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The Survey Jones Made:
E. Lester Jones and the Postwar Triumph of the Coast and Geodetic Survey

Caption: The headquarters staff of the US Coast and Geodetic Survey assembled outside headquarters on New Jersey Ave., on March 6, 1925. E. Lester Jones, dressed in a dark suit, is the twelfth person from the left in the front row.

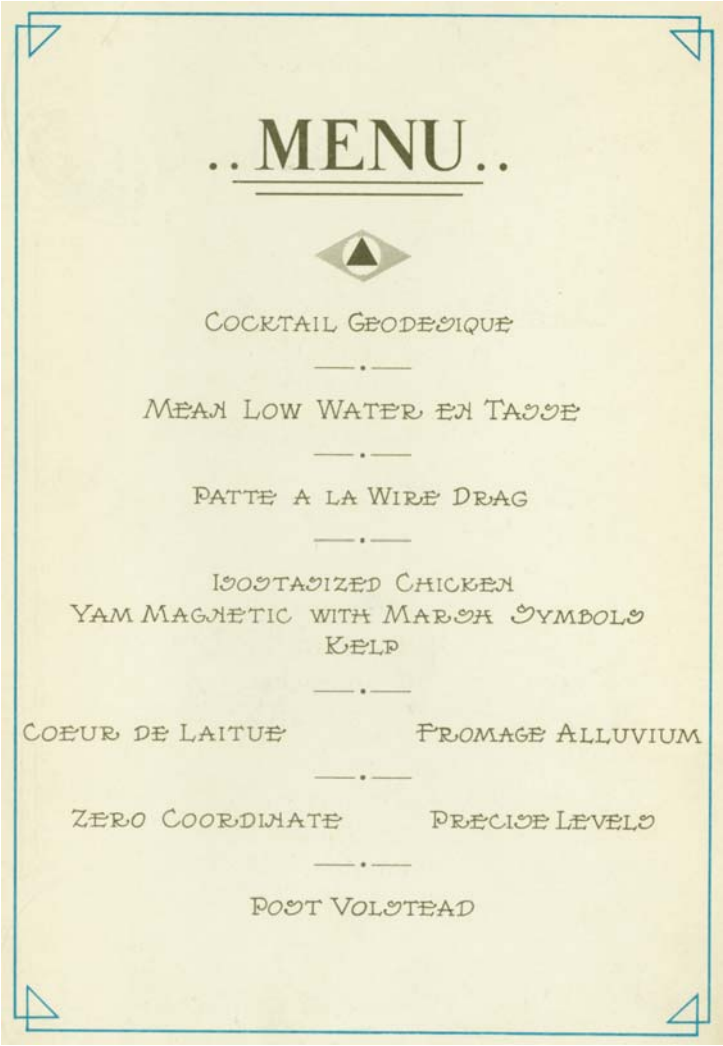
Ernest Lester Jones (1876-1929) became the 11th Superintendent of the Coast and Geodetic Survey in 1915, and served as Superintendent, and then Director, until he died in 1929. He led the Survey for 14 years, apart from a leave of absence for military service in World War I; he died from the long-term effects of the poison gas exposure he suffered while serving as Colonel Jones in the Division of Military Aeronautics on the Western Front. Jones did not rise though the ranks like many Survey leaders, nor was he a practicing scientist or engineer when selected to replace the retiring Otto Tittmann. Nevertheless, E. Lester Jones was the Alexander Dallas Bache of the 20th century—only Ferdinand Hassler and Bache played larger roles in the history of the Survey and its successor NOAA than did Jones. He positioned the Survey in larger historical context, and organized a Centennial Celebration for the Survey in 1916 that represented and reflected the Survey's status at the apex of American governmental science, a height it has never occupied again. He worked tirelessly to extend the Survey and its mandated responsibilities, and to fund and develop new technologies to fulfill those new responsibilities. He worked as well to support the personnel of the Survey and raise their salaries and working conditions. In particular, he orchestrated the creation of the Uniformed Corps of the Survey, the ancestor of NOAA Corps, in order to expedite Survey personnel entry into service in World War I. Significantly, postwar he worked though Congress to establish parity between similar ranks of Survey Corps and military

officers' salaries and benefits, which continues to the present day. This salary parity by itself has probably had more impact on personnel retention and organizational and scientific continuity in the Survey and later NOAA than any other single action taken by Survey and NOAA leadership in the 20th century.

Jones' background will be described later; for the moment, it should be noted that he first intersected with the Survey around 1913 when he was appointed Deputy Commissioner of the Bureau of Fisheries, which was, like the Survey, in the Department of Commerce, newly separated from Labor in what had been the Department of Commerce and Labor. The Bureau of Fisheries had established the Alaska Fishery and Fur Seal Service which was embroiled in scandal over the poor management of the seal populations of the Pribilof Islands. Jones was directed to investigate the matter[1]. His activities brought him in close contact with Survey personnel working on the Alaska Survey. Shortly thereafter he was asked to succeed Otto Tittmann upon his retirement as Superintendent. Jones' work in the Pribilof Islands and the Survey were of a piece; Jones' major role was to establish boundaries and to set things right. He never advocated for novel ideas and technologies, but rather, he singled out problems that needed to be fixed—it just happened that only new ideas and technologies would do. He was hence not a revolutionary or major innovator in his time directing the Survey—yet he wrought more changes in the Survey in his tenure than any other leader with the possible exception of A.D. Bache.

Jones was unlike any Survey leader before or since, and his quiet and efficient methods of leadership meant he cruised through the water like a sleek frigate that leaves little wake. He left the Survey with budgets and responsibilities far higher than they were when he entered, yet his managerial talents were such there were few scandals in his tenure. Despite the fact that many of the years of his tenure postwar he was in declining health, and Acting Director Faris was really the leader of the Survey in terms of day to day operations, Jones steered the Survey through the first stages of a global depression that would eventually cause great changes to the Survey and its activities; but these were held in abeyance during Jones' tenure. Perhaps the best "memorial" to Jones and his service in the Survey was the celebration that Survey staff organized in 1925 to celebrate the 10th anniversary of Jones' reign in the Survey. As with the Survey Centennial Jones created, there had never been any function like this for any previous leader of the Survey, not even Bache. The nature of the feast, the participation of so many Survey personnel, and the toasts addressed to Jones make clear how Jones was regarded by the men and women who worked under him. And even the "silly" names of the food items on the dinner menu convey the breadth of Survey functions and activities that Jones had expanded and successfully funded. Behind the menu lies the story of the Coast and Geodetic Survey as it was revitalized and expanded by the greatest Survey leader of the 20th century.

[1] See Jones, 1915.



The menu items refer, to the initiated, to landmarks of scientific and technical progress in the Survey during Jones' tenure, distributed across the divisions and offices of the Survey. The references are interesting both for what they include, and for what they do not. Turning first to what they reference directly:

- Patte a la Wire Drag refers to the Division of Hydrography and Topography and their elaboration of the techniques for wire-dragging in hydrographic surveys, a technique originally developed in the late 19th century in Europe and in the U.S. in the Army's Lake Survey. The Survey's techniques for wire-dragging were developed under the direction of Nicholas Heck in the administration of Otto Tittmann, but particularly expanded in surveying work under Jones.

- Cocktail Geodesique and Isostasized Chicken are references, largely esoteric, to the work of the Geodesy Division, which culminated in the creation of the North American Datums of 1923, 1927, and 1929 (to be explained later) and the global adoption in 1924 of the Survey's Hayford Reference Spheroid as the International

Reference Ellipsoid as the basis for the Figure of the Earth, and finally, the relative triumph of the concepts of isostatic equilibrium and compensation associated particularly with William Bowie. Isostasy refers to a theory and concept of geophysical equilibrium. As Bowie defined it: "The continents will be floated, so to speak, because they are composed of relatively light material; and, similarly, the floor of the ocean will, on this supposed earth, be depressed because it is composed of unusually dense material. This particular condition of the approximate equilibrium has been given the name 'isostasy'".[2] These were in turn situated in major developments in the emerging sciences of geophysics, in which many Survey personnel played prominent roles both inside the Survey and outside it, particularly through their roles in the leadership of the new American Geophysical Union which was founded in 1919, 2 years after Bowie's seminal publication on isostasy.

- Yam Magnetic with Marsh Symbols refers to the work of the Division of Terrestrial Magnetism, which under Jones was in 1925 was in the process of becoming the Division of Terrestrial Magnetism and Seismology with primary responsibility within the federal government for research and data acquisition in seismology. The Marsh Symbols and the Fromage Alluvium both refer, in a very vague way, to the renewed emphasis in the Survey on analyzing and mapping geologic and geomorphological conditions, particularly with reference to coastal change.

- Mean Low Water en Tasse and Precise Levels are references that link the activities of the Divisions of Geodesy, Hydrography and Topography, and the Charting Division. Mean Low Water and Mean Sea Level had been concepts and derived data throughout the history of the Survey back to the days of Hassler. But it was particularly Jones who advocated for the extension of sea-level datums inland by extending precise leveling surveys throughout the United States. As he did in so many other contexts, Jones identified and accentuated a problem which, given sufficient money and personnel, the Survey could and would solve for the betterment of all. Jones wanted the Survey's precise sea-level datums to be extended nationally, to all states, and to most or all municipalities in order to integrate disparate engineering and scientific activities to a common vertical datum.

- Post Volstead is a reference to the Volstead Act, passed in 1919, the federal law banning possession of alcohol pursuant to the 18th Amendment in the US Constitution. Apparently, it was widely ignored in the District of Columbia (and elsewhere) and presumably the reference "Post Volstead" meant that, for the purposes of the celebration, the act had been at least temporarily repealed.

Left unreferenced in the menu for the dinner celebrating Jones' ten years tenure in the Survey are a number of developments of enormous significance to the history of the Survey, although some of these came about in the four remaining years of Jones' life and service in the Survey. These include:

[2] Bowie, 1917, p. 7.

• The participation of the Survey and Survey personnel, including Jones, in World War I. Jones had been a protégé of Woodrow Wilson at Princeton University which was a factor in his selection as Superintendent of the Survey in 1915. Once the decision had been made to enter the war, Jones directed the Survey into military service on a scale not seen since Bache during the Civil War. Jones orchestrated the passage of laws in Congress that established the Uniformed Corps of the Coast and Geodetic Survey, the ancestor of modern NOAA Corps, the seventh uniformed service in the US government. Under the new laws, members of the Survey field corps, consisting of assistants, sub-assistants, and aids (but not enlisted men and lower level staff members) passed into military service at requisite ranks and later were transferred back into the Survey. Similarly, Survey ships passed into military service until they were eventually de-commissioned and returned to the Survey after the war. During their war service, Survey personnel did a combination of "traditional" survey activities, only transferred to the battle front, and new exercises in the development of special instruments and techniques, especially in ocean acoustics, with far-reaching consequences for all subsequent work of the Survey and its successors.

• Jones also orchestrated the return of Survey personnel and ships to the Survey after the war ended. Survey officers in the new Uniformed Corps had become military officers of comparable rank, but much higher salaries. Many declined to return to the postwar Survey at the traditional salaries, provoking a crisis in the Survey. Jones settled matters by securing Congressional authorization for parity between Survey and military officers of comparable rank which led to increases in Survey salaries never before experienced in Survey history. The Survey's ability to retain competent staff increased with consequences that continue to the present era.

• Jones led what can only be described as a cartographic explosion in the history of the Survey. Jones embraced the airplane, both as a new platform for aerial photography, which would change charting and mapping, and also as the source of a whole new class of Survey chart users. The Survey had pioneered nautical charts; Jones would take those into the sky as aero-nautical charts. He advocated for new facilities and equipment including the purchase of the first offset lithography presses from the Harris Company, a cartographic production relationship that continues to the present day in NOAA and the FAA, the inheritor of the Survey's aeronautical chart production function.

