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Chapter One:
Henry S. Pritchett and the Great Reorganization of the Coast & Geodetic Survey

In 1897 the astronomer and mathematician Henry S. Pritchett succeeded the retired Civil War General William Duffield as the ninth superintendent of the US Coast and Geodetic Survey.

Before attempting more complete discussion of what took place between 1897 and 1900, and what these new orderings and activities of the Survey meant, it is important to discuss the various reasons why any re-organization of the Coast and Geodetic Survey was necessary, or at least desirable, in the first place. The first great era in the history of the Coast Survey ended with the death of Alexander Dallas Bache in 1867. Bache, the second superintendent and successor to Ferdinand Hassler, the founder of the Survey, left an organization which had begun to realize the potential that Hassler had foreseen but never fully realized in his own tenure. The Coast Survey had been thoroughly mobilized for service in the Civil War, and the transition back to peacetime authority and peacetime budgets was not an easy one.

There were two great sources of problems for the Survey, one of them military and the other civilian. The military problem was that, since the beginning of the realized Survey, Army and Navy officers had been deployed to service with the Coast Survey under conditions that were never optimized for the Coast Survey. The Coast Survey served as a training academy in geodesy, surveying, and cartography for military officers, and some military men served significant lengths of time with the Survey, but most came and went with a frequency that did not enrich the Survey sufficiently for its investment. Further, many of the ships deployed to the Survey were Navy vessels, and all of the most important and largest ships were Navy ships, which presented problems to the civilian organization which was the Coast Survey. In fact, authority for the Survey had shifted between civilian control in the Treasury department and under the Navy department several times.[1] Further, the Naval Hydrographic Office, founded in 1866 to provide charts for foreign ports and the seas outside American territorial waters, became in

[1] See Theberge's history of the Coast Survey 1807-1867 at the NOAA History website for the definitive account.

various senses a rival organization and a source of a variety of problems for the Coast Survey for the remainder of the 19th century.[2]

The other great source of problems was civilian in nature. The Coast Survey in the 19th century, apart from episodes of control by the Navy, was a small agency within the Treasury department entirely dependent on Congressional appropriations for its entire budget, apart from the occasional philanthropy of wealthy men to provide ships and access to ships. The Survey, unlike the Smithsonian Institution, had no endowment. Survey personnel were paid salaries commensurate with both university scientists and government scientists in general, which were quite low. From the time the Survey was working continuously as an organization, meaning the 1830s, in the many decades that followed there were many important Survey personnel who spent their entire working lives with the Survey, meaning that they had were paid salaries that provided little opportunity to prepare themselves for retirement. And, for civil servants in the late 19th century, there were no federal pensions for civilian service (as opposed to military service) so many Coast Survey personnel worked literally until they died, if they could.

Despite these problems, in the 30 years between Bache's death, and the beginning of Henry S. Pritchett's term as superintendent in 1897, a remarkable amount of work in many areas was accomplished. Three particular developments, out of many that could be described, will convey the expanded scope and agenda of scientific work and maritime service in that time.

First, in 1867 the Coast Survey acquired responsibility for charting the coastal waters of Alaska, and also determining the Alaska-Canadian boundary, in conjunction with the government of Great Britain. This enlarged mission of the Coast Survey had fortuitous consequences that survive into the 21st century, because work in Alaska "opened up" the entire Northeastern Pacific Ocean, as well as the Bering and Arctic Oceans, to the ships and personnel of the Coast Survey. Since the very beginning of active Survey work in Alaskan waters, the Coast Survey traveled to and from Alaska by what may be called "the scientific route". This means that Survey ships took many different routings, and Survey scientists and crews acquired a wide variety of oceanographic data, not directly related to their nominal duties for coastal charting. The full significance of much of it was not necessarily apparent in the 19th century, but it became readily apparent in the next.

Second, under the tenure of Benjamin Peirce, who succeeded Alexander Dallas Bache as third superintendent in 1867, Peirce's son Charles Sanders Peirce was hired by the Coast Survey. C. S. Peirce made voluminous contributions to the Survey, and American society in general, but in particular it was Peirce who began serious Survey research on the earth's gravity fields and instruments to study gravity. This was a substantial enlargement of the scientific agenda of the Survey, beyond the scope of both Hassler and Bache. The gravity work brought the Survey into the forefront of international geodetic research, and also further connected Survey personnel and the Survey as an institution to

[2] The definitive source on these matters is Manning (1988).

international scientific associations, with ramifications that carried on into the next century.

Third, the Coast Survey connected the previously separate Atlantic and Gulf Coast Surveys to the Pacific Survey, and in doing so created the foundation for the United States Datum, which the Survey then expanded to the continent, as the North American Datum. The initial transcontinental connection between the Atlantic and Pacific coasts was the great arc of the 39th parallel, a first-order geodetic triangulation network begun in 1871, but not completed until almost two decades later. The long march overland gave the Survey a terrestrial focus, and a rationale for new methods and instruments appropriate to the vast plains and mountains along route. Midway in that journey, in 1878, in order to signify its greatly expanded scope, and also to help differentiate the Survey from the nascent US Geological Survey organized under the new Department of the Interior, the US Coast Survey became the US Coast and Geodetic Survey, the name it would carry for almost a century.

Towards the end of the 19th century, then, the US Coast and Geodetic Survey had responsibilities that spanned the continent of North America, and embraced the American coast lines and coastal waters of the Atlantic, Pacific, and Arctic Oceans and the Bering Sea. The publishing technologies developed and used by the Survey were amongst the most sophisticated in the nation. The Survey maintained the official standards of weights and measures and scientific metrics for the US government, represented the nation on a variety of international scientific bodies, and served as the defacto national training academy for geodesy without rival in the entire western hemisphere.

