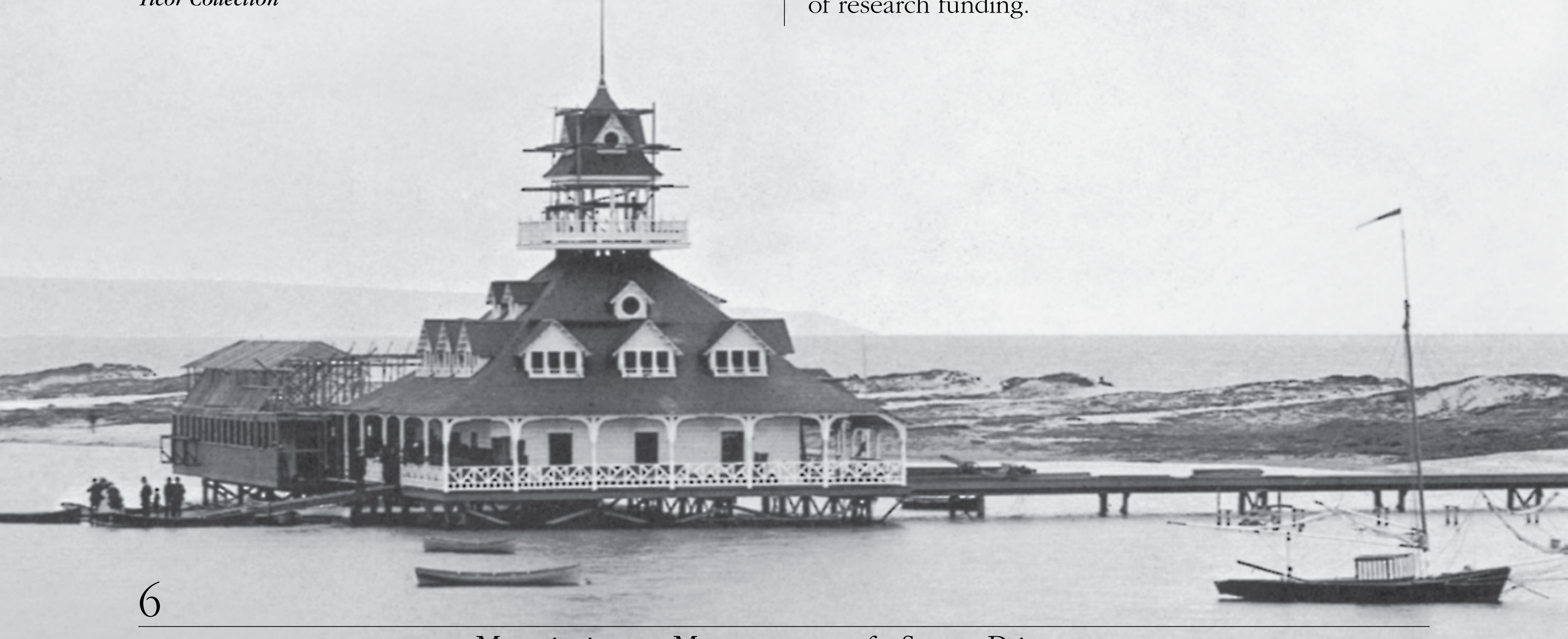
Mare Incognitum

How Scripps Institution of Oceanography took root on the Pacific Shore and some of the Maritime Technological efforts that resulted.

By Robert A. Knox, Ph.D.