• During the war Survey personnel had participated in a wide variety of activities involving aerial acoustics and hydro-acoustics. Postwar, Jones directed the entry of the Survey into major development of hydro-acoustic techniques for determining water depths and horizontal positioning of Survey craft. The latter exercise involved the development, elaboration, and perfection of Radio Acoustic Ranging (RAR), one of the most important contributions of the Survey to the earth sciences in the 20th century. Using RAR, the Survey extended hydrographic surveying beyond the limits set by the curvature of the earth along the coast, revealing bathymetric features that helped transform our knowledge of the earth's history. And, as a part of RAR work, the Survey scientists made the serendipitous discovery of the deep sound channel of the ocean, one of the most important discoveries in oceanography in the century.

E. Lester Jones and Alaska and Government Service

Ernest Lester Jones was born in East Orange, New Jersey, on April 14, 1876. He attended local schools and then in 1894 went to Princeton University. In 1897 he married Virginia Brent Fox. He and his wife then went to Europe where Jones studied for a year at the University of Heidelberg and perhaps elsewhere in Germany, although it is not entirely clear when he studied. The following year he returned to Princeton and graduated with a B.A. degree. His most detailed posthumous biography says that, following Princeton, "Mr. Jones was engaged in research, secretarial work, and business for a number of years"[3]. For nine of these years he was associated with the business of his father who ran a printing company. From 1907 to 1913, he owned and operated a large stock farm in Culpeper, Virginia. In preparation for this role, he studied veterinary medicine in Massachusetts and developed his stock farm as a model of modern scientific management. He specialized in breeding and rearing draft horses, but also maintained a herd of shorthorn cattle and a herd of jersey milk cows[4]. Then, in 1913, President Woodrow Wilson, who had known him at Princeton University, appointed him to a position in the federal government that was far removed from the Piedmont of Virginia.

When, in 1867, the United States purchased Russian America, now known as Alaska, it acquired Russian territorial claims and land-use management practices along with the territory. The first major oceanic territorial claim that extended far beyond "cannon-shot range" was the Russian Imperial Decree, the Ukase of 1821, which claimed rights to 100 Italian miles of the ocean waters off Alaska in the Bering Sea and around various islands, such as the Pribilofs. The intent of the claim was to protect and preserve fur seal populations from over-hunting. In 1878 the US government decreed a complete ban on fur seal hunting on the islands; although, this failed too, in large part because hunting operations shifted to pelagic hunting which meant shooting seals in the water. Predation continued and increased; and seal populations plummeted. This led to stronger restrictions, and eventually a complete 5-year moratorium on harvesting fur seals on and around the Pribilof Islands and other breeding grounds. The ban was administered by the US Navy which had jurisdiction over the territory.

The hunting and fishing restrictions imposed by Washington were part of a larger political movement to change the status and government of Alaska as a US territory. In 1884, the First Organic Act relinquished control by the Navy to a territorial administration in which a total of thirteen officials were made responsible for a population of 32,000 people of which only 430 were white settlers.[5] Alaska remained marginal to larger American interests, except for issues concerning fishing and sealing, until the Klondike gold rush in Alaska and adjacent Canada beginning in 1897-98. The influx of 30,000 new settlers, the complex commercial re-organization of the entire Pacific northwest coast in response to the gold rush, and other matters compelled a new re-organization of the territory. In a revised act of 1900, substantial reforms in

[3] Faris, 1929.
[4] Brown, 1915.
[5] See Gislason, 2006.

administration were introduced, but complete control over Alaskan fish and game animals remained in the hands of the federal government through the Department of Commerce. However, in 1907 these changes were imperiled by the entry of the Alaska Syndicate formed by the fortunes of J.P. Morgan and the Guggenheim family. Amongst other resources they monopolized were the majority of the salmon canning factories which resulted in their being dubbed the Fish Trust.

In 1910, the US Congress passed a law banning the killing of many or most species of "fur-bearing" animals in the Territory of Alaska, enforced by special agents of the Department of Commerce. However, there were no laws prohibiting hunting of the animals as such, nor possession of live animals, nor possession of the furs of killed animals. This created a situation in which strict legal enforcement of the hunting ban essentially required agents to catch hunters as they were in the act of killing animals, an all but impossible task. Enforcement was haphazard, officials were corrupt, the local populations disobedient and contemptuous. It was a recipe for disaster.

Matters were only compounded in 1912 with the federal passage of a Second Organic Act for Alaska, which established Alaska as an official territory of the nation but maintained complete federal power to regulate the territory's fish, game, and fur resources, which was a legal stance not applied to any previous US territory. As a result, the territorial government began in substantial opposition to federal enforcement efforts as a matter of territorial rights, overlaid on the problems and conflicts of resource depletion and economic and social impacts on the local population.

President Wilson and his new Secretary of Commerce Redfield began by dismissing George M. Bowers as Commissioner of Fisheries. Bowers had been appointed to the post in 1908 and was in many respects an able administrator, but he had no scientific training or experience, and in any case the Bureau's affairs in Alaska were engulfed in scandal. It appears that Wilson and Redfield initially attempted to appoint E. Lester Jones as Commissioner, but this was assailed by committees from the American Society of Naturalists and the American Society of Zoologists, who preferred instead Dr. Hugh M. Smith, a career scientist in the Bureau of Fisheries. The response of Wilson and the Department of Commerce in 1913 was to appoint Smith as Commissioner, but also E. Lester Jones as deputy commissioner of the US Bureau of Fisheries. It was his first experience in government service; he would spend the rest of his life at it.[6]

The assignment was difficult from the start. The problems in Alaska were long-standing and complex, and the problems back in Washington were considerable. Wilson and Redfield had appointed Smith as head of the Bureau instead of Jones, but one critic complained that "that position [deputy commissioner] in many respects, even more important to science than that of the commissionership itself, and which should have been filled only on the recommendation of the Commissioner, was at once filled by the appointment of Mr. Jones."[7] Jones spent considerable time over two years in

[6] See Ashmun Brown, 1915; Scientific Monthly editorial, 1916; Macmahon, 1926.
[7] Evermann, 1916.

reconnaissance trips to many areas of Alaska on the mainland, the Aleutians, and other areas where contention reigned. At the end of 1914, he published a hard-hitting, incisive, and profusely illustrated report on his investigations. The report's general summary was entirely indicative of Jones:

> "In the foregoing report it has been my aim to bring out forcibly the main issues and needs in connection with the fisheries and fur-bearing animals of Alaska, including affairs pertaining to the Pribilof Islands. Attention has also been called briefly to a few highly important needs of the Territory, some of which are but indirectly related to the primary subjects of my investigation. I have endeavored to view all matters from the standpoint of a practical business man, seeking only to suggest simple and direct ways of correcting any existing evils or practices observed, and at the same time to indicate proper needs and ways and means for building up and expanding Alaska's interests as circumstances may permit.
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> "The fact must be thoroughly understood and emphasized, however, that if the laws made by Congress relative to the protection and upbuilding of these resources are to be enforced it is absolutely essential that adequate appropriations be made." [8]

Jones was essentially correct in enough of his allegations that major and positive changes in the administration of Alaskan fishing and fur-bearing animals ensued. And it was noted in the Wilson administration that Jones could couple decisive criticism and analysis with a calm and managerially competent plan for improvement, which generally required extracting more appropriations from the Congress to effect the necessary changes. The Wilson administration could use Jones elsewhere in such a capacity.

Otto Tittmann had been declining in his direction of the Coast and Geodetic Survey, and the Survey was saddled with major problems of equipment and budgets. After discreet investigations, Secretary of Commerce Redfield sent a memorandum to President Wilson in 1915 noting: "I have consulted Mr. Charles D. Walcott, director of the Smithsonian Institution, on the subject of the Titttmann resignation and the Jones appointment, and he thinks it is the right policy to pursue".[9] It is notable that Jones' appointment to be chief of the Coast and Geodetic Survey, a role he filled until the day he died, was not sought by him; his first knowledge of the matter was when he received and read the letter of appointment.[10]

Thus, in 1915, Ernest Lester Jones was named to succeed Otto Tittmann as the 11th Superintendent of the Coast and Geodetic Survey. Apart from Superintendent Thorn (1885-89) who was brought in to clean house in the Survey after Gilded Age scandals, and Superintendent Duffield (1894-97) a spectacularly unfortunate choice as leader, Jones was the only head of the Survey during its entire existence who did not have a

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[8] Jones, 1914, p. 153.
[9] Quoted in Macmahon, 1926, p. 774-775.
[10] Corey, 1924, p. 26.

foundation in geodesy or cartography or any other branch of the broad earth sciences. Jones soon acquired considerable knowledge of all phases of the activities of the Survey, but his most important skills were those of knowing and managing people. His conflict with Wickersham notwithstanding, Jones had great facility for noting the crux of problems and grasping solutions. His general sense of the Survey, which was now to become his life's work, was that it was a vital but marginalized agency staffed with personnel of extraordinary talent and abilities, who were paid too little and worked too hard, without sufficient access to the instruments and materials that would make their work much more productive and satisfying. Jones resolved to change that during his tenure. He did not have, nor make, a mandate to change anything in particular in the work of the Survey; instead, he would end up changing everything.

The First Phase of the Jones' Era

When Jones entered the Survey, he encountered an organizational system substantially unchanged from the era of Henry S. Pritchett (1897-1900). The Survey was organized into divisions, of which the largest were Hydrography and Topography, under Herbert C. Graves as chief, along with the smaller divisions of Geodesy, under William Bowie, and Terrestrial Magnetism, under Andrew Braid. In addition, there were two small divisions that serviced the entire Survey — Accounts, under John M. Griffin, and the Office, under Philip A. Welker. The Office division had major sub-divisions called sections, particularly that of Instruments, under the celebrated instrument designer Ernst G. Fischer, and the Library and Archives section, under Robert M. Brown. The first major change Jones made was in the ways maps and charts were produced, which is understandable given his experience in commercial printing working for his father. Before Jones, each of the three major divisions, Hydrography and Topography, Geodesy, and Magnetism, had its own charting operation, and these shared the cramped quarters of the printing shops. Jones put the entire printing operation its own division, called the Division of Charts, under Dallas Bache Wainwright, the last direct descendant of Benjamin Franklin to work for the Survey, who reported directly to him.

To compensate for his lack of experience in the functioning of the Survey, Jones changed and enlarged the position of Assistant Superintendent, a role introduced by Henry S. Pritchett. Jones selected for the position Robert Lee Faris, previously the assistant chief of the Hydrography and Topography division, before that chief inspector of magnetics. Prior to his assignment in magnetics, he was a skilled participant in virtually all activities of the Survey, including primary surveys in the Yukon River delta as well as captaining various Survey ships. The match was a good one, and Faris continued as the Assistant Superintendent and later Assistant Director of the Survey for the next 18 years of his life, dying in office in 1932.