At the same time, towards the end of the 19th century, the Coast and Geodetic Survey reached its nadir. The tenures of Superintendents Hilgard, and Duffield, in particular were mired in major political scandals. Hilgard, a German immigrant and talented instrument designer, was eventually forced to resign from the Survey in response to allegations of inappropriate behavior in his office. Duffield, a retired Civil War general without the slightest knowledge or interest in geodesy, was a particularly disastrous leader, whose most signal achievement was to dismiss as many of the most distinguished and long-serving scientists in the Coast and Geodetic Survey as he was able to discharge. But eventually the tide turned, Duffield retired a final time, and, in 1897, a 40-year old astronomer with a doctorate in mathematics from the University of Munich, Henry S. Pritchett, was named the ninth Superintendent of the Coast and Geodetic Survey. With his entrance, the Great Re-organization of the Survey began.

Pritchett served in that post only three years, before moving on to become the President of MIT, where he unsuccessfully attempted another great re-organization, a proposed merger of MIT and Harvard.[3] During his administration, a major reorganization and revitalization of the Survey took place, which created the "modern" 20th century Survey that eventually became a major component of NOAA. During Pritchett's administration, the following signal activities were either begun or accomplished:

[3] From the Pritchett biography, MIT Archives.

- The scientific components of the Survey were re-ordered into three great divisions, Hydrography and Topography, Geodesy, and Terrestrial Magnetism.
- Permanent astronomical observatories were established at Ukiah, California and Gaithersburg, Maryland as American components of the International Latitude Service, which in turn was a component of the International Polar Motion Service, both established by the International Geodetic Association.
- Permanent observatories for terrestrial magnetism were established at Ewa, Ohau, in Hawai'i, Sitka, Alaska, and Cheltenham, Maryland, with the latter developed as the national standard facility.
- A permanent port facility was established in Seattle, Washington, as a home base for the Alaska Survey and, by extension, all Survey activities in the Pacific Ocean.
- Work began to create a new national datum, the United States Datum, based on the Hayford ellipsoid, integrating and correcting data from all extant transcontinental geodetic arcs and surveys.
- The Office of Weights and Measures began the move out of its original home in the Coast Survey to a new independent position, eventually to be re-named the National Bureau of Standards.
- A complete reordering of the production of hydrographic charts was accomplished, triggered by the removal of US Navy officers and ships for service in the Spanish-AmericanWar, never to return to the roles they had played since the foundation of the Coast Survey. The Coast and Geodetic Survey gained the legal and budgetary authority to acquire large vessels of their own, under complete control of civilian sailing masters and crews. This was reflected in the creation of the first official flags of the Survey.
- As a result of the Spanish-American War and its consequences, Coast and Geodetic Survey personnel began work for the Philippines Survey, extending the domain of the Survey across the entire Pacific Ocean.

The achievements of 1900 were but dimly glimpsed in 1897. Several recently appointed superintendents had either been removed for scandal, or had so prosecuted their tasks as to provoke scandal. Duffield, in particular, had effected or attempted the dismissals of the most senior and most accomplished members of the Survey, with only partial success. Given this, the leadership of the department of the Treasury looked well outside both the Survey and the other sources of Survey leadership (mainly the military) for a successor to Duffield. They found the man they wanted in Henry S. Pritchett.

Pritchett grew up in Missouri in a family of modest means but far-reaching ambitions in education and research. Pritchett's father was a teacher and astronomer, who, when Henry was young, absented himself from the family to attend Harvard University for a full year. His father was a fervent Union supporter in a contested and confederate-leaning state, eventually leaving the family again to spend the bulk of the Civil War working in Washington for the US Sanitary Commission, whose Vice-

President was Alexander Dallas Bache, Superintendent of the Coast Survey. Henry Pritchett eventually attended Washington University in St. Louis, and then taught astronomy there for 16 years (1881-1897). The mathematical astronomy that was his predilection was perfect preparation for his tenure at the Coast and Geodetic Survey. Near the end of his life, Pritchett recalled his astronomical career in a letter to George E. Hale, director of the Mount Wilson Observatory in California:

> "I grew up in the astronomy of position, a field peculiarly attractive to the amateur observer. Thus a large number of persons got considerable satisfaction out of the work and passed on to other intelligent people a knowledge of astronomy and of the celestial bodies. Since that day, the old astronomy has become quite secondary to the fascinating developments in astrophysics; but the spectroscope is an instrument not so easily handled, and, as a consequence, the amateur astronomer has almost entirely disappeared. I think it would be of great value if some simple form of spectroscopic apparatus could be devised for the use of amateurs".[4]

In 1894, Pritchett traveled to Munich, Germany, to obtain a doctorate in astronomy under the celebrated Professor Seeliger. His studies began with elliptic functions and definite integrals, and the theory of planetary perturbations and photometry. In a little over a year and a half, he completed his thesis, entitled "Über die Verfinsterungen der Saturntrabanten" [On the Eclipses of Saturn's Moons]. He traveled widely, in and out of university circles, and made many connections and friendships in the community of European scientists, as he had earlier done the same amongst American scientists and political officials. These connections were about to pay off.

In 1897, two years back at Washington University, Pritchett received a letter from Lyman J. Gage, the Secretary of the Treasury, inviting him to come to Washington to discuss a matter. When Pritchett arrived, Gage remarked at his youthful appearance. The Secretary went on: "If you accept the job I am about to offer you, it won't take you so long to grow old". The offer was to become, effective immediately, the Superintendent of the US Coast and Geodetic Survey. Pritchett made inquiries amongst his friends in the Capitol, and also requested an interview with President McKinley. Pritchett explained that the Survey was a scientific institution, and that he must have a free hand to dismiss or hire personnel on every level based solely on scientific competency alone, regardless of political backing. McKinley and Secretary Gage agreed, and Pritchett accepted the position on the spot. That same day, he was called before a Congressional Committee concerned with the problems of the Survey. He was unable to answer many questions. A Congressman remarked: "You seem to know very little about questions under your jurisdiction. How long have you been Superintendent of the Coast Survey?" Pritchett pulled out his watch, and then replied: "About four hours and some minutes."[5] And so it came to pass that a widely-read and well-connected astronomer with no experience in the Coast Survey became its leader for three years. But, as his biographer stated: "When, for example, he was called to Washington as superintendent of the Coast

[4] Flexner (1943), p. 33.
[5] Ibid, pp. 50-54.