Introduction

One purpose of this issue of *Mains'l Haul* is to outline the stories of the major ocean research institutions of the Pacific and their adoption of, involvements in, and sometimes leadership of advances in "maritime technology," broadly construed. In a few of these instances of technological involvement the results have had impacts beyond the research communities themselves, and into areas of commercial development or military significance. This issue seeks to highlight such cases of broader impact. But it must be noted that for the most part the ocean research community, including Scripps Institution of Oceanography, has been less an originator of radically new technology with widespread application, as in the manner of inventing the transistor, laser, GPS or the cell phone, and more an ingenious adopter, adapter, improver and applier of more or less existing technologies drawn from numerous sources. Scripps' contribution has been to incorporate them cleverly into instruments and systems that answer the needs of the research agendas that form the *raison d'être* of Scripps and sister institutions. In turn, those agendas, since the earliest days, have been heavily influenced by the enormous lack of pertinent observations and measurements of marine phenomena – a huge lack by comparison to the observational base on land or in the atmosphere – and by the resulting scientific imperative to improve that observational portfolio so as to build up clearer understanding and prediction of the phenomena. In all of this it must be borne in mind that Scripps *per se* has not and does not accomplish much as a well-organized entity in the manner of, say, an army division. Rather, the advances stem from the efforts of individual scientists or like-minded groups of scientists, and their staffs and students, bent on attacking some scientific question that intrigues both them and, necessarily, some source of research funding.



The Coronado Boathouse, pictured in 1887, provided the earliest platform from which to study the marine environment. It was from this boathouse that Dr. Fred Baker and William Ritter began to gather information from local waters with the hope of some day having a marine biological station in the San Diego area.
Courtesy of the San Diego Historical Society, Ticor Collection

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The staff of the Marine Biological Association of San Diego in June 1904, at the boathouse of the Hotel del Coronado, where Ritter's work was based before the acquisition of the La Jolla site. Front row, left to right: J.F. Bovard, Effie Rigden (Mrs. Michener), Alice Robertson, Calvin O. Esterly. Back row, left to right: Robert Day Williams, B.D. Billinghurst, William E. Ritter, Loye Holmes Miller, Charles A. Kofoid, Harry B. Torrey.

Courtesy Scripps Institution of Oceanography Archives, UC San Diego Library

Nearshore Beginnings

Scripps Institution of Oceanography is now (in 2012) 109 years old and as its website[1] notes: it is "one of the oldest, largest, and most important centers for ocean and earth science research, education, and public service in the world. Research at Scripps Institution of Oceanography encompasses physical, chemical, biological, geological, and geophysical studies of the oceans and earth." The beginnings were much more modest and delicate. Save for some remarkable coincidences of geography and a handful of individuals, Scripps Institution might never have existed, or might have been established elsewhere.

The story of the early years is ably told in the Scripps history[2] on which much of this section is based. William E. Ritter came to California in 1885, spending one year teaching at Fresno before entering the University of California, Berkeley, graduating in 1888. He spent a further year at Berkeley, then two years at Harvard, obtaining a Ph.D. in Zoology for a thesis on the eyes of the Blind Goby, a rare species to be found along the Point Loma shore. He returned to Berkeley in 1891 to chair the new Zoology department and to marry Mary Bennett, whom he had met during his Fresno teaching year. They honeymooned in San Diego, where he could collect more marine specimens. More importantly, he met medical Drs. Fred and Charlotte Baker. Fred was active in many civic circles and was an enthusiastic amateur marine naturalist, in addition to his professional medical work. He became a primary and persistent proponent of San Diego as the best location to fit Ritter's ongoing search for a permanent location for his summertime, and later full-time, marine biological investigations.

The Scripps Institution ca. 1909 on its present site, looking south toward La Jolla Shores and Point La Jolla. The building is the George H. Scripps Memorial Building ("Old Scripps"). It and the land were provided by Ellen B. Scripps as discussed in the text. The building was designed by noted architect Irving Gill. In the late 1970s, the building was slated for demolition for reasons of age and presumed seismic hazard. A campaign to save the building was led by a few members of the Scripps community, and upon investigation the building proved less vulnerable to seismic hazard than presumed. Funding from several sources, including important private donations, enabled the necessary renovations. The building was designated a National Historic Landmark in 1982. It remains in use for offices and a small meeting room.