E. Lester Jones walking from the Capitol to Survey headquarters

Jones was a complete outsider to the functions of the Survey, but a quick learner, and as an outsider he saw problems freshly. As Faris put it in a memoir of Jones after his death:

> "It was a part of his philosophy of human affairs that the best work can only be done when men have the best tools and appliances for doing it, and so it was among his basic endeavors while Director of the Coast and Geodetic Survey that the Bureau's engineers be supplied with adequate ships and modern instruments and equipment."[11]

The Survey's deficiencies revolved fundamentally around the fact that the Survey's responsibilities exceeded its capabilities, the facilities available to it were old and inadequate, its ships were old and increasingly dysfunctional, and that, possibly more important than anything else, its personnel were poorly paid, particularly so in relation to their skills and acquired knowledge in comparison to the salaries those same abilities could garner elsewhere. There was also little if anything paid to them upon retirement,

[11] Faris, 1929, p. 2.

which impelled many skilled veterans of the Survey to leave in their prime for other jobs in hopes of acquiring pensions elsewhere. Whatever else, Jones was never subtle. He immediately applied himself to discovering who, in Congress, controlled funding and support for the Survey and began to craft what he called an Urgent Deficiency Bill to address the problems. He also ordered a complete reorganization of the Superintendent's Annual Report to the Congress, the most major change in the reports since Bache had initiated them in 1852. Henceforth, starting with the 1915 edition, the very first section of the report became THE NEEDS OF THE BUREAU, which laid out the problems as he saw them, beginning with "New Building" and finishing with "Retirement". The tenor of the argument may be gauged by his introduction:

> "Part 1 explains the needs of the Bureau by text and illustrations, and is an appeal for greater recognition of its essential requirements. With the increased work in recent years there has been no corresponding increase in the force and equipment, which is a pertinent cause for the backwardness of much of the work".[12]

Jones campaigned for a new building to replace or augment the warren of spaces occupied by the Survey at its headquarters on New Jersey Avenue, a block from the Capitol, to which the Survey had moved in 1874. The core of the complex was a former hotel and a former mansion, and in all there had accreted five different buildings that did not match up—Jones even included a composite elevation sketch in the report demonstrating that none of the floor levels of the buildings matched, and that "the buildings are joined together by fractional stairways, bridges, and narrow passageways"[13]. He described the poor conditions of the ships, the deficiencies of much equipment, and the rather alarming matter that the entire chart archives of the Survey, dating back to Hassler, were housed in a non-fire-proof structure such that records "that cost millions of dollars and could not be replaced short of the expenditure of other millions of dollars are constantly in danger". [14]

And so the Jones' administration began, off and running. Congress responded, the money increased, salaries grew, ships were commissioned, and eventually the Survey even got a new building—but Jones and the Survey would find themselves in a period "constantly in danger" before that happened.

The Centennial of the US Coast and Geodetic Survey

The plan for the Survey of the Coast began with President Jefferson and Ferdinand Hassler in 1807. Jones became Superintendent of the Survey in 1915 and soon announced that the Centennial of the Coast and Geodetic Survey would be celebrated in 1916, which was the actual centennial of the first field work initiated by Hassler . It would appear that the main reason the centennial wasn't celebrated in 1907 was that Jones wasn't yet in charge of the Survey. Jones was brought on board to revive a

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[12] Annual Report, 1915, p. 5.
[13] Ibid, Illustration 2.
[14] Ibid. p.6

somewhat moribund bureau, but the Survey's legacy as the oldest scientific agency in the government and its relationships to other federal agencies and enterprises, along with Jones' adroit abilities at organization, insured that the Survey's centennial was marked with ceremonies and activities on a scale never seen before, and, alas, never seen since, notwithstanding the many activities of NOAA's 200th Anniversary in 2007.

Central Hall of the New National Museum, April 5, 1916

There were three major elements to the centennial celebration which was held on April 5 and 6, 1916. First, the Smithsonian Institution, which had been associated with the Survey in a myriad of ways in its history, agreed to dedicate the main exhibition space of the New National Museum (now the National Museum of Natural History) to a series of displays about the history of the Survey. The exhibits featured old geodetic and cartographic instruments and tools, in some cases paired with their modern equivalents, and many examples of historic and contemporary maps, charts, and other graphics. The exhibits were opened to the public from morning until late evening to allow people who worked days to attend. In addition, all Survey personnel who worked in or near Washington, D.C., were given a day off, half on each day, in order to allow them to attend the exhibition.[15]

The second component of the centennial was a symposium on the history of the Survey and its relations to other federal agencies which was held in the auditorium of the

[15] Centennial Report, 1916.

new National Museum on the afternoon and evening of April 5th, and the afternoon of April 6th. After opening remarks by Jones, the directors or chiefs of the following federal agencies gave addresses on the relationships between their bureaus and the Coast and Geodetic Survey: the Department of Commerce, the Bureau of Fisheries, the National Bureau of Standards, the US Navy Hydrographic Office, the US Geological Survey, the US Army Corps of Engineers, and the Lighthouse Service. In addition, the Director of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington (Louis Bauer, formerly head of the Division of Terrestrial Magnetism in the Survey), a prominent member of the House of Representatives, three Professors from Columbia and Northwestern Universities, and former Superintendent Tittmann, now president of the National Geographic Society, also spoke on specific earth science topics related to the work of the Survey. The papers were collated and published by the Survey a few months later.[16]

Finally, on the evening of April 6th, a lavish banquet was held at the New Willard Hotel near the White House, attended by President Woodrow Wilson who was the principal speaker, along with members of the diplomatic corps in Washington, high-ranking officials of the federal government and allied institutions such as the Smithsonian and the National Geographic Society, along with various high-level employees of the Survey. The main gathering was entirely male, although a small viewing balcony in the ballroom was filled with spouses and other women associated with the major banquet members[17].

The Survey goes to War

The Centennial celebration marked a distinct high-water mark in the history of the major federal agency with responsibility for measuring the tides of the national waters. The occasion was celebratory and peaceful, as the Survey had few competitors as the premier scientific agency in the government. That combination of circumstances and consequences would never come again. Western and central Europe and Russia had been engulfed in war since 1914. Woodrow Wilson had campaigned successfully for re-election in 1916 on a platform to keep the United States out of war; a year later, his Administration entered the war "to make the world safe for democracy". The US entry into the war, and the preparations for that entry by the federal government, produced dramatic changes. The Survey and its leadership and the methods by which they led were altered more so than at any other time in Survey history including the Civil War[18]. Survey personnel participated in traditional and very novel applications of their geodetic, hydrographic, and cartographic skills, and made connections within American military agencies and bureaus that would yield a cascade of new instruments and approaches to Survey work in the postwar period. But a system of German and American cooperation in oceanographic and geodetic research that whole generations of Survey personnel had participated in was threatened and weakened. Survey personnel suffered and died in the

[16] Centennial Celebration, 1916.
[17] Banquet in commemoration, etc. 1916.
[18] As part of positioning the Survey for wartime service, Jones published a summary of the service and experiences of Survey personnel in the Civil War. See Jones (1916).

war and its aftermath, and ultimately, the last casualty of World War I in the Survey was to be the man who led the Survey into war to begin with: E. Lester Jones.

In a sense, the entry of the United States into the war required Jones to address the problems previously faced separately by A.D. Bache and, to a lesser extent, by Henry S. Pritchett. The Survey had always been a civilian agency, yet civilians in a war zone are considered noncombatants, refugees, or spies. If members of the Survey participated in the war in any capacity on the battle front then they would have to enter the military, but on what terms? And how would the disparate skills and experiences of Survey personnel be recognized adequately to allow Survey personnel to be appointed to military ranks appropriate to their abilities? Second, in 1898 under Pritchett the Survey finally took operational control of its own ships, as they were now no longer operated by Navy crews. Yet civilian ships and civilian sailing masters were problematic in a war zone, especially one characterized by the new menace of submarines attacking civilian shipping on all waters of the Atlantic Ocean. And finally, Survey personnel were historically paid low wages for the work they did, and Jones had entered federal service quite vocal about the problems associated with this.

Jones, the Secretary of Commerce, and requisite members of the Wilson administration and the Congress negotiated a plan that would address all three levels of problems with the civilian Survey. An act of Congress established a Commissioned Service of the US Coast and Geodetic Survey[19]. Members of the Survey field corps (assistants, sub-assistants, and aids) could be appointed to requisite rank in the service, the rankings of which were similar to the rankings of the US Army, from second lieutenant to colonel, and the US Navy, from ensign to captain. The new service was a hierarchy of officers that could be entered only at the bottom, after "passing a satisfactory mental and physical examination conducted in accordance with regulations prescribed by the Secretary of Commerce". However, once Survey civilian personnel were admitted into the Commissioned Service, they could be transferred to military service at a military rank commensurate with their Survey commissioned service rank (meaning that, for example, a Survey Commander could become a Navy Commander or an Army Lieutenant Colonel). In addition, provisions were made that Survey ships could be transferred to military service and would be considered military vessels, until which time as they were de-commissioned from military service. With these changes, the Survey—or at least its officers—was ready to go to war[20].

The United States declared war on Germany and its allies on April 6, 1917, some three years into the struggle. On May 22, 1917, the signing of a manpower bill began the commissioned service corps of the Survey. The war ended with the Armistice signed November 11, 1918. Hence, Survey personnel and all other American forces had less

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[19] 40 U.S. Stat. L., 84, 88, May 22, 1917.

[20] The Survey Commissioned Service, like its successors ESSA Corps and NOAA Corps, was an elite service—it contained only officers. There were no provisions for non-officers in the Survey Commissioned Service, and hence no mechanism for lower level employees of the Coast and Geodetic Survey to pass directly into military service, or to pass back from military service into the Commissioned Service of the Survey.

than two years' time at war. With some exceptions, Survey personnel went into the war to perform a certain role or fight in a certain area, and their experiences were limited to that. Five major areas and activities characterize Survey personnel in the war, all of which had significant impact on the direction of the Survey after the war.

- Ship convoy duty in the Atlantic or elsewhere

- Artillery orienteering, artillery spotting, and sound and flash ranging on the battlefront in Europe, and the development of military grids related to geodetic networks;

- Research and development work with underwater acoustics and allied matters for anti-submarine warfare and other aspects of war in the oceans;

- Research and development of instruments, especially radio and magnetic equipment, computing, and other allied research, primarily conducted "stateside" in association with Army and Navy labs;

- Battlefield cartography, aerial observation, and the applications of aerial observation and photography to mapping.

The larger story of what Survey personnel did during the war is literally outside this story—when they went into military service they vanished from Survey records, and if they survived and returned then only general information and anecdotal evidence of the war came back into Survey files. But their experiences at the front, and the new technologies they encountered, had major impact on the Survey and its operations postwar. These matters can be summarized by considering the war in three very different domains: the war on land, dominated by the story of the long bloody line of the Western Front; the war at sea, primarily in the Atlantic; and the new war in the air, glorious and terrifying, encompassing aeroplanes and aerial photography and also poison gas, used as a terrestrial warfare tactic diffused through the atmosphere, primarily through gas artillery shells.

The major American experience in what was for decades called the Great War occurred in western Europe along the Western Front. The war began in 1914; by the time the Americans in the Allied Expeditionary Force (AEF) arrived in 1917 (as opposed to Americans individuals who volunteered earlier in other services) the front was largely static, and the battle field was a vast series of thousands of miles of trench complexes running in a great zone, with the fabled No Man's Land between the forces. The major military initiatives involved artillery barrages fired from cannons with ranges that exceeded the line of sight. In response, the armies on both sides developed techniques for "sound and flash" ranging to determine the positions of enemy artillery. The "flash" was the light from cannon muzzle blasts as seen at night. The "sound" was the acoustic blast of the cannons as it reverberated through the air. It was in this regard that Coast and Geodetic Survey personnel now in military service saw significant action in the war.

As members of field artillery spotter battalions, associated with Army military intelligence units, they participated in the use of multiple acoustic arrays and visual observatories, all located at well-defined positions. The general method was the same for both light and sound; from multiple known positions, the directions to the sources of light and sound could be determined, and where these intersected must be the position from which the blast occurred.[21] Sound ranging in particular was significant for Survey personnel. It put them in the forefront, literally, of the application of acoustics to position-finding; and it introduced them to the use of sets of hyperbolic curves. For acoustic ranging, two or more sets of linear arrays of microphones were deployed; their positions and alignments defined as precisely as possible. The sound of a cannon blast would reach one end of the array before it reached the other end. That time difference meant the cannon was located along a certain line that was a hyperbolic curve. If the same blast was received by a second microphone array, then the cannon was also located along a second hyperbolic curve. The cannon must be located at the point where the two curves intersected. As we will see, variations on this acoustic technique would come back to the Survey postwar in very different applications.