Survey, he seemed to see through the whole organization as though it was a piece of plate glass". [6] The major changes he effected to the Survey survive to the present day.

The Weight of the Office of Weights and Measures

The first significant project he attempted may seem counterintuitive—he advocated that the Office of Weights and Measures, the very essence of Hassler's legacy in government service, should be *removed* from the Coast Survey, its home since Hassler founded the office in 1836. But as Pritchett saw matters, the labors of scientific and material standards were burgeoning, and rightly so, but the Coast and Geodetic Survey, by virtue of its perennially constricted personnel and budget, was paying an increasingly high price to maintain the office. As Pritchett recounted the story in 1902:

> "On coming to the Coast Survey in 1897 I found the Office of Weights and Measures engaged in the work which I have just mentioned. In its service were two scientific assistants, an instrument maker and a messenger, and a small appropriation was made for office expenses. The work was under the charge of a field officer of the Coast Survey. The arrangement by which a field officer was in this way detailed temporarily for this duty did not seem to me good administration; it deprived the Coast Survey of the services of a much-needed officer, and in addition there was required for this duty not a surveyor but a physicist". [7]

Pritchett therefore asked Congress to appropriate sufficient funds to hire a physicist of high standing to accept direction of the Office, and eventually, he persuaded Dr. S.W. Stratton to leave the University of Chicago to accept the post. Stratton's job included the assignment to prepare a report recommending changes in the office; Stratton prepared a scheme for a National Bureau of Standards, which was evaluated within the Survey as well as without. Many of the Survey's best scientists, including then Assistant Superintendent Tittmann, were German immigrants or their children, quite familiar with counterpart European agencies. After their criticisms were digested, the final plan was revised and submitted to Congress. Pritchett noted that the new proposed bureau "as finally planned is not intended to be simply a copy of the Reichsanstalt [the German office of measures] but a standardizing bureau adapted to American science and to American manufacturers".[8] Congress accepted the proposal, and in 1901 the National Bureau of Standards was established under the Department of the Treasury. Both the Survey and the Bureau were later transferred to the Department of Commerce, where their successors remain, the Bureau now the National Institute of Science and Technology (NIST), and the Survey now the oldest element of the National Oceanic and Atmospheric Administration (NOAA).

The Spanish-American War, and the War with the Navy

[6] Ibid, p. 196.
[7] Pritchett (1902) p. 281.
[8] Ibid, p. 283.

The Coast Survey and the American military services have always been as closely related as siblings, and at times in their histories they contended and fought as only siblings can. Officers, crews and ships of the US Navy were attached to service with the Coast Survey from the very beginning of actual field operations in 1816. US Army officers and occasionally enlisted men were also attached for service, and over the decades many hundreds of US military personnel spend tours of duty, including multiple tours over many years, working on hydrographic, topographic and geodetic surveys. There were disputes and turf battles, and the histories of contention between leaders of the various services and bureaus form much of the extant scholarship of the early Coast Survey. Long simmering disputes occasionally erupted in major crises, and these generally correlated with the advent of war. In 1861, on the eve of the Civil War, all Army and Navy officers were abruptly withdrawn from the Coast Survey, in anticipation of the mobilization against the emerging Confederacy. Post-war, Army officers never returned to service as they had before the war, although the US Navy once again resumed its traditional roles in support—and occasional competition—with the Coast Survey.

The second half of the 19th century was an age of western imperialism, global expansion of trade and colonialism, and the coal-fired gunboat and dreadnought. The United States was an emerging player, although still a minor one compared to the great naval powers, which were then the United Kingdom, France, Germany, Russia, Italy, and Japan.[9] As the size and reach of the US Navy expanded, so did the responsibilities—and ambitions—of the Naval Hydrographic Office. In theory, there should be little or no reason for competition between the Hydrographic Office and the Coast and Geodetic Survey, because they had distinctly different arenas of operation. The Coast and Geodetic Survey was responsible for charting the coastal waters and adjacent lands of the United States and its possessions, while the Hydrographic Office was directed to securing or publishing charts and sailing directions for the waters of the world ocean that were outside of and beyond American territory. But every war that expanded American possessions created a direct conflict between the two bureaus. Any foreign coastal waters were the domain of the Hydrographic Office so long as the United States didn't possess them—but as soon as the nation acquired them, they became the responsibility of the Coast and Geodetic Survey. The conflict between the two agencies was as inevitable as the potential for collision between two ships sailing for the same spot.

In 1895, rebellion in the Spanish colony of Cuba broke out, and was suppressed brutally by the Spanish Army and Navy. The United States took great interest in the conflict, unfortunately much less out of concern for the rights of the Cubans in revolt than for the consequences of the rebellion should it spread to the other Spanish colonies, particularly Puerto Rico and the Philippines. Nor was the United States greatly concerned about the rights of Puerto Rican and Philippine nationals on their own islands. The emerging objective of American concern was the possibilities for acquiring, at the least, more favorable resource access and trade relations, if not more direct control, of any colonies Spain might lose in the rebellion.

[9] See tables and graphs from the report to accompany H.R. 10450, submitted by Mr. Foss, from the Committee on Naval Affairs, committed April 5, 1900 to the Committee of the Whole on the State of the Union 956st Congress, 1st Session, Report No. 930).

