkel of the Coast and Geodetic Survey assisted the Society by making a geometric analysis of oblique aerial photographs taken over the Pole. This recalls a time nearly a half century ago when it was the calculations of Coast and Geodetic Survey mathematicians, Hugh C. Mitchell and Marvin Duval, that proved the authenticity of Admiral Robert Peary's discovery of the North Pole in 1909.

More than half of the Bureau's energy and effort must be devoted to field surveys to gather the essential data required for charting and for its other functions. Photogrammetry is considered, in the Survey, a principal survey method or tool, and though it is relatively new, it is on this 150th Anniversary accepted, appreciated, and used as one of the principal methods of providing essential information required for charting. We are justly proud of our small but active and alert Photogrammetry Division and trust that the readers of this series of articles will find the ensuing papers informative and interesting.

Photogrammetric Surveys for Nautical Charts

BENNETT G. JONES, *Coast and Geodetic Survey*

INTRODUCTION

THIS paper describes the photogrammetric surveys, or mapping, performed for the construction and maintenance of nautical charts of the coastline of the United States and its territories. The instruments and procedures described herein were developed by the Coast and Geodetic Survey during the last 30 years to suit the peculiar needs of its nautical charting program; they differ in many particulars from those employed for mapping inland areas for the publication of topographic or other maps. These differences are due to several factors:

(1) the mapping is confined to a narrow but irregular belt of coastline broken by many water areas, that is, the bays and sinuosities of the coast;

(2) a very large part of the charting program must be devoted to the maintaining of charts on issue and, consequently, the mapping procedures have been developed to provide an effective means of keeping the land details on the charts up to date; and

(3) the maps must provide accurate and complete information about the alongshore features of interest to the mariner.

Nearly half the 800 charts on issue at present are published at scales of 1:40,000 or larger, to provide for navigation in harbors and inland waterways. The land information on these charts is important to the navigator and must be charted in considerable detail, and then kept up to date because of the continual natural and manmade changes that occur along much of the coastline. This information includes those map details above the sounding datum, particularly the shoreline, the foreshore, aids to navigation, landmarks, and the culture and topography near the coast. Many charts must be revised and reprinted from one to several times each year. Aerial photography and photogrammetric methods provided a relatively new and very effective means of revising the charts immediately after the changes occur.

OBJECTIVES

The photogrammetric surveys, in addition to furnishing land information for construction and maintenance of charts, also provide control data for inshore hydrographic surveys. Usually the coastal mapping is planned and performed in conjunction with inshore hydrography. Thus, the objective of the coastal mapping pro-