Courtesy Scripps Institution of Oceanography Archives, UC San Diego Library

Ritter spent several subsequent summers assessing the pros and cons of various coastal locations, notably San Pedro, for his field programs. His fundamental perspective was of the untapped promise of the Pacific Coast for basic marine biological surveys – understanding what organisms lived where and how. As he wrote later: "Imperfectly as had any of the fields of Zoology in Western America been cultivated, the least studied of all had been the teeming life of the great ocean on whose margin the University is located." [3] His scientific target was to reveal the biogeography of a nearly unknown marine realm, one ripe for investigation. Other marine biological stations already existed elsewhere, for example the Marine Biological Laboratory in Woods Hole (1888), and the Stazione Zoologica in Naples (1872). The California coast was to be Ritter's province.

Pros and cons of the sites were many. San Francisco Bay was, of course, handy to the University, but was nearly landlocked and under the influence of rivers. Pacific Grove already had the Hopkins Laboratory of Stanford University, a much more substantial effort than the fledgling University of California program under Ritter's direction. In San Pedro, harbor improvements and dredging would demolish some of the best collecting grounds. Baker kept up his advocacy. The San Diego region had much to offer – rich diversity of nearshore marine forms, accessible and deep water nearby, and benign weather enabling boat work in most months of the year. And there was serious effort by Baker and others to obtain the funds needed to underwrite Ritter's work, something at which the Los Angeles/San Pedro interests had fallen short of for the summer of 1902. The San Diego Chamber of Commerce, goaded by Baker, established a Marine Laboratory Committee to seek private funds. They met with good success, including a promise of $500 from a "wealthy rancher," who hoped that Ritter could meet him when he next came to San Diego. That "rancher" was newspaper magnate E. W. Scripps, whose support (and that of his half-sister Ellen B. Scripps) would prove absolutely crucial to the establishment, survival and growth of the institution.[4] The Ritter-Scripps meeting took place in the summer of 1903, following which Ritter reported to the Chamber of Commerce Committee: "I am not going to report now that San Diego is unquestionably the best place on earth for such an institution. I am simply going to say that it is undoubtedly an excellent place from several points of view – one of the best." Further, "There can be no doubt that a laboratory capable of great things for biological science might be built in San Diego."[5]

Thus, in September 1903, the San Diego Marine Biological Association was formed, in the words of its

This 1939 photo places Roger Revelle (second from left) on the deck of the *E.W. Scripps*. Purchased in 1937, the ship made the first of the Institution's long research voyages. Of the sixty years of Revelle's involvement with Scripps, he was part of deep-sea explorations for nearly three decades.

Courtesy Scripps Institution of Oceanography Archives, UC San Diego Library

by-laws: "to carry on a biological and hydrographic survey of the waters of the Pacific Ocean adjacent to the coast of Southern California; and to prosecute such other kindred undertakings as the Board of Trustees may from time to time deem it wise to enter upon." [6] Initially an independent association, it was contemplated *ab initio* that in due course, "the founding of the institution having been perfected and its endowment secured, the whole or such part thereof as may in the judgment of the Trustees seem best, shall, under such conditions as the Trustees may impose, be transferred to the Regents of the University of California to become a department of the University co-ordinate with its already existing departments." That joining with the University took place in 1912, though another forty-eight years would pass before a complete university campus (UCSD) was initiated in La Jolla through the remarkable leadership and insight of Scripps director Roger Revelle. UCSD took good advantage of the by-then considerable intellectual luster and physical resources of Scripps as a kernel from which to grow, thereby enjoying a running start into the major leagues of U.S. research universities such as very few latter-day startups have enjoyed.