There was more flying through the air over No Man's Land than the artillery shells. The war was also the first time airplanes were used in combat. They bombed positions, and they were also used to photograph and observe positions and battlefield conditions. In was in this domain that E. Lester Jones participated, a rather unique one for Survey personnel. Jones had orchestrated the legal changes necessary for civilians in the Survey to enter military service. Then he did so himself, starting in the local National Guard unit in Washington, DC. He took a leave of absence from the Survey, leaving Robert Faris in his familiar role of Acting Superintendent, and went to Europe. Here is what little is known about what happened to him:

> "On October 5, 1918, he was promoted to Colonel, Air Services, Division of Military Aeronautics, and on October 8 he sailed for France. Upon arrival he was assigned to special and highly confidential duty with various units at battle zones and later under Brigadier General William Mitchell, Chief of First Army, Air Services, and served on the Meuse-Argonne Offensive, Defensive Sector, and also served in Italy".[22]

It is unknown to the present day what he was doing on "special and highly confidential duty," but sometime during that service he was exposed to poison gas and badly wounded. However, he remained in Europe on or near the front until the Armistice in November, 1918. He was decorated by the King of Italy as Officer of the Order of S.S. Maurizio and Lazzaro, and Fatigue de Guerre; he was also made an Officer of the French Legion of Honor. And then he returned to the United States and civilian service once more.

Outside of the battlefront in western Europe and the skies overhead, World War I was fought in the Atlantic Ocean. There were some traditional naval engagements, but

[21] Trueblood, 1919.
[22] Washington Post, April 10, 1929.

the major developments in naval warfare involved the first major use of submarines, particularly to destroy supply ships sailing in the vast convoys between the Americas and Europe. Many and possibly most Survey personnel who entered war service participated in convoy duty and also a variety of efforts to detect and destroy enemy submarines. Again, novel technologies involving acoustics were developed and deployed for this.

The history of ocean acoustics technologies in the American case is closely linked to the story of Reginald Fessenden and the Submarine Signal Company. The company began supplying underwater sound-generating and sound-detecting equipment to ships to prevent groundings and shipwrecks in the early 1900's. Following the Titanic disaster in 1912, Fessenden turned his skills to developing acoustic equipment that could detect icebergs. It did—but he found he could also detect the ocean bottom. This led to rapid development of many acoustic technologies[23]. The applications stemming from these two new discoveries have dominated ocean acoustics ever since. During the war years, much submarine detection work was done by the US Army, as its Coast Artillery units had primary responsibility for protection of the near-shore waters of the nation. Various Survey personnel in military service worked on different aspects of underwater acoustics, acquiring knowledge, and maybe more important, connections, that would be tapped soon after the war. One of those men was Nicholas Heck. The connections he made would prove critical after the war.

Finally, the final contingent of Survey personnel re-assigned to military service during the war participated in basic research and instrument development. These included men assigned to the Naval Observatory in Washington, who worked to develop a new generation of ship compasses and other navigational instruments for the Navy.

The Transition back from the War

World War I ended on the 11th hour of the 11th day in November, 1918. The members of the Survey who participated in the war were exposed to new places, many new technologies, and the devastating impacts of those technologies on people subjected to them. Even before leaving Europe, Colonel Jones became a founding member of the core of veterans who established the American Legion, as an aid to returning veterans and a source of support for what they had faced and what they would endure in the future. He was the first commander of George Washington Pioneer Post No. 1 of the American Legion and was instrumental in writing the by-laws of the Legion.

When Colonel Jones returned to Washington, he mustered out as a civilian once more eager to put the war behind him and to infuse the Survey with the new technologies and capabilities the war had highlighted as useful to its core missions. However, his first challenge was a crisis to some extent of his own devising. The Act that enabled Survey civilians to move directly into military service at their requisite rank as officers also increased their pay to that of military officers at that rank. When they returned, their pay would be cut back to the traditionally low pay rates that had characterized the Survey since the era of Hassler. Many men, including many of the best and most capable of

[23] Blake, 1914.

them, refused to return. As before, Jones identified this as a problem to be described clearly and then eliminated correctly. Pulling every Congressional string he could, he enabled a packet of legislation to address the problem. First, Congress passed a law raising Survey pay scales for officers in the Uniformed Corps to parity with their counterparts at the same rank in the military, a condition that prevails to the present[24]. He also initiated a law that brought more civilian personnel of the Survey under the new rules and standards for Civil Service in the federal government. This excluded himself, as he was a Captain in the Survey's commissioned service. Since the days of Hassler, the Superintendent of the Survey served with life tenure, or at least served with that capability. Under Jones' new rules, all that ended. The new post of Director was established, with a term of four years, with possible renewals by the President. So Jones was the last Superintendent, and the first Director, of the Coast and Geodetic Survey[25].

The Survey returned to action in 1919; Jones served for the next ten years. He was the Bache of the 20th century, and there were great changes and advances in every division of the Survey as summarized at the beginning of this chapter.

Many of these changes are critical enough to be explored in more detail. Three pertain to the three major divisions of the Survey: for the Geodesy Division, the first US Military Grid System, the North American Datum and the International Reference Ellipsoid; for the Division of Topography and Hydrography, Radio-Acoustic- Ranging and the introduction of aerial photography and photogrammetry; and for the Division of Terrestrial Magnetism, the rise of Seismology. In the Division of Charting, there would be two major developments, in printing technology and a new type of chart, that affected the entire functioning of the Survey and all of its products which continues to the present day. Under Jones, the Survey finally acquired offset lithography presses for chart production, and it acquired federal responsibilities for navigation charts for civilian aviation.

The First U.S. Military Grid System

The American military entered World War I several bloody years after the other combatants, and it quickly discovered that the military technologies of the European armies were far advanced by comparison. This led to many efforts to reduce the disparity between American and foreign military capabilities. The first major project that the civilian Survey attempted for the U.S. military in the immediate postwar era came out of the American experiences aiming cannons on the Western Front during the war.

Immediately prior to the war, the French Army developed the 75, a small, highly accurate cannon with a range beyond human visual range; this precluded aiming the cannon by "firing in" and using the visual sight of shell explosions to direct the aiming. In order to take advantage of the longer range, the French developed a series of "military grids" which were specialized maps in conformal projections that gunners could use to

[24] Joint Service Pay Act of 1920. 41 U.S. Stat. L., 812, 825, June 4, 1920.
[25] 41 U.S. Stat. L., 874, 929, June 5, 1920.

aim the cannon[26]. There was an evolving series of grid systems culminating in the Nord de Guerre (the North of War, reflecting the fact that most of the mapping system was north and east of French territory in Germany and the Low Countries). As members of the American Expeditionary Force, integrated with the British and French militaries, the Americans were exposed to the grid system and its applications.

While the war was still on, the staff of the U.S. Army Corps of Engineers asked specialists at the Coast and Geodetic Survey to assist them by designing a military grid system for the contiguous United States. William Bowie, the Survey's ranking geodesist, and the Survey's major geodetic computer/mathematician Oscar Adams were the leaders of the project. Bowie was commissioned a major in the Army and served in that capacity through the end of the war until February, 1919. Adams organized the formidable computations of the tables for the projection and was assisted by Army personnel of the 472nd Engineers who were assigned to the offices of the Survey for the project.[27]

The original conception of the project was the calculation of a grid system (in French, a quadrillage) for the eastern coast to aid the Army's Coast Artillery to aim and fire on enemy ships offshore. Eventually, the project expanded to develop a system of grids for the entire "lower 48 states", called progressive maps, as they progress to the west across the country. Because of the problems created by the curvature of the earth and the difficulties in mapping curved space in a flat map, the system used a series of meridional zones, 9 degrees of longitude wide, each extending from latitude 28 north (central Florida) to 49 degrees 10 minutes north (just north of the main part of the US/Canadian border), along with specific extensions necessary to cover southern Florida and the southern tip of Texas, the Upper Peninsula of Michigan, and eastern Maine. For each zone, a polyconic projection was established and specific points along the boundaries of each zone were calculated and interpolated.[28]

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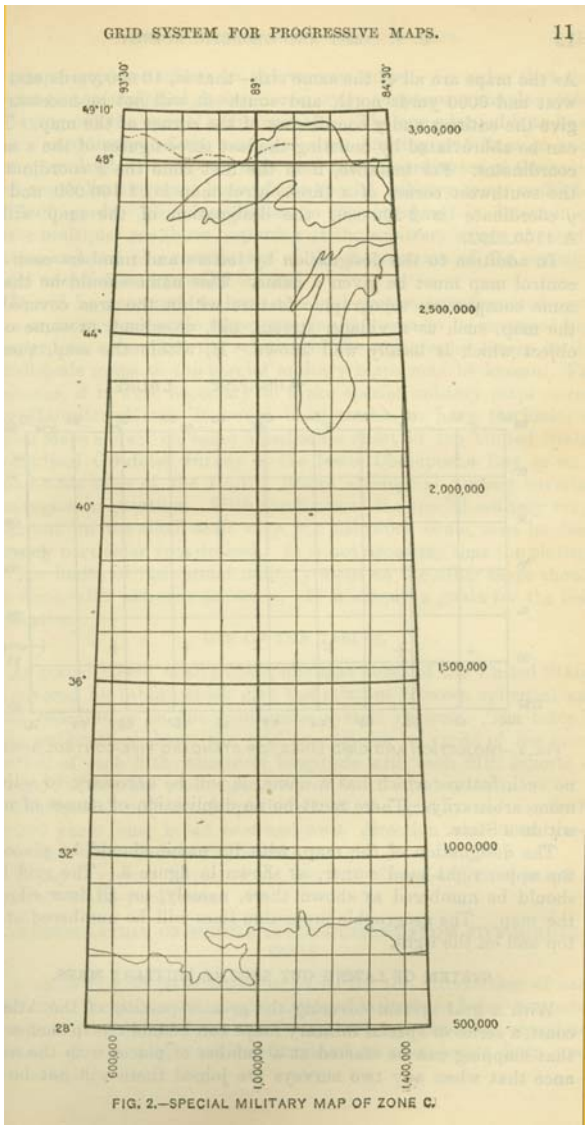
[26] "Conformal" maps preserve the same angular relationships between lines on the earth and those on the map, so that, for example, on the map and on the earth, lines of latitude and longitude always cross at right angles.

[27] Preface, Bowie and Adams (1919).

[28] The polyconic projection was invented by the Survey's founder, Ferdinand Hassler. Full description of it is beyond the scope of this history, but it suffices to say that for relatively small areas of the earth, within the ranges of artillery, the projection has minimal distortion of a nature that would affect aiming. See Adams (1919) and Deetz and Adams (1928) for details.



Zone 6, Special Military Map

It is unclear how much use the military grid system received by the U.S. Army, as it was finished essentially when the war ended. However, it was the first of two military grid systems that the Survey developed for the U.S. military, the other being the World Military Grid that the Survey devised on the eve of the Second World War with computational assistance from the Mathematical Tables Project of the WPA. And the original grid system was also an element of the beginnings of closer collaboration between the mapping agencies of the U.S. government, civilian and military, organized in 1919 into the Board of Surveys and Maps.[29] This new union reflected many developments, but one important driver was the idea, espoused by the Survey, to base all American (and North American) surveys and maps on the same datum, a development

[29] See The Military Engineer (1920)

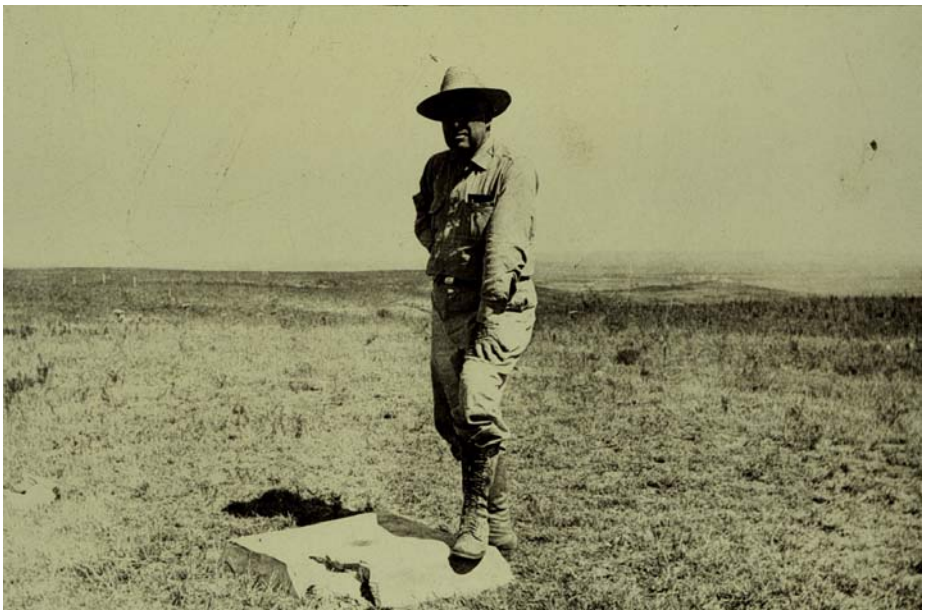
with enormous consequences for the subsequent history of the United States and the world.