On February 15, 1898, the visiting American battleship the U.S.S. Maine exploded and sank in the harbor of Havana, Cuba. The immediate consequence of that disaster was a complete mobilization for war by the American military. For the second time in its history, the Coast Survey experienced the abrupt withdrawal of all military officers and ships assigned to service with the Survey. This change triggered a crisis in the Survey, and responding to the crisis exercised fully the powers of Superintendent Pritchett and his small band of Congressional allies. And so it came to pass that the Coast and Geodetic Survey itself went to war, in response to an offensive attack—not by Spain, but rather by the Naval Hydrographic Office.

The expanded scope of American naval activities, some directly related to the war with Spain or some not, had greatly increased the demands for Coast Survey charting, which meant commitments of ships and personnel to do the work. In August, 1898, the Navy asked the Coast and Geodetic Survey to chart the south side of the island of Puerto Rico. Later that same year, the Survey signed an agreement with the newly created Territory of Hawai'i to incorporate W.D. Alexander and his staff, who were once the Hawaiian Government Survey, then the Hawaiian Territorial Survey, into the Coast Survey itself. In 1899, the new ship Pathfinder sailed to Hawai'i to begin surveys of what were now American coastal waters. These changed mandates were made legal by Congressional language authorizing the Survey to work in the Atlantic and Pacific on "coasts of outlying islands under the jurisdiction of the United States".[10]

The Naval Hydrographic Office, in this same era, had been re-vitalized and expanded by Commander Royal B. Bradford and John D. Long, the Secretary of the Navy. By 1898, they had secured authority to construct "a series of charts of the coasts and waters between the state of Washington and the territory of Alaska" (i.e., the Pacific coast of Canada). In 1899, they secured authority to chart "the imperfectly known parts of the coasts and harbors of the Philippine Archipelago"[11]—which meant the Hydrographic Office was attempting to secure control of mapping the very same territory of "the coasts of outlying islands under the jurisdiction of the united States" that had been given to the Coast and Geodetic Survey.

The conflict between the two agencies soon expanded in 1900, as now-Admiral Bradford attempted to secure legal authority—and substantial budgets—to chart the coastal waters of the United states itself, thereby essentially displacing the Coast Survey. Bradford and his allies mounted a public relations campaign, built around nationally circulated copies of a pamphlet that made a series of claims that cut to the heart of the history of the Coast Survey and its whole engagement with science and the government. The Navy advocates argued that all maritime nations used charts made by their militaries, and not civilian agencies; that the bulk of the charting work of the Coast Survey had in any case been done by the military officers assigned to it; that the Survey had failed in its long history to complete its fundamental assignment of mapping the American coastal

[10] The Sundry Civil Act of March 3, 1899, in U. S. Statutes at Large, 30, 1082.
[11] Ibid, pp. 302, 374.

waters; and that in large part this was because its major efforts in recent decades had been overland geodetic surveys far from the coastal areas that were its mandate.[12]

The Navy's assault was eventually repulsed by the strenuous defense mounted by a handful of major Congressional allies of the Survey, in conjunction with the spirited testimony of Henry S. Pritchett. In March and April, 1900, he demolished the Navy's specific arguments, and forged the foundations for the next great era of the Coast and Geodetic Survey. He noted that Navy officers' service in the Survey generally assisted them more than their work assisted the Survey, by virtue of the fact that, in the average three years' posting each had, they could only begin to learn the scientific skills that modern geodetically-grounded charting required. He noted that the Survey's mandate to chart American territorial waters had expanded continuously through its history, but that even so the Survey always dropped other work to answer urgent requests from the American military command to chart new territory or harbors should these be required. He defended both the trans-continental geodetic networks and scientific activities like research in gravity and terrestrial magnetism as central to the core mission of charting coastal waters, due to the nature of the constraints of the physics of the earth. And finally, he argued that the very potential for success of the Survey was ultimately grounded in its status as a rigorous civilian scientific agency that would work best situated in a department of commerce:

> The Chairman: "I suppose they have to have a separate corps?"
>
> Mr. Pritchett: "Certainly they do. The Navy would have to have a separate corps and provide the machinery for doing the work; the experience of all nations has shown that, and our experience has shown that. When you have done that you will practically have the Coast Survey. If you think it wiser to have the Coast Survey under the Navy Department it would be better, possibly, to transfer our bureau there, but really the place I believe it should be is under a bureau of commerce, because its relations with commerce are so much closer than with the work of the Navy; but wherever you do put it, it does not matter, the work must be done by a corps of men who spend their whole time at it. This is the day of specialists, the time has gone by when men could do a half dozen things well, and as for the statement as it is here, that the Navy in ten years could make the charts of the whole world, that could not be made by any man who knew what he was talking about".[13]

And so the battle raged—Pritchett was convinced there must be one integral Coast Survey, regardless of where it was situated, although some homes were much better than others. In anticipation that, unless other changes were made, after the hostilities of the immediate war diminished naval officers would once again be assigned to the Survey, perpetuating a potential conflict that had plagued the Survey for the better part of a century, Pritchett and his Congressional advocates urged instead that the Survey should acquire control of its entire operations, and henceforth not be dependent on military