Prewar Years

Scripps began small and stayed that way for some time. The 1918 roster lists just twelve "officers," including both scientists and such functions as librarian and business agent,[7] sometimes combined in one person. Even by 1934 this roster had grown only to twenty-six. In these prewar years the emphasis continued to be heavily along the marine biological lines begun by Ritter. In terms of maritime technology, these efforts did not demand much nor did they give rise to novel developments. In the main the work was the classical laboratory-based study of collected specimens, needing microscopes, sample jars, chemicals and dissecting apparatus, none of which was peculiarly marine or novel. One niche in which there was a small technological flowering at Scripps and elsewhere, albeit one that had little impact beyond the research community, was in the design of different sampling bottles, primarily for biological specimens. As Peter J.S. Franks noted in "A Century of Phytoplankton Research at Scripps," [8] "Lest I give the impression that Scripps was a hotbed of sample-bottle development, it seems that between the late 1800s and mid-1900s any oceanographer worth his salt had developed a bottle bearing his name. In a haphazard search of the National Oceanic and Atmospheric Administration image archives, I came across more than 100 bottles developed during this time, mainly in Europe and Scandinavia."

To Ritter's credit he also recognized the need to understand the physical and chemical surroundings (the ocean) in which the organisms of study lived. But even these physical and chemical studies mainly used tools that had already been developed elsewhere and had achieved a fair degree of standardization, simplicity, familiarity and acceptance.

In the realm of physical oceanography, as one example, the Norwegian polar explorer Fridtjof Nansen had designed the eponymous sampling bottle in 1910. Fastened to a wire lowered over the side of the ship by a winch, the bottle was "tripped" (upended) by a small weight ("messenger") sliding down the wire from above. Tripping served to close the bottle valves and capture a seawater sample for later laboratory analysis of its salinity and other properties, and also to release another messenger to fall farther down the wire to trip the next bottle, and so on through a series of bottles placed at desired intervals along the wire. Attached to the upending bottle would be one or more "reversing" mercury thermometers, a clever design due to Negritti and Zambra in 1874. The upending breaks off a column of mercury in the thermometer, preserving a record of how long the column was (*i.e.,* of the in-situ ocean temperature) at the time of reversing. A second kind of reversing thermometer, with its mercury column exposed to ocean pressure, captured an indication of the depth of the instrument at reversal.

Such mechanical and a handful of electro-mechanical devices were the norm during this period. A good overview from the perspective of the early 1940s is given in Chapter X of the famous 1942 text/encyclopedia of oceanography, *The Oceans,*[9, 10] by a trio of Scripps authors. Modern readers will be struck by the absence of electronics, let alone anything in the way of digital circuitry, from these devices. With the exception of some early underwater sound sources, used for sonic depth measurements and also for target (submarine) detection, none of these devices had appreciable impact beyond research uses, nor did any survive the postwar electronics/computer revolutions.

Waves and The War

World War II, of course, overturned the plans of nearly everyone, and Scripps scientists were no exception. For the Western Allies the war had enormous maritime components – the Battle of the Atlantic that came perilously close to choking off the life of Britain, and the rolling up of the Japanese forces in the Pacific, one island landing and one naval operation at a time. Objects of inquiry suddenly shifted from U.S. coastal marine biology à la Ritter, to matters of underwater sound and target detection, conditions on beaches for amphibious operations, and more. These kinds of questions demanded rapid answers involving the state of the ocean and its variability in real time, or even into the near future (forecasts); retrospective reference to climatic atlases, seasonal averages or museum specimens were not enough.

The problem of trying to create useful forecasts of waves on landing beaches fell on the desk of young Austrian-born Ph.D. student Walter Munk, who had left his Scripps studies for Army duty and was assigned as Assistant Oceanographer in the Army Air Force Directorate of Weather in July 1942. There he was apprised of some of the plans for the North Africa landings later that fall, and learned that waves on that coast commonly exceeded what the landing craft could bear. The urgent problem then was to try to predict, shortly ahead of time, a day on which the surf would be acceptably small.