Geodesy, Meades Ranch, Kansas, and the World—and Isostasy

As was noted in the chapters on Superintendents Pritchett and Tittmann, Jones the non-scientist became director of one of the most acclaimed scientific agencies in the world, and probably the division of the Survey with the greatest international stature was that of geodesy. John Hayford's position as chief geodesist was being complemented, rather than threatened, by the rise of William Bowie and their research on isostasy described below. Hayford had, among other matters, developed a reference ellipsoid (named for him) that was, during Jones' tenure, adopted by the International Union of Geodesy and Geophysics (IUGG) in 1924 as a proposed international standard. The details of the ellipsoid are beyond the scope of this history, except for the flattening, which is essentially the fractional departure of the ellipsoid from a round spheroid. In the Hayford case, his flattening was 1/297. Subsequent research has indicated, repeatedly, that his flattening was too great—modern ellipsoids converge around 1/298 as the fractional flattening[30].

In the same era, Hayford, Bowie, et al. also finished a continental datum, the North American Datum (NAD), which was the successor to the United States datum of Pritchett's era. As the Survey had persuaded Mexico and Canada to join in a common datum, the new datum was renamed for the continent. This datum, ultimately NAD 27, was defined by a different reference ellipsoid, the Clarke Ellipsoid of 1866, as tangent to a point on the ground on Meades Ranch, Kansas. The ellipsoid had a flattening of 1/294.98, hence almost 1/295. Why did the Survey, including Hayford and Bowie, adopt datum values different than Hayford's own? The Hayford ellipsoid was a match for the world as a whole, proposed as a common global datum. NAD 27, however, was a datum designed to optimize "fit" to the continent of North America alone.

[30] In the ancient science of geodesy, the Earth is approximated by a conceptual model, called the ellipsoid of revolution. The ellipsoid has an estimated radius for the Equator, called the semi-major axis (a), and an estimated radius for the great circle going through both the North and South Poles, called the semi-minor axis (b). The Earth's flattening (f) is defined as the difference between the semi-major axis (a) and the semi-minor axis (a-b) divided by the semi-major axis (a), hence f = (a-b)/(a).



Geodesist standing at the datum, Meades Ranch, Kansas (undated)

Bowie was at the height of his influence and stature in the field of geophysics during the Jones era. This meant, in effect, that Bowie's assertion of a state of global isostasy based on the Pratt model held sway with many, but not all, influential geodesists in the discipline. See the Tittmann chapter for much more on isostasy, but, succinctly: the Pratt model proposed that continental blocks of material extended to great depths and that they floated in the lower substrate with their bottoms at about the same level, the depth of compensation. The Pratt model was conducive to explaining the possibilities and constraints on vertical movement of continents, especially their edges, but silent on the possibility and mechanisms for horizontal movement which was at the heart of the great debate on continental movements popularly associated with Alfred Wegener[31]. That the Pratt model was espoused by Bowie was not surprising as he opposed the concept of continental drift. The Survey, under his direction, attempted to detect any relative movements between the continents of North America and Eurasia by "tightening" the determination of longitude differences between points on the edges of each continent, using radio time signals. This, then, was the great extension of Survey methods going back to the era of Bache and "the American Method" of telegraphic longitude in the 1850s. At that time, it was believed by participants in the great debate that continents moved, if they moved at all, at something like 50 feet a year which was based on the distance across ocean basins and a general sense of the earth's age that was much shorter than present conceptions. The greatest accuracies obtainable with radio wave longitude (and latitude) determinations were on the order of 10 feet in accuracy. Since these determinations did not reveal movement over time—because actual rates of continental movement are orders of magnitude smaller than 10 feet a year—then Bowie and others concluded that the geodetic evidence argued against drift[32].

[31] See Oreskes, 1999, for a definitive treatment of these matters.
[32] See especially Bowie, in American Association of Petroleum Geologists 1928,

At the same time, as will be seen ahead in the section on the Survey and the invention of Radio Acoustic Ranging, the Survey was to pioneer vast and accurate hydrographic surveys out to the edge of the continental shelves and down continental slopes, revealing new details and greater resolution of many submarine canyons and other features on the margins of the continents including seamounts and trenches. The canyons were to prove evocative and very difficult of explanation. These accumulating anomalous earth features, not easily interpreted by the standard models of geophysics, would contribute ultimately to major re-evaluations of the processes that had shaped the Earth, most famously in the so-called "paradigm shift" labeled plate tectonics[33]. As a part of that shift, the great majority of geophysicists would eventually abandon Bowie's major theses, although that would be decades in the future after Jones' time.

Terrestrial Magnetism and Seismology

As we have seen, Pritchett established the "modern" division of terrestrial magnetism and a set of national magnetic observatories, some of them permanent standard observatories, and others that were operated for a series of years in a given locale and then were shifted elsewhere once the basic magnetic regime and the rates of secular change in magnetic declination or deviation were established. These observatories, from the beginning, included seismological equipment as a component of the "variation of the needle" could well be earth tremors experienced by the instruments, rather than magnetic storms or other temporary disturbances in the earth's magnetic field. The Survey's seismological instruments at magnetic observatories registered the great San Andreas or San Francisco earthquake of 1906, which became a source of data for intensive analysis of the earthquake itself. Further, the Survey re-surveyed triangulation points in the California geodetic network post-earthquake to detect and measure earth movements geodetically. These side applications of the seismological instruments and the use of the very geodetic network itself as, in effect, an earthquake detector, plunged the Survey into whole new realms of the earth sciences.

[33] The term was introduced by Thomas Kuhn (1962) along with several dozen disparate definitions or uses of the term! The standard history of the initial phases of Wegener's receptions is Oreskes (1999).

Survey observer with magnetometer, Sitka Observatory, 1929

Jones once again saw an opportunity to advance and expand the work of the Survey. In his postwar Director's annual reports, the opening sections on "What the Survey Needs" began to include much more material on the dire necessity to the Survey to acquire responsibility, funding and instruments appropriate to the seismological hazards of the tectonically active parts of the United States, especially in the western states. These hazards included the societal impact of earthquakes, in general, but also the specific damage to structures and facilities associated with earthquakes. He advocated for the Survey to receive the wherewithal it needed to address matters appropriately[34].

Jones' entreaties worked. In 1925, the Coast and Geodetic Survey acquired, from the Weather Bureau in the Department of Agriculture, the primary responsibility for seismology in the federal government. Under the Department of Agriculture, most of the seismological work was observational only with little analysis of the data. This changed completely under Jones. The Division of Terrestrial Magnetism was renamed Terrestrial Magnetism and Seismology, and the Survey, and later ESSA and then NOAA, maintained the lead in various aspects of seismological research for almost the next half century. Jones picked Nicholas Heck, first introduced in the Tittmann chapter as the chief developer within the Survey of wire drag for hydrographic surveying, to be the head of the combined division. His research on the seismic activity of ocean basins would

[34] Jones, 1925.

eventually, by the time of the Patton directorship, yield geophysical evidence that several decades later substantially undermined Bowie's primary assertions about isostasy and the mechanisms of continental movement.

The Changing Practices of Topography and Hydrography

Probably the greatest immediate impact of Jones on the activities of the Survey occurred in the Division of Hydrography and Topography. As always, he proceeded by identifying terrible problems and unmet needs, such that major expansions in charting of American waters were vitally necessary, particularly on the Pacific Coast and most especially in Alaskan waters.[35] He also carefully explained the processes of mapping and the nature and symbols of nautical charts, one suspects for a Congressional audience more than anything else.[36] As usual, it worked. Based on the connections he and the Survey had made by their war service, he arranged for the Survey to acquire four ships from the Navy which were re-furbished for hydrographic and oceanographic work. The largest ships were renamed the *Pioneer*, the *Guide*, and the *Discoverer*, and a converted motor yacht, donated to the Navy by the Lydon family for the war, which was named the *Lydonia*.

E. Lester Jones and his wife Virginia aboard the *Lydonia*, 1926

Surveying from the Air

Jones pioneered the application of aerial photography and photogrammetry to topography in the Survey. In this, he continued as the A.D. Bache of the 20th century. By this is meant that, more than introducing a new technology, he integrated that technology thoroughly in the working structure of the organization. Over a half century

[35] See Jones (1916, 1917, 1918, 1923, 1927)
[36] And Jones (1922)

earlier than Jones, Bache had prepared the way for photography, in numerous applications, to be introduced into the Coast Survey. As Bache noted near the culmination of the enterprise, on the eve of the Civil War: "But above and before all other reasons, photography was to be introduced as a regular part of office detail, and great changes were necessarily consequent. I determined therefore to have a thorough revision of the whole system".[37] Photography under Bache began in the offices of the Survey, and thoroughly transformed the technologies and services of the office.

By the late 19th century, photography went to the field, in part for personal and official documentation of field work, notable and unusual events, and so on. In the 1890s, photography in the field was used analytically, beginning with techniques adopted from British surveyors with whom the Coast and Geodetic Survey worked collaboratively in the re-survey of different parts of the border between Alaska and the western provinces and territory of Canada. Here, stereo-pairs of photographs were used to characterize and map the topography of rugged mountains and glacial valleys[38].