[12] The definitive source for the 1900 disputes and Congressional battles remains Manning (1988).
[13]Committee on Naval Affairs, March 19, 1900, statement of Mr. Henry S. Pritchett, Superintendent Coast and Geodetic Survey. p. 8

support at all. While fending off further attacks by the Navy during the remaining months of the Congressional session in spring and early summer of 1900, Pritchett urged approval of an authorization, through the Sundry Civil Act bill, that would switch the pay and subsistence of the navy crews of Coast Survey ships over to the budget of the Survey. He further negotiated with Navy Secretary Long to transfer jurisdiction of these men, not just their salaries, to the Survey. The changes were implemented piecemeal, as specific Survey vessels had already sailed away for the summer hydrographic season, but by December, 1900, the Navy Department closed its enlistment records for sailors and men on Coast Survey vessels. Those men now didn't just serve the Coast Survey—they were in the Coast Survey. It has been said that Ferdinand Hassler created the foundation upon which Alexander Dallas Bache built the house. But it was Henry S. Pritchett who finally realized Hassler's dream of scientific civil service—for the first time in its history, apart from the years of the Civil War, and for the rest of its existence, the Coast and Geodetic Survey was finally an entirely civilian organization. This change was signified by the competition, within the Survey, to create designs for nautical flags and pennants to signify to the maritime world that the ships flying them were under the command of the Survey.[14]

The Survey in the Philippines: "War is God's way of teaching Americans geography"—Ambrose Bierce

The involvement of the Coast and Geodetic Survey in the Philippines began in the earliest stages of the Spanish-American War. The Survey had, by 1898, spent almost half a century exploring and charting the waters of the Pacific, but solely in the eastern Pacific: along the west coast of the country, the coasts of Alaska and the Aleutians and their surrounding seas, and Hawai'i, based on cooperative research with the Hawaiian Government Survey of the Kingdom, over a decade before the islands were annexed to the United States. The north-east quadrant of the Pacific Ocean that includes all these coasts was also explored progressively, by Survey ships and crews taking "the scientific route" between different destinations. However, the greater part of the western Pacific had never been explored or even visited by the Survey at the time that war broke out between the United States and Spain.

Nevertheless, the Survey was the premiere earth science agency of the country, and the earth sciences are thoroughly international. The Survey maintained productive relationships with English and especially German oceanographic research and mapping enterprises and agencies, the latter based in good part on the fact that for many decades after the failed German liberal revolution of 1848, wave after wave of superbly trained German scientists immigrated to the United States and worked with the Coast Survey.[15]

[14] See frontpiece, Superintendent's Report of 1899 for a display of all the flags and pennants. The NOAA Central Library holds a collection of other flag designs submitted to the competition.

[15] Spurred by research that began with work on the career of the German immigrant Adolph Cluss, who worked with the Coast Survey 1849-50 upon his arrival in the US, before becoming a celebrated architect in Washington, DC, the NOAA Central Library has developed a web-based directory of other German immigrants who worked with the Coast Survey, accessible at: http://lib.noaa.gov/edocs/cluss/sciences.html

Thus it was that Superintendent Pritchett had access to recent English Admiralty charts that had been re-scaled and printed by the Survey cartographic division. On May 2, 1898, the day before the battle of Manila Bay, on impulse, he took an enlarged chart of Manila Bay to the White House, thinking it would be useful to President McKinley. The chart was far superior to any other map McKinley had. McKinley was suitably impressed. He remarked "I see I must learn a great deal of geography before the war is over, and I am going to ask you to help me".[16] Pritchett returned to the Survey headquarters on New Jersey Avenue, a block from the US Capitol, and ordered his cartographic staff to ransack the archives for the best available charts, and to create new ones if necessary. Thus the war in the Philippines, as it was fought from Washington, was fought with charts created by the civilian Coast and Geodetic Survey. As the Superintendent's report of 1899 noted: "Miscellaneous drawings were also furnished: San Juan [Puerto Rico], Hawaiian Islands, Guam Island, Ladrone Islands [the Marianas Islands], and a new chart of the Philippine Islands".[17] The next year, it published the very first American Atlas of the Philippines, which was based on a revised, re-scaled, and corrected version of a Spanish-language atlas of the islands originally published by the Jesuit Observatory of Manila, with the cooperation and assistance of various Jesuit scientists working in Manila and in Washington.[18]

With American success in the war, the United States found it had inherited colonies, and not territories, for the first time in American history—and also it inherited the liberation struggles within the colonies. The war in the Philippines turned into what the Americans called the Philippine Insurrection, which lasted for many years. The Coast and Geodetic Survey did its best to avoid direct involvement in the conflicts, squaring off instead with its old adversary—the US Navy Hydrographic Office.

The dispute was the by-now familiar question of which agency should receive authority for coastal charting, this time for the specific coasts that were now under US jurisdiction as a result of the war. These included Puerto Rico and surrounding waters in the Caribbean (but not Cuba, which is another story) and a variety of Spanish-ceded island possessions in the Pacific, of which the greatest was the 7,000 island archipelago of the Philippine Islands. The Navy Hydrographic Office demanded responsibility for the Philippines, so once again Pritchett was called to Capitol Hill. The Navy had suggested that Navy war ships could be used for surveying in between military duties. Pritchett wasted no words.

> "That is exactly the fallacy that I suggested. If you take any navy officer who is accustomed to survey work—take such a man as Captain Moser—he will tell you that the business of a man-of-war in patrolling work can not be done together with coast-survey work. The work takes men to a large extent out of naval discipline. The men turn out in the morning, say at 5 o'clock, in order to

[16] quotation from Pritchett's 1929 memoir of his service as Superintendent, quoted in Flexner (1943, p. 56-57).
[17] Superintendents Annual Report for the year 1899, p. ___
[18] *The Atlas of the Philippine Inlands*, UC C & G S Special Publication No. 3, 1900.

get the advantage of the smooth water, and work as hard as they can when the weather will allow them, and the regime of the ship is totally different from the duty of patrolling. If you have a half dozen small vessels in the Philippines, why should you not turn them over to the use of the Coast Survey, and let the naval officers cooperate, as they have always done?" [19]

Eventually, Pritchett prevailed over the Hydrographic Office, but then he prudently attempted to avoid conflict with the populace in the Philippines. When asked, before the same Congressional committee, about his plans, Pritchett noted "We are authorized to survey the Philippines. We have a report prepared but we cannot survey the Philippines now without a gun, besides I really prefer to wait until the matter is settled".[20]

With the initial truce in the Philippines, American mapping of the islands began. The chief administrative authority for the Philippines was the Philippine Commission, which created a Committee on Surveys to direct a wide variety of scientific and cartographic initiatives. Their major report to the Commission describes seven types and levels of investigations presented in the order of their importance and foundational place relative to the other survey types.