There clearly was no time to invent or deploy any new technology or hardware for the purpose. Everything had to be based on whatever already existed in the way of instruments, data sources and physical understanding of waves – an extreme case of the "ingenious adaptation and application" noted in the Introduction, and one with lives on the line. Munk quickly decided to involve his famous mentor in the effort, the Norwegian-born[13] Director of Scripps Harald Sverdrup, and the two of them produced wave forecast schemes based on available weather maps and their indications of storms, on empirical rules for the strength of waves that propagate away from storms ("swell") and for waves generated by weather closer at hand ("sea"), plus a few elementary dynamical principles of wave propagation. By today's standards these empirical formulae are very crude. But they were taught at Scripps to some two hundred military officers for later use in making wave predictions for various landings, including those at Iwo Jima, Okinawa, the Philippines, Sicily and Normandy, and thus made their way into the war effort with notable success. For Normandy, a combined US-UK team gave Eisenhower the fateful advice that waves for June 5 would be too great, while those on June 6 would be difficult but manageable, so June 6 became D-Day. (Parallel UK work on wave forecasting is recounted in Chapter Four of *Of Seas and Ships and Scientists: The Remarkable Story of the UK's National Institute of Oceanography.*[14]) This forecast was primarily for sea and surf, and based on nearby weather, since the Cherbourg peninsula shields the Normandy beaches from all but very large swells coming in from the open Atlantic.

Walter Munk (l) and Harald Sverdrup at Scripps, 1940
Courtesy Scripps Institution of Oceanography Archives, UC San Diego Library

In the years since the war, this audacious undertaking – to cobble together existing information and understanding of wave dynamics and thereby to fashion a useful forecast – has burgeoned into sophisticated computer models of the wave spectrum and wave generation process, global observations of winds and wave heights inferred by satellite instruments, regular global wave predictions by civil and military weather services, commercial services to advise ships about optimal routes to skirt storms and high seas, and any number of regular wave forecast products tailored to local areas and used by surfers and beachgoers. But the lineage – the realization that it is actually possible to use science to do more than guess about future wave conditions – traces to Sverdrup and Munk.[15, 16] And the broader impact of their first step was fundamental. Taking into account all the wartime operations that made use of wave forecasting, a modern text on waves writes, in a pedagogical tone to its student readers:

"If you will admit the obligation of the scientist to the society that makes his science possible, then you will from time to time find yourself in a position similar to that of Sverdrup and Munk. I am sure that they were aware of the inadequacies of what they did and that if they had known at the time how to remedy them they would have. The point is that in meeting a practical situation you need not be – in fact you should not be – apologetic about making assumptions that are doubtful and working on an inadequate data base. If you can produce anything helpful, that is your justification. The danger lies in becoming enamored with what you have done and mistaking palliatives for insight. Sverdrup and Munk never made this mistake, and as evidence of the discharge of their moral obligation there are some thousands of World War II veterans alive today who would have been dead in the surf had Sverdrup and Munk not done their best with what they had."[19]

Ed Barr and the MBT on deck in benign conditions aboard RV *Horizon*, 1952. The towing cable is attached near the nose of the device. Pressure and temperature sensors are exposed to the sea via the perforations nested within the tailfins.

Courtesy Scripps Institution of Oceanography Archives, UC San Diego Library

Mechanical Bathythermographs (MBTs) and Expendable Bathythermographs (XBTs)

By the late 1930s it had become apparent to many oceanographers, particularly those involved in ocean acoustics of naval relevance, that the variability of conditions in the upper ocean (the top few hundred feet, where submarines of the time operated), particularly of temperature, gave rise to variability of the speed of sound in the ocean and hence to variable refraction or bending of sound rays in that region. Thus the ability to measure and understand the acoustic ramifications of this upper ocean variability in terms of target detection for destroyers, or destroyer avoidance for submarines, loomed large as an unmet need in the run-up to the war. Atlases and compilations of average conditions were insufficient; current observations of actual variable conditions were needed. The tedious business of stopping a ship to lower a Nansen bottle was altogether too time consuming and sparse a sampling method; something to be done rapidly and repeatedly from a ship underway was required.