Under Jones, photography went into the air. A part of Jones' "important and highly confidential" work on the western front in World War I had involved the application of aerial photography to daily assessments of the battlefield. Within a year of the return of Jones and the other Survey officers and men who had served overseas, Jones had developed a program for aerial photography experimentation between the Survey and the military Air Services of the Army and Navy, as they possessed the planes and cameras. Echoing Bache, Jones noted:

> "The surveying done by the Bureau differs to a greater or less degree from surveying carried on by other organizations in this country, and this has necessitated the development of special methods and equipment to suit our special needs...A study is made of all inventions, discoveries, and improvements that give promise of usefulness in surveying. Thus it was that the development of aerial photography was a subject of interest to members of the Coast and Geodetic Survey before the World War, an interest that was intensified by the rapid strides made by aeronautics during the war. As soon as possible following the Armistice arrangements were made with the Air Services of the Army and Navy to carry on cooperative experiments in aerial mapping..."[39]

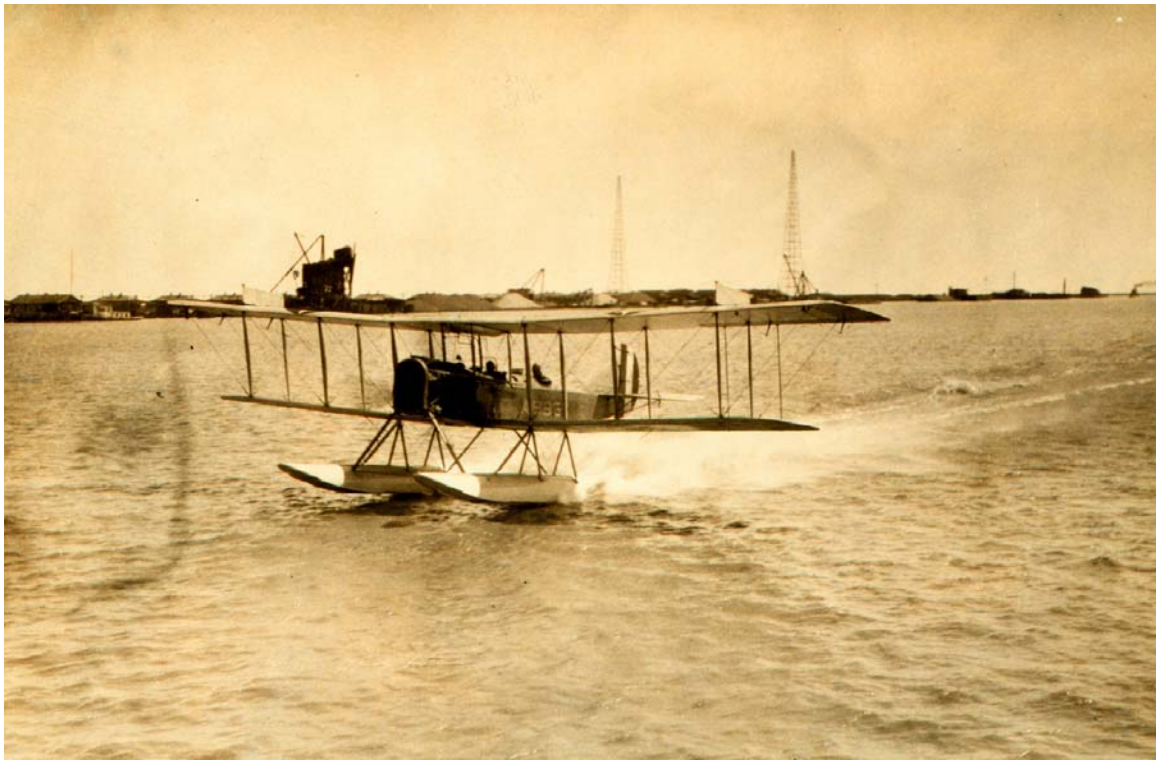
The initial applications of aerial photography were made in environments that were basically flat as topographic relief imposed distortions in the photography that were problematic. The first trial project was photographing the shore of Atlantic City, New Jersey, in June and July of 1919. Initially, mosaics of photographs were assembled from which rectified and re-scaled maps were created. Following these, there were field inspections using the photographs paired with establishing or re-occupying suitable

[37] Bache, 1860, pp. 18-19.
[38] See Flemer (1893, 1897).
[39] Jones, 1922, p. 461.

control points. Then, the final accurate compilation of the data was made, the revised map plates were finished, and the maps printed.[40]

The next experiment was aerial photography of underwater features, taken by the Navy Air Service in the clear and shallow waters off Key West, Florida, in July, 1919. This application developed directly from war experiences, in which submarines not seen from surface ships were successfully photographed from airplanes. In Florida waters, the objective was to test whether aerial photography could be used to replace wire drag to detect and map underwater coral formations, but the results were disappointing.

In 1920, the Survey scaled up in two much larger applications of aerial photography: with assistance from the Army Air Service, the entire coast of New Jersey was photographed, as well as the Mississippi River delta in Louisiana. The latter application was quite successful, as photography from above had capabilities beyond anything that could be accomplished down in the waters and willows of the swamps and bayous. "The aerial survey discovered scores of lakes unknown before. The advantages of the aerial method over the ground method in this type of survey are very evident even to the casual observer"[41].



Navy Air Service Float Plane with Survey camera system, Mississippi River delta, 1921

[40] Ibid, pp. 479-480.
[41] Ibid, p. 482.

Early in the applications of aerial photography, the Survey anticipated they needed no planes as they would acquire all the photography they needed through the military air corps. This later changed, and in the era of Patton and beyond, the Survey ended up devising its own unique multi-lens camera systems. But from the beginning, aerial photography affected the throughput of Survey work as thoroughly as photography did in Bache's day. T-sheets rapidly turned into rectified and rescaled maps devised from aerial photography with much less field work than in the pre-airplane era. As Jones noted, this meant that there was much better delineation of difficult to map natural features, like lakes in a marsh. At the same time, there was an erosion of cultural features on the T-sheets, particularly place names, because the field crews spent much less time traveling on the ground.

Sound in the Water and Positioning

As we have seen, while Fessenden tried to reflect sound horizontally off icebergs, he also discovered that sound in the water could reflect off the bottom and could thereby reveal ocean depths. These discoveries took place immediately before the Great War, and so ocean acoustics developed quickly as an arena of warfare technology. These developments had a deep impact on members of the Survey, in all their disparate participations in the war effort. For some, ocean acoustics became a matter of survival, as they navigated ship convoys through submarine-threatened waters. For the Survey scientists who stayed stateside, ocean acoustics became a major focus of research they participated in as part of Army and Navy research projects and laboratories. The Navy's preoccupation with ocean acoustics is understandable, but less so that of the Army. In that era, the Navy projected power outside the United States' waters, while the Army Coast Artillery staffed coastal forts fortified with enormous gun batteries that were essentially land-based battleships which would be primary defenses against attack or invasion from the sea. As a result, both the Army and the Navy and the Survey were occupied with establishing positions, distances, and depths in coastal waters, particularly through the use of these new and novel capabilities in ocean acoustics.

Many innovations in hydrographic surveying were made in this era, but the most important of these was the story of the Survey and its allied agencies and other cooperating scientists, and the invention of Radio Acoustic Ranging (RAR).

The Invention and Early Development of Radio Acoustic Ranging

Hydrography is based on establishing a water depth associated with a specific horizontal position on the surface of the water directly above the water depth. The basic technologies and systems to do this were formalized for the Survey by Ferdinand Hassler and his assistants, and had really not changed very much in the century that followed. Horizontal positioning was established by the geometrical establishment of a three-point fix, utilizing sextants to observe towers, flags, or other signals located on the shore or on fixed buoys and other sites that were positioned into the land-based geodetic network or locally established datum. The limits on the system's capabilities were line of sight constraints, including obstructions, weather effects such as fog and rain, and ultimately

the curvature of the earth. Establishing depths depended on lowering a weighted line to the bottom on a line or wire of known length, and was constrained by the myriad inaccuracies that increased with increasing depth, water currents, etc.

The Survey decided to explore the new developments in ocean acoustics as applied to hydrography. As noted, the two principal elements of hydrography were quite different although they are accomplished simultaneously: horizontal positioning, and vertical water depth. The earliest applications of ocean acoustics, pre-war, were attempts to establish horizontal positioning of ships as aids to navigation, using underwater bells mounted on or adjacent to lighthouses and buoys marking dangers. The pioneer enterprise in this was the Submarine Signal Corporation, now a part of Raytheon Corporation. Submarine Signal proposed "to surround the coast with a wall of sound so that no ship can get into dangerous waters without warning, to make collisions between ships possible only through negligence."[42] As mentioned earlier, Reginald Fessenden joined the company and introduced a cascade of new acoustic technologies and applications, many of which were used in the Great War, particularly for anti-submarine warfare.

Among the many Survey scientists who served in various capacities in the war was Nicholas Heck, introduced earlier for his work developing and perfecting wire-drag for hydrography in shallow waters and waters with unseen hazards. During the war, he served in the US Navy in American waters and off the British coast, working with British and American research groups on methods to detect submerged submarines. There were many aspects to the research, but a major part was trying to determine the complex question of velocity of sound in seawater[43]. Sound velocity changes with temperature, and also salinity and pressure, and possibly other matters. How the ocean is structured, relative to these variables is at the very heart of oceanography, and so it came to be that Survey research under Heck, devoted to very specific and well-structured traditional hydrographic activities of the Survey, brought the Survey scientists into the forefront of basic discoveries in oceanography.

What became Radio-Acoustic-Ranging (RAR) started out from work on a very limited and specific objective. Heck, a pioneer in many types of geophysics applications in the Survey, wanted to obtain an acoustic vertical depth finder, called the Sonic Range Finder, originally developed by the Navy for the task of measuring depths acoustically instead of by line or wire. Heck had attended the annual meeting of the American Association for the Advancement of Science (AAAS) in Boston in 1922, where he heard a presentation by War Department physicist E. B. Stephenson on the subject of "Variation of the Velocity of Sound in Sea Water with Temperature".[44] Heck wrote to Stephenson stating that the Survey proposed to use the Navy's "sonic range finder" for measuring water depth, but that "so far as can be learned the Navy has not yet made tests to determine the variation in the velocity of sound in sea water. As our vessels are especially equipped to take deep water soundings by direct measurement and to

[42] Blake, R. F. (1914).
[43] Proceedings, GSA (1954) and The Buzzard (1954).
[44] Heck to Stephenson (Jan. 4, 1923) in Correspondence between N.H. Heck and Stephenson.

determine temperature at various depths, it is believed that we will be able to contribute a great deal to the problem of getting absolute measurements by this method. The outstanding problem is the variation in the velocity of sound in sea water".[45]

Several weeks later, Stephenson replied from his post at the Subaqueous Sound Ranging Section of the US Army Coast Artillery Corps at Fort Wright, New York, on Long Island Sound. He provided Heck information about his own research into the velocity of sound in sea water, but he also made another offer, one with far-reaching implications for the Survey and the very history of oceanography. Heck wanted acoustics technology to establish vertical depth, but Stephenson had another idea: "I am very glad to note you propose to use the Sonic Range Finder… There is a possible application of our apparatus and method to your work…namely, the accurate location of the position of your ship at any time and any place within 50 miles of our stations…*To determine the position of your ship it would merely be necessary to drop a small bomb over board*…"[46](Emphasis added)

Stephenson proposed using a new system the Army had been working on, appropriate for determining on shore at a coastal artillery battery the position of a vessel in the water by using hydrophones placed offshore in known locations, based on the differences in time between the reception of the sound of an explosion (the small bomb) set off next to a vessel as received by the various hydrophones. The time delay would yield, just as in the case with artillery sound ranging, families of hyperbolic curves. With data from three or more hydrophones, it would be possible to estimate graphically the position of the vessel when the bomb was exploded. The vessel in the water could be an ally ship deliberately exploding the bomb, or it could be an enemy ship or submarine spotted and targeted by an aircraft. In all cases the data came to shore facilities at which the vessel's position was derived.

Heck replied two days later. "In the third paragraph of your letter of January 15th, you mention very interesting results in the determination of the accurate location of a ship. We are even more deeply interested in this problem than in the use of the sonic range finder, for the reason that we find it difficult to maintain the desired standard of accuracy. This is especially true in the location of off-shore ends of sounding lines. Our vessels are also obligated to stop work during a fog. I am especially interested in knowing whether the method being developed at Fort Wright has possibilities for use on the Pacific Coast; whether the apparatus could be temporarily installed at an isolated station; whether it is entirely or only in part a military secret, and if the latter, whether substitutions could be made to adopt it for the use of this Bureau"[47].

Both Heck and Stephenson went up their chains of command to request permission to proceed, and to pull in such other specialists as would be needed to adopt and test the Army's new idea. A formal request to the Army was sent by the Survey

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[45] Heck (ibid)
[46] Stephenson (Jan.15, 1923) in Correspondence between N.H. Heck and Stephenson.

[47] Heck to Stephenson (Jan, 17, 1923) in Correspondence between N.H. Heck and Stephenson.