1- The needs of the public service in regard to surveys may be grouped under the following heads:

1st. Coast & Geodetic Surveys,
2nd. Topographic Surveys,
3rd, Surveys of the Public Lands, Mining Claims, etc.,
4th, Surveys of those private properties for which the issuance of certificates of ownership may be sought in the Court of Land Registration,
5th, Surveys, in detail, for special constructive purposes,
6th, Sanitary Surveys,
7th, Geological, Biological, Ethnological, and other scientific studies.[21]

The sequence of types of surveys presented crystallizes the aims and means of American science and technology at the turn of the 20th century. Geodesy is paramount, then all else. The reasons for the emphasis on nautical charts before topographic maps was indicated clearly by Charles B. Elliott, who had also been a member of the Philippine Commission, along with Worchester.

"For the Philippines, water transportation will always be of even greater importance than land transportation. The Archipelago is separated from the American continents by the broad Pacific and from the coasts of Asia by the turbulent waters of the China Sea. It is a maritime country in the strictest sense of the word... Marine surveys are of general as well as local importance, and it was only reasonable that the United States government should bear a portion of the

[19] Testimony before the Committee on Naval Affairs, March 19, 1900. pp. 11-12.
[20] Ibid, p. 13
[21] Committee on Surveys (1904, p. 1)

> expense of a complete coast and geodetic survey. An arrangement was therefore made under which the coast waters were to be resurveyed and recharted. The work was placed under the general control of the superintendent of the Coast and Geodetic Survey at Washington, who detailed an officer to act as director of a bureau in the Philippine government. Under this arrangement, which has proved quite satisfactory, the United States government has paid about fifty-five percent and the Philippine government forty-five per cent of the cost of the work".[22]

And so the mapping of the Philippines began, not on the islands, but at sea level. Soon enough, though, the great triangulation networks began to march across the mountain peaks of the larger islands and then across straits and channels between the islands. In anticipation of a myriad of hydrographic and other charts, the Coast Survey established the 4000 series of numbered charts, devoted exclusively to Philippine charts. The Insular Government of the Philippines created a Bureau of Coast and Geodetic Survey which worked in tandem with the US Coast and Geodetic Survey, with particular emphasis in both agencies in nurturing local specialists in all phases of the work. By 1923, the Philippine government had requested a 3-D relief model of the archipelago "as an invaluable aid, not only in the teaching of physical geography in the schools of the Philippines but as a help to the Scientific staffs of the various Philippine Government bureaus in their studies along the lines of seismology, geology, mineralogy, meteorology, etc".[23]

And so the work progressed in the Philippines, for four decades, until the day after Pearl Harbor in the Hawaiian Islands was attacked, and the Coast and Geodetic Survey went to war. That mobilization will be discussed in its time.

"The Variations of the Needle must be Shown"

Pritchett directed a Survey dedicated to cutting-edge science, but funded by legislative processes that preceded the invention of photography, the telegraph and the telephone. In December, 1899, the US Senate directed there be furnished a report on the present status of the Survey, with particular regard to the status of "surveys which may have been inaugurated on the islands now under the possession of the United States"—those being, of course, the Caribbean and Pacific islands gained through the Spanish-American War. Pritchett's reply was couched in language that sounded even older than that of Ferdinand Hassler, dead some 66 years at that point.

> "The object of surveys of the coast, as defined by existing law, is to furnish the information needed to commerce and in defense. A survey sufficiently complete to furnish this information requires a hydrographic development showing the depths of the water in the approaches to the coast, on the bars, and in the harbors and estuaries frequented by navigators, a careful location of hidden dangers, whether they be rocks or shoals, and whether they are permanent or shifting. There is also required a

[22] Elliott (1917, pp.326-327).
[23] Bureau of Coast and Geodetic Survey, 1923, p. 5.

knowledge of the tides and currents whose bearing on the needs of the navigator is patent to everyone. A topographic survey of the shores is needed in order that the sailor may identify the locality through natural and artificial aids to navigation on shore, for defensive purposes, for showing the facilities of commerce, and for the study of harbor improvements. The triangulation is the mensurational part of the survey on which the correctness of the hydrographic and topographic representations depend, and which properly connects in distance and bearing the features of the map. Last but not least in importance, the variations of the needle must be shown and data must be at hand for predicting it in advance".[24]

The reality of Survey science, as opposed to the archaic formalized language of Congressional reports, was based on investigations and instruments that were increasingly sophisticated and international. Survey earth science was, necessarily, *global* science, whether or not this was necessarily explained to Congress on all occasions.

Two initiatives of this globally-networked science from Pritchett's tenure will give the range of endeavors the Survey was pursuing. The first was the establishment of two permanent stations, at Ukiah, California, and Gaithersburg, Maryland, that were the American components of the International Latitude Service. They were part of a new global network, under the International Geodetic Association, designed to answer one of the most important challenges in the theory of the earth system.

In 1765, Leonhard Euler (1707-1783) the great mathematician and physicist, proposed that there was a disparity between the earth's axis of rotation, and its axis of figure, the latter being the principal polar axis of inertia. One axis should rotate around the other, and the earth therefore should wobble, with a period of rotation to be determined. For the next century, this theory, and attempts to prove it or disprove it, occupied an important place in the concerns of those whose profession it was to observe the complex relationships between the terrestrial and celestial spheres. . By the late 19th century, a combination of new and sensitive instruments, coupled to a network of increasingly global cooperative scientists, demonstrated Euler to be correct. The Coast and Geodetic Survey was at the heart of the exercise.

"The crucial test was made in 1891 by the International Geodetic Association and the United States Coast and Geodetic Survey. Observations for latitude were made by the former at Berlin, Strassburg, and Prague, and at Waikiki in the Sandwich Islands; and by the Coast and Geodetic Survey at Rockville (in Maryland), San Francisco, and also at Waikiki. The last station was especially important because its longitude is about 180° different from those of the German stations. Consequently, if the latitudes of the latter are found to increase during a certain period then that of Waikiki must be expected to simultaneously decrease by the same amount. As this was found to be the case, we may say that the two independent series of Marcuse and Preston, at Waikiki, firmly established the fact that the earth's axis of figure was slowly revolving around its axis of rotation.

[24] Pritchett (1900) pp.2-3.

"Meanwhile Chandler, of Cambridge Mass., had already begun his investigations upon the law of variation. The results obtained by him mark an epoch not only in this subject, but the whole progress of precise astronomy. For he was able to trace variations of latitude as far back as the time of Bradley (1750), and to show that many of the discouraging discrepancies encountered since that time were due to fluctuations in the latitude".[25]

The convergence of Euler's theory and Chandler's variations together with an increasingly cooperative international scientific community and increasingly accurate and precise instruments indicates how the Survey's concerns were evolving in ways not necessarily apparent to, say, a Congressional committee budgeting nautical charting. Erasmus Darwin Preston, of the Survey, had worked even earlier than 1891 in Hawai'i, performing gravity measurements on the slopes of Mauna Kea on the big island of Hawai'i. Note that Preston arrived before the islands were annexed to the United States, so his presence wasn't dictated by the demands of charting the coastal waters of the United States and its possessions. He was there because the science demanded it.

As the Survey's contribution to the International Latitude Service, the Ukiah and Gaithersburg stations, part of a global network of similar observatories located at 39° north latitude, were equipped with a variety of standardized instruments, operated under standardized protocols, and reported and analyzed by international committees.

International geophysical scientists were linked by increasingly similar objectives, but their work was also threatened by similar phenomena. Those whose profession it was to attend to 'the variation of the needle', meaning the fluctuations of terrestrial magnetism, found themselves menaced, in the late 19th century, by the latest products of advanced urban life. Edison's electric lights and the whole cascade of electrical utilities had provoked a crisis in the study of terrestrial magnetism. As Louis Bauer, who became the first head of the Division of Terrestrial Magnetism of the Survey, and later the founding director of the Division of Terrestrial Magnetism of the Carnegie Institution of Washington, noted:

"The selection of a suitable site for a magnetic observatory to be continuously and uninterruptedly in operation for a period of fifteen years, at least, is a most difficult matter in view of the rapid spread and development of electric car lines and electric power and lighting establishments. Nearly every prominent magnetic observatory over the entire globe has suffered more or less in recent years from stray industrial electric currents. Thus the two principal observatories in England, Kew and Greenwich, in operation for half a century and more, have been affected by the London electric car lines. Kew is at present making preparations to move to another site. Nearly every magnetic observatory in France has suffered, and its principal observatory has been moved... By the decree of the Emperor, forbidding a closer approach of electric car lines than 16 kilometers, the Germans have been able to keep their principal observatory at Potsdam free from disturbance. Considerable pressure

[25] Schlesinger (1900) p. 503.

has been exerted, however, on the part of the inhabitants of the district where electric car lines are excluded for better rapid-transit facilities than now existing, and there has been some talk of placing the observatory in a more isolated site..."[26]

The crisis of electrical interference had been developing for some years, although organizations varied in their recognition of the problem. At the height of the conflicts between the Coast Survey and the Navy, it possibly gave Mr. Pritchett some satisfaction to note that the Navy had been quite slow to recognize the problem.

The Chairman. "In your general investigations touching the various scientific work and various scientific departments about Washington, has your attention been drawn to the astronomical work being done by the Naval Observatory?"

Mr. Pritchett. "Naturally I have had a good deal of interest in that, having been at one time assistant astronomer in the Naval Observatory, and being more or less connected with astronomical work all my life...

"In reply to the request of the Chairman of the Committee, the following statement has been prepared relative to the equipment, standing, and organization of the United States Naval Observatory:

This observatory is one of the best equipped astronomical institutes in the world, and is the most expensive one. It includes also a complete magnetic observatory, which, however, is useless on account of the nearness of the trolley lines, a state of affairs which was foreseen before the erection of the magnetic instruments. The output of the work of the Observatory for many years past has been so meager as to bring upon it the constant criticism of astronomers in this country and in Europe".[27]

The magnetic crisis triggered by trolley cars added impetus to change the ways that the earth's magnetic field was observed, but addressing the phenomena of terrestrial magnetism, as it was then called, has been a constant in the Survey since its conception. The three primordial instruments of surveying are the plumb bob, to establish the vertical, some standard of measure, to measure distances, and the compass, to establish directions relative to north. Of the three, the compass is almost always wrong, in that it almost never points directly north, due to the disparity between the earth's magnetic field and its geographic organization by rotation around its axis. Hence, establishing magnetic deviations, both in place and over time, has always been a central preoccupation of the Survey, or any other survey. By the late 19th century, the Survey had established programs to determine, for all county seats in the United States, the paired azimuths of true north, derived astronomically, and magnetic north for that moment (since magnetic deviation changes steadily over time, a process called secular variation) for specific points, laid out with sets of monuments. The monuments and their alignment allowed surveyors or others who needed confident use of their compasses to note the local variations of the geomagentic field and correct for them.

[26] Bauer and Fleming (1903), p. 308.
[27] Pritchett (1900B) p. 417.