Assistant R.L. Faris, in his periodic capacity as Acting Director of the Survey (due to the episodic disabilities brought on by Director Jones' war injuries). As was characteristic of modern scientific developments, a complex array of specialists and institutions were eventually enlisted for the enterprise. The principal leaders and scientists were Heck and Stephenson, Colonel R. S. Abernethy, the commander of the Sub-Aqueous Sound Ranging Section of the Coast Artillery Corps, the physicist Dr. E.A. Eckhardt of the US Bureau of Standards, who was an authority on radio technology, and the Survey Corps member Jerry H. Service, who organized the Survey's research under Heck's general guidance[48].

A full description of how Radio-Acoustic-Ranging was developed is beyond the scope of this history, but it suffices to say two things: the Survey "turned around" the Army's concept of the system completely, and they developed a plan to work systematically on all elements of the technology at once, allowing incremental progress to be made constantly, so what became known as RAR evolved considerably over time. The Survey "turned around" the Army concept, because for hydrographic surveys, they wanted the data to accumulate and be assimilated *on the ship in the water*, not on shore. This meant, among other matters, that the hydrophone systems on the edge of the shore or mounted under buoys had to be connected to semi-automatic or automatic radio signaling systems, which could signal back in near-real time when the sound of the explosion of the bomb was received at the hydrophone. Further, given that, at 0 degrees Centigrade, the velocity of sound in seawater is approximately 1454 meters/second, and the Survey wanted horizontal positional accuracies of around +/- 10 meters, the system would require distinguishing radio signal timings in centiseconds if not milliseconds, far beyond human capabilities. Therefore, a major degree of system automation and electronics development was demanded in order to accumulate and process the data on the boat. That also meant the bombs would be exploded close to the ship. This was one part of the system that was definitely designated for human management. Later in 1923, Heck wrote to Director Jones, specifically lauding Colonel Abernethy because "[h]e has placed a non-commissioned officer of long experience aboard to direct the bomb firing work, an assistance that was of great importance because of the lack of familiarity of most of our personnel with this kind of work, and the danger of doing such work without such skilled advice".[49]

[48] In 1945, Captain Heck organized his original correspondence to and from these men during 1923-24 and had it incorporated in the Survey's Library and Archives Collection, and it is supposed that this reflects Heck's judgment of the principal players in the development of Radio-Acoustic-Ranging. There were many other specialists, many more being listed in the Survey's Special Publication No. 107.
[49] Heck to Jones (Oct. 23, 1923 in Correspondence between N.H. Heck and Col. Abernethy.

Timing the Fuse before throwing the RAR bomb

Fully developed RAR was a system in which the hydrographic survey ship established its horizontal position by exploding a bomb off the vessel, while simultaneously recording the time of the explosion with a chronograph. Sound traveled through the water to the hydrophones, and automatic equipment radioed back to the ship at the instant the sound was detected. The time between the explosion and the detection at the hydrophone could yield the distance the sound traveled in the water. Specialized chart frames and protractors were then used to plot the hydrophone locations and then the ship's position.

Initial development work was made at the Army's "laboratory" in the shallow waters of Long Island Sound, using the Army's network of shore and island based receiving stations. But from the beginning, the Survey hoped to adapt the system to use in the very different, much deeper waters of the Pacific coast. There, starting in 1924, the Survey ship *Guide*, under the command of Commander R. F. Luce, made considerable improvements in the system. Within a year or two, off the Oregon coast, the *Guide* was able to accurately determine its position well over 150 nautical miles offshore, an unparalleled feat in human navigation and geodesy. The Survey, and its partners, had developed the first precise positioning system in human history that was completely uncoupled from any type of visual observation.

The key to RAR's working was, of course, that complicated matter of the nature of the velocity of sound in sea water. Experience in the field quickly demonstrated that

the path of sound in sea water was complex. As Heck noted years after the initial system was developed: "There was one great surprise in the results. All of those who discussed the project in its early stages questioned whether radio acoustic work would be successful on the northwest Pacific Coast of the United States on account of heavy surf noise interfering with the signals and the difficulties of installing shore stations and cables, while it was taken for granted that no difficulty would be encountered on the Atlantic Coast. The exact opposite proved the case and it is only recently in the course of the Georges Bank work that use under Atlantic Coast conditions has proven practicable".[50]

Resolving those counter-intuitive field results in Atlantic and Pacific waters required much further research, past the end of Jones' directorship of the Survey. Hence, how the problems were solved will be disclosed in the Patton chapter. Suffice to say that, in resolving the velocity and sound path of sound in sea water, the Survey stumbled upon, and correctly theorized one of the greatest discoveries of 20th century oceanography—the deep sound channel of the ocean.

E. Lester Jones and Offset Lithography

Jones was a capable and intelligent man, but not a scientist. He managed scientists ably instead. He did have great experience in printing and publishing, based on his years working for his father's printing press operations. As noted, one of his first actions when he became Superintendent of the Bureau in 1915 was to keep the three major scientific divisions devised by Superintendent Pritchett: Geodesy, Topography and Hydrography, and Terrestrial Magnetism, but combine the three separate charting and mapping sub-divisions into one integral Printing Division which answered directly to Jones. Then, over a period of years, he introduced an entirely new system for map production in the Survey, using presses built by one American company. His innovations were successful enough that the same system—and the same presses from the same company—are still used by NOAA for chart production in the 21st century.

On the eve of Jones' tenure in the Survey, there were two methods of printing maps and charts in use. The first method was direct engraving, using an intaglio press purchased new in 1851 and still in use in 1915. (That press was the first and only intaglio press the Survey ever possessed—it is presently on display in the NOAA Science Center, in Building SSMC-4, in Silver Spring, Maryland). The press utilized copper electrotype plates and, towards the time Jones entered the Survey, aluminum plates as well. The Survey also possessed several lithographic transfer presses, which were used to transfer print chart designs photo-mechanically to the lithographic plate.

The Superintendent's Report for 1914 describes the status of printing technologies as they were on the eve of Jones' entry, and a hint at the future.

"In the engraving section, besides the new charts on scales of 1:400,000 and 1:200,000 which are being engraved, the 1:80,000 charts of the coast of Maine will be

[50] Heck (1932).

engraved. The greater number of ledges and details along this coast are best represented by the sharper prints from an engraved copper plate.

"In order to make an advance both in quality of prints and in rapidity of printing, new offset presses are needed in the printing section.

"The 'direct process,' by which a photoprint is made on a sensitized aluminum plate from the chart drawing, replacing the glass negatives and prints on transfer paper, promises to be the sole method employed in the future. To carry on this method conveniently, a pneumatic printing frame should be provided, and to be independent of the sun an additional open arc electric lamp will be required".[51]

As soon as Jones entered the Survey, he re-ordered the annual report, beginning the volume with a section called "Needs of the Survey". What follows is his section on "Better Facilities for Printing Charts" from the 1915 report, in its entirety. In this section, Jones laid out the rationale for re-organizing the method of printing nautical charts to offset lithography, the method in use to the present day, 90 years later.

"By far the larger part of the results of our surveys reaches the navigator and the engineer in the form of charts. Every effort should be made to have this final product to be of an excellence commensurate with the large amounts of time and money spent in collecting and arranging the material the chart shows in a condensed form. The final stage in producing the chart is its printing, and the best press adapted to the work should be employed in order to maintain this branch of the work to the highest standard, and a sufficient number should be provided to render it possible to meet urgent demands properly.

"Each copy of a chart is run through the press from two to five times, the average being three times. First, for the black plate; second, the buoy plate, by which the buoys are colored; third, the tint plate, by which the land areas are distinctly defined from the water areas; and on certain charts blue and yellow tints are also used.

"It is most important for the distinctness of the charts that the colors on the different plates should register or fit exactly in their assigned places. How close this register must be will be understood when it is stated that the outline of the symbol which represents a buoy is only one-twentieth of an inch in width. Within this outline the red color must fit.

"Faulty register is produced by the expansion or contraction of the chart paper during the intervals between the printings of the three plates.

"To obviate this lack of register and to assure the same conditions for the three runs, the second and third runs should follow the first as closely as possible, all three being completed in one day. With a single press this rapid sequence in printing is

[51] Tittmann, O. H., 1914.Annual Report of the Superintendent, US Coast & Geodetic Survey, to the Secretary of Commerce, for the Fiscal Year ending June 30, 1914. p. 120.

impracticable, due to the amount of unproductive work it involves. This consists in the necessary cleaning up of the press after the run of the black plate to prepare it for the red buoy color, and a second clean-up after the run of the buoy plate to prepare the press for the run of the tint color. Each of these clean-ups consumes at least an hour's time of additional unproductive work from this source alone.

"It therefore becomes necessary to run a number of different charts through the press for one color before it is changed for another color.

"Our press is the flat-bed type, which is being rapidly replaced by the rotary offset press in all large commercial lithographic establishments. The Hydrographic Office, United States Navy, has two of the latest type one-color offset presses which have proved highly satisfactory.

"A two-color offset press has now been perfected which can be run with the same force as a single-color press. By means of this type of press the two most important impressions, the black base and the buoy color, could be done at one printing.

"The offset press presents three distinct advantages for our chart work. First, sharper prints; second, the rapid drying character of the ink used permits the printing of the various colors in rapid succession; third, a reduction in the cost of paper, by omitting the high-surface finish of the paper required by the present process.

"It is therefore recommended that Congress be asked for one of these modern two-color offset presses".[52]

The lack of modern presses was only one of a myriad of problems the Survey faced in the printing of charts in Jones' estimation. The other major problems were the sub-standard salaries the Survey paid to its skilled workers, and the appallingly poor physical facilities of the press operation. The Survey's headquarters, then still on New Jersey Avenue near the Capitol, were built into a former mansion and former hotel next door which had been converted to the work of the Survey. In addition to descriptions of the poor facilities, Jones' 1917 report contained six full page photographs of the Survey's poor facilities.

In the end, it was the mobilization of the Survey for service in the First World War that provided the funds Jones insisted must be invested for optimum work by the Survey. The Survey's field scientists and officers were mobilized into service in the war, or in research stateside on war-related instruments and technologies. The charting operation of the Survey redoubled domestic chart production for the aid of mariners in submarine-infested waters, and also took on major responsibilities for production or re-production of military maps and charts for the AEF. Jones directed the mobilization, but also adroitly secured sufficient funding to change the printing plant completely.

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[52] Jones, E.L., 1915. Annual Report of the Superintendent, US Coast & Geodetic Survey, to the Secretary of Commerce, for the Fiscal Year ending June 30, 1915. p. 19-20.

Immediately after post-war mobilization, when Colonel Jones returned to civilian status as head of the Survey, his first post-war Annual Report recounts his success.

"…The emergency requirements of the war threw a great burden upon the Coast & Geodetic Survey. Demands were made on us for charts in unprecedented numbers by the Navy Department and the Shipping Board. .. On my presentation of these facts to you [Secretary of Commerce], you in turn brought them to the attention of the President, and under date of March 8 and June 17, 1918, he authorized allotment of… $105,000 for providing needed facilities for the work of preparing charts, military maps, and other special work for the Army and Navy by the erection of a suitable building for the purpose. On September 18, 1918, an additional allotment of $29,250 was made for the purpose of equipping the building. ..

"Another great improvement was the installation of a Harris offset automatic printing press, with a capacity of printing charts 34 by 48 inches at the rate of 3,500 per hour. This press, too, was purchased through an allotment of $14,000 made for the purpose by the President from the funds placed at his disposal by Congress for national security and defense during the war with Germany and Austria. At the time the allotment was made, the Bureau was largely engaged in the printing of navigational charts absolutely necessary for the use of the Army and Navy, and realizing the resulting disaster in case of a breakdown of one of our other presses the purchase of this other additional press was authorized".[53]

The Harris press installed in 1919, under the rationale of war-time emergency funding, was the first of a long series of Harris presses that continued to print Survey charts, then ESSA charts, and finally NOAA charts, to the present day.