Compass readings vary over space and time, and also in response to local conditions, such as mountain ranges full of iron ore. Over time, the goal to determine magnetic deviation for specific spots evolved to embrace projects to make much more finely-tuned continual measurements from specific observatories, with correction factors determined to allow those results to be interpolated elsewhere. These observatories were directed to conduct precise observation of the three magnetic elements, as they are called: the first element is the absolute intensity of the magnetic field as sensed at that spot; the second is the azimuthal direction of the field, equivalent to the way the compass needle points relative to true north, which was determined astro-geodetically; and third the dip of the magnetic field, because the earth's magnetic field is organized around the magnetic poles in such a way that lines of magnetic attraction are curved from pole to pole, and so, from any given spot, the field dips at an angle to the horizontal parallel to theslope of the field at that point.

Three sets of instruments have been developed to measure, in concert, the three magnetic elements: the magnetometer (see illustration from Bauer, 1902), which measures magnetic deviation; the dip circle (see illustration from Bauer, 1902) which determines the dip of the field, and the earth inductor (see illustration from Bauer, 1902), which, in concert with the magnetometer, gives the absolute intensity of the field. The instruments were extremely delicate and quite sensitive to air temperature variations, which introduced error in the measurements. As a result, a proper magnetic observatory, as the facility used to house these instruments came to be called, was expensive to build and maintain. During the dark times of the Survey in the late 19th century, there was but one magnetic observatory, which was moved repeatedly, in response to changing constraints of the Survey's work, and also the new problem of electrical trolley cars. The discontinuity of observations from any one site impacted progress in any national program of magnetic work.

Once again, Pritchett had a solution. He proposed elevating the magnetic work to the status of a specific division of the Survey (along with the other two divisions, Geodesy, and the combined division Hydrography and Topography). After beating back the attempt of the Navy to take over the Survey, in order to replace the services of the Navy officers, now permanently withdrawn from the Survey, Pritchett had acquired authority to hire 30 new, permanent assistants. A good number of these positions were reserved for the newly expanded magnetic observatories. In Pritchett's final round of budget negotiations with Congress, he requested, and received, funding for:

> "For continuing magnetic observations and to establish meridian lines in connection therewith in all parts of the United States, and for making magnetic observations in other regions under the jurisdiction of the United States, including the purchase of additional magnetic instruments, and the lease of sites where necessary and the erection of temporary magnetic buildings;"[28]

[28] Public—No. 158, An Act making appropriations for sundry public expenses, etc. Under the Treasury Department, 1902, p. 13.

After thorough and rigorous hunting for potential observatory sites that would not be susceptible to electric contamination, three observatory sites were first selected: a site on the extensive grounds of the Reform School for Colored Boys, in Cheltenham, Maryland, about 15 miles from Washington, DC, was to be the national standard observatory, to which all instruments were to be calibrated; an isolated hill on a peninsula outside Sitka, Alaska was to be the high latitude station; and a site on a non-magnetic uplifted coral plain at Ewa, on the coast of the island of Oahu, in the Hawaiian Islands, was to be the tropical site. Additional sites were planned for the middle of the continent, near Baldwin, Kansas, and a site in Puerto Rico, originally on the island of Vieques, the latter situated in "a region recommended as a desirable one for a magnetic observatory by the International Magnetic Conference held at Bristol, England, in 1898, and one which the recent volcanic eruptions on Martinique and concomitant magnetic storms have made doubly interesting and important for magnetic observations".[29]

The new era in terrestrial magnetism, with new permanent staff positions and new permanent national observatories[30] had far-reaching consequences for the Survey. The magnetic observatories, like the latitude observatories of the International Latitude Service, served national objectives and also international scientific goals as well. The demands for new instruments of sufficient sensitivity and reliability continued to expand the instrument designing and manufacturing capabilities of the Survey. And finally, the magnetic instruments themselves were sensitive enough, and the magnetic field faint enough, that additional instruments were acquired solely to assist in factoring out non-magnetic disturbances that might affect instrumental measurements. Bauer and Fleming, in discussing the original instrument arrays for the three original observatories, under accessories, note that each observatory would be "supplemented by a seismograph".[31] The original purpose of the seismographs was to filter out earth movements that might disturb the magnetometers. Hence, the contribution from earth tremors to the 'variation of the needle' of the magnetometer could be eliminated. However, eventually the seismographs would propel the Survey into the very heart of both the revolution of plate tectonics and the scientific Ground Zero of the Cold War.

After three years of adroit labor as Superintendent, Henry S. Pritchett resigned his post and accepted the position of President of the Massachusetts Institute of Technology (MIT). On his arrival, the Survey had been moribund, many of its most respected and longest-serving scientists had been dismissed, its very existence was threatened by the Navy, and its fundamental ability to survey the coasts was as dependent on Navy personnel as had been the case in the days of Hassler. During his administration, every one of those problems had been addressed. Pritchett left the Survey as a completely civilian scientific agency, participating on the most rarified levels of international earth

[29] Bauer and Fleming, op. cit., p. 307.
[30] Postwar development in the Maryland suburbs eventually contaminated the Cheltenham site, so the national standard observatory was reconfigured at the Fredericksburg, Virginia Observatory, which is actually situated in a very rural location at Corbin, Virginia. The Hawaiian observatory had to be moved during the Second World War, because a newly constructed navy air base nearby interfered with the instruments; the observatory was relocated a few miles to its present site at Ewa on Oahu. The Sitka observatory is still situated in place, in the same non-magnetic building, constructed in 1902.
[31] Bauer and Fleming, op cit., p. 330.

science, and sailing its own ships under its own crews and sailing masters, not just to the expanding waters of the coastal possessions of the United States, but increasingly to every edge and corner of an ellipsoidal world.

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