The Transition from Nautical Charts to Aero-Nautical Charts

> "Therefore, while we are regretful that the Coast and Geodetic Survey is no longer in the Navy, we are looking forward to an achievement by this branch of the service which will add even more reputation to it than all its achievements of the past, because we are on the threshold of a period when the battles of the world will not be fought on the land or sea alone, but in the air, and I look to you gentlemen to chart the air as you have charted the ocean, so that when the airy navies grapple in the central blue, they will be able to miss the pockets and hit the enemy!"[54]

The postwar world was full of airplanes flown by pilots who needed maps. E. Lester Jones, while on leave from the Survey as Colonel Jones on the western front in World War One, had advocated the use of aerial photography for map-making and had also advocated the production of maps for aviators. Immediately post-war, aviation maps were produced exclusively by the Army and Navy until the Civil Aviation Act of 1926

[53] Jones, E.L., 1919. Annual Report of the Superintendent, US Coast & Geodetic Survey, to the Secretary of Commerce, for the Fiscal Year ending June 30, 1919. p.23. Extraneous sections removed for clarity.
[54] Secretary of the Navy Daniels, 1917, in Buzzard, 1947.

began the modern era of civilian flying. Under the Act, the Coast and Geodetic Survey was given responsibility for civilian aviation maps. For a century, the Survey had created nautical charts, so it now produced aero-nautical charts. The Survey's charts were widely sought after as being superior to all others, and the Survey's name for them—aeronautical charts—was adopted around the world[55].

The cartography associated with aviation evolved rapidly, with a high degree of collaboration in design and testing of the maps by aviators themselves[56]. By the 1920s, U.S. military aviation maps were primarily "strip maps", long narrow maps printed on thick paper, and often used in a scrolling apparatus that would allow small sections of the map to be revealed at a time which helped in the very cramped quarters of the cockpit. These strip maps were oriented along the major flight direction line between known destinations, whatever that direction was. When the Survey received responsibility for maps for civil aviation (the military retained responsibility for maps for their own pilots) it began producing strip maps, the first of which was for the flight line between Kansas City, Kansas, and Moline, Illinois. The strip maps were produced from 1926 until 1937, but by the middle 1930s they were being phased out.

Airway Map 137 A, the Columbia River Gorge, 1931

As airline routes and airplanes proliferated, many maps were necessary to display routes to and from a given airport. It was decided to adopt an entirely different system, using rectangular charts that would "tile" to fill the United States. A pilot then would carry the relevant maps covering the probable areas to be traveled over. The Survey created a new system of charts called "sectionals" as each chart covered a single section of the system. Because compass directions were so critical to airplane navigation, instead of using the Survey's non-conformal polyconic projection, the Survey used a system of maps based on the Lambert conformal projection which was the same projection system used by the French for their Norde de Guerre which was the inspiration for the Survey's Military Grid System. The development and use of the sectionals will be described in the Patton chapter, for, with the advent of the Survey's strip maps, the Jones' era came to a close.

[55] Ristik (1960) p. 62.
[56] See Ehrenberg, 2006.

E. Lester Jones, RIP

On April 9, 1929, after a last illness of several months, Jones died in Washington, DC. His obituary in the next day's Washington Post was titled "War Gas Victim". His exposure to poison gas on the battlefield in Europe, during his execution of "special and confidential duty among various military units" in 1918, impaired him to some degree or other the rest of his life. It also made him sympathetic to the travails and plight of other war veterans, although, as has been seen, this patrician administrator entered the Survey before the war with the primary goal of raising the status, salaries, and amenities of the men and women under him. Jones was a co-founder of the American Legion, and was the director of the first post of the Legion, in Washington. He had also been a trustee of the National Geographic Society, and had acquired the honors and responsibilities of a true leader, many of which were listed and lauded in the many memorials issued after his death.

But these paled in comparison to what he had thought his finest achievement, which became personified in the battle that his successor, Raymond Patton, and Jones' widow Virginia Jones had to wage after his death. Jones was buried in Arlington National Cemetery as Colonel Jones, based on his service in World War One. Patton and Mrs. Jones fought long and hard, and eventually successfully, to have Jones' gravestone changed to include, right below his name, the title that had been the most important to him in his life:

Director, U.S. Coast and Geodetic Survey

References

Adams, Oscar S., 1919. The General Theory of Polyconic Projections. Special Publication No. 57. Washington, D.C.: Government Printing Office.

American Association of Petroleum Geologists, 1928. Theory of Continental Drift: A symposium on the origin and movement of land masses both inter-continental and intra-continental, as proposed by Alfred Wegener. Tulsa, Oklahoma: American Association of Petroleum Geologists.

Bache, Alexander Dallas, 1860. "Rules for photographing, drawing, and engraving of maps and charts, etc."pp. 18-25. In Annual Report of the Superintendent for the year 1860. Washington, DC: Government Printing Office.

Blake, R. F., 1914. "Submarine Signaling: The Protection of Shipping by a Wall of Sound and Other Uses of the Submarine Telegraph Oscillator." Transactions of the American Institute of Electrical Engineers Vol. 32, Part 2: 1549-1561.

Bowie, William, 1917. Investigations of Gravity and Isostasy. Special Publication No. 40. Washington, D.C.: Government Printing Office.

Bowie, William and Oscar S. Adams, 1919. Grid System for Progressive Maps in the United States. Special Publication No. 59. Washington, D.C.: Government Printing Office.

Brown, Ashmun, 1915. "Dr. E. Lester Jones, Scientist, Heads Uncle Sam's Big Coast Survey". The Washington Star, May 2, 1915.

Buzzard, The, 1954. Obituary of Captain Nicholas H. Heck. January 5, 1954. Washington DC: The US Coast and Geodetic Survey.

Corey, Herbert, 1924. "Friend of the Under Dog". *Collier's, The National Weekly* (October 18): p. 26.

Correspondence between Capt. N.H. Heck and Colonel R. S. Abernethy Coast Artillery Corps, 1923. Rare Book Room, NOAA Central Library. QC242.H4 1923.

Correspondence between Capt. N.H. Heck and E.B. Stephenson, War Dept., 1923. Rare Book Room, NOAA Central Library. QC242.H4 1923.

Daniels, Josephus, 1917. Quoted in the US C & GS personnel journal *The Buzzard*, August 21, 1947.

Deetz, Charles H. and Oscar S. Adams, 1928. Elements of Map Projection with Applications to Map and Chart Construction. Special Publication No. 68. Washington, D.C.: Government Printing Office.

Ehrenberg, Ralph, 2006. "'Up in the air in more ways than one': the Emergence of Aviation cartography in the United States," in James Akerman (ed), Cartographies of Travel and Navigation. Chicago: University of Chicago Press.

Evermann, Barton Warren, 1916. President Wilson's Scientific Appointments. *Science* Vol. 44, No. 1133 (Sept. 15): 385-387.

Faris, R.L., 1929. Memoir of E. Lester Jones. American Society of Civil Engineers.

Flemer, John A., 1893. "Phototopography as practiced in Italy under the auspices of the Royal Military Geographical Institute, and as practiced in Canada under the auspices of the Department of the Interior. Also a short historical review of other photographic surveys and publications on the subject". Appendix No. 3, Annual Report of the Superintendent for the year 1893. Washington DC: Government Printing Office: 37-116.

Flemer, John A., 1897. "Photo-topographic methods and instruments". Appendix No. 10, Annual Report of the Superintendent for the year 1897. Washington DC: Government Printing Office: 619-736.

Gislason, Eric, 2006. A Brief History of Alaska, 1867-1959. Posted at: http://xroads.virginia.edu/~cap/BARTLETT/49state.html

Heck, N. H., and E. A. Eckhardt and M. Keiser, 1924. Radio Acoustic Method of Position Finding in Hydrographic Surveys. US Coast and Geodetic Survey. Special Publication No. 107. Washington DC: Government Printing Office.

Heck, N.H., 1932. "The Start of the Acoustic Work of the Coast and Geodetic Survey". In: United States Coast and Geodetic Survey Association of Field Engineers Bulletin, No. 5 (June).

Jones, E. Lester, 1915. *Report of Alaska Investigations in 1914***.** Washington, D.C.: Government Printing Office.

Jones, E. Lester, 1916. Military and Naval Service of the United States Coast Survey in the Civil War. Special Publication No. 37. Washington DC: Government Printing Office.

Jones, E. Lester, 1916. Elements of Chart Making. Special Publication No. 38. Washington, D.C.: Government Printing Office.

Jones, E. Lester, 1917. Use of mean sea level as the datum for elevations. Special Publication No. 41. Washington, D.C.: Government Printing Office.

Jones, E. Lester, 1918. Safeguard the gateways of Alaska: her waterways. Special Publication No. 50. Washington, D.C.: Government Printing Office.

Jones, E. Lester, 1918. The neglected waters of the Pacific Coast: Washington, Oregon, and California. Special Publication No. 48. Washington, D.C.: Government Printing Office.

Jones, E. Lester, 1922. Surveying from the air. Philadelphia, Pa: Press of J.B. Lippincott Co. Reprinted from: Journal of the Franklin Institute, 1922: 461-490.

Jones, E. Lester, 1923. The Evolution of the Nautical Chart. Washington, D.C.: Government Printing Office.

Jones, E. Lester, 1925. Earthquake investigation in the United States. Washington, D.C.: Government Printing Office.

Jones, E. Lester, 1926. Tide and current investigations of the Coast and Geodetic Survey. Washington, D.C.: Government Printing Office.

Kuhn, Thomas S., 1962. The Structure of Scientific Revolutions. Chicago: University of Chicago Press.

Macmahon , Arthur W., 1926. "Selection and Tenure of Bureau Chiefs in the National Administration of the United States II." *American Political Science Review*. Vol. 20, No. 4 (November): pp. 770-811.

Military Engineer, 1920. The Board of Surveys and Maps. Vol. 12, p. 62. Washington, DC: Government Printing Office.

Naske, Claus-M. *A History of Alaska Statehood*. New York: University Press of America, 1985. p. 34.

National Cyclopedia of American Biography, 1933. Entry for E[rnest] Lester Jones.

Oreskes, Naomi, 1999. The Rejection of Continental Drift: Theory and Method in American Earth Science. Oxford: Oxford University Press.

Proceedings, Volume of the Geological Society of America Annual Report for 1954. Pp. 111-118, Plate 8. July, 1955.

Princeton University, 2006. Honorary Degree Recipients, 1748-2006. Ernest Lester Jones, A.M. 1919.

Scientific Monthly, 1916. The Progress of Science: Scientific Appointments under the Government. [Editorial] Vol. 3, No. 3 (August): 308-309.

Ristow, Walter W., 1960. Aviation Cartography: a historico-bibliographic study of aeronautical charts. Washington, DC: Library of Congress, Map Division.

Trueblood, Edward A., 1919. *Observations* of *an American Soldier During His Service with the AEF in France in the Flash Ranging Service.* Sacramento, Calif.: News Publishing, 1919.

US Coast and Geodetic Survey, 1916. Banquet in commemoration of the one hundredth anniversary of the organization of the United States Coast and Geodetic Survey, Thursday evening, April 6th 1916, New Willard, Washington D.C. 4 p. Collection of the NOAA Central Library Rare Book Room.

US Coast and Geodetic Survey, 1916. Centennial Celebration of the United States Coast and Geodetic Survey, April 5 and 6, 1916, Washington, DC. Washington DC: Government Printing Office.

US Coast and Geodetic Survey, 1916. Report on the Exhibits at the Centennial Celebration of the United States Coast and Geodetic Survey, April 5 and 6, 1916. Washington, DC. Manuscript, NOAA Central Library Rare Book Room.

Vaughan, Thomas Wayland, 1924. Letter to W.W. Campbell (February 21). Carbon copy in the Archives, Scripps Institution of Oceanography.

Vaughan, Thomas Wayland, 1928. Letter to W.W. Campbell (September 13). Carbon copy in the Archives, Scripps Institution of Oceanography.