The first step in this direction was the creation of the purely mechanical bathythermograph or BT (sometimes later called MBT for Mechanical BT, to differentiate it from its electronic successor the expendable bathythermograph or XBT). Rossby and Spilhaus built the first BT in 1937 at the Woods Hole Oceanographic Institution (WHOI). Vine and Ewing added important improvements of functionality and durability in 1940. The WHOI director Columbus Iselin, who was convinced, correctly, of the importance of rapid underway upper-ocean temperature measurement, to underpin advancements in the understanding of underwater sound and its tactical application to submarine warfare problems, supported the BT development and urged its use by the Navy. Getting the operational Navy to subscribe to this view proved harder than actually building the BT.[20]

Louis Garrison manning the BT winch in distinctly non-benign conditions, aboard RV *Horizon*, 1950.

Courtesy Scripps Institution of Oceanography Archives, UC San Diego Library

The BT had its innings in the war and, subsequently, as a naval device and as a research instrument for upper ocean studies. It was purely mechanical. A small smoked glass slide, about the size of a microscope slide, was pushed in one direction by pressure as the BT descended, while a stylus was driven at right angles by the ocean temperature acting on a thermostat-like coiled metal tube, thus scratching a graph of temperature versus depth on the smoked glass. But it was a bother to keep calibrated, a nuisance to retrieve the data from a bit of smoked glass, and a terror to operate at sea. The device consisted of a heavy brass rocket-shaped body that was dropped over the side of the moving vessel, rapidly spooling out wire from a small freewheeling winch. Inside the brass body, but in contact with the water, lay the temperature and pressure sensitive components and the glass slide. The operator was a sitting duck:

"In any kind of rough weather this BT position was frequently subject to waves making a clean sweep of the deck. In spite of breaking waves over the side the operator had to hold his station, because the equipment (the BT) was already over the side. One couldn't run for shelter as the brake and hoisting power were combined in a single hand lever. To let go of this lever would cause all the wire on the winch to unwind, sending the recording device and all its cable to the ocean bottom forever. It was not at all uncommon, from the protective position of the laboratory door, to look back and see your watchmate at the BT winch completely disappear from sight as a wave would come crashing over the side."[21]

When the end of the wire was reached (and at even moderate ship speeds this was at disappointingly small BT depths, constrained by the amount of wire on the winch and how effectively the BT could pull it off the winch in order to sink), the BT was winched back aboard, frequently breaking the surface, skipping on a wave crest, and hurtling aboard to endanger people on deck. "Probably the greatest hazard was a swinging BT after it had left the water. A familiar saying was: 'sight, surface, oh son of a gun,' or words to that effect, as the instrument swung in circles around the boom."[22]

In the postwar era engineer James Snodgrass of Scripps felt that the time had come to step away from purely mechanical devices and embrace the new possibilities of electronics. Snodgrass conceded the prior track records of the two approaches: "When I first came to Scripps Institution of Oceanography in 1948 it was quite evident that the word "electronics" was in many ways what might be considered a dirty word and, more often than not, preceded by an uncomplimentary adjective. Mechanical instruments had been used in oceanography literally for decades and were performing creditably. Since mechanical instruments

A modern XBT probe is launched nose-down and outboard of the hand-held launcher. The operator can be much more shielded from the weather. The wire connecting the probe and launcher is too fine to be visible in this photo.

NOAA Teacher at Sea, Catherine Prenot Fox onboard NOAA ship, Oscar Dyson
July 24 - August 14, 2011

had achieved relatively high reliability there was little or no inclination to turn to electronic instruments, which, aside from being relatively fragile, was [*sic*] at the time quite temperamental and admittedly unreliable."[23] This view echoes the edgy remark of Roger Revelle to the effect that "the best oceanographic instruments should contain less than one vacuum tube per unit."[24] Revelle, of course, would be open to new techniques of demonstrable capability, but at that time the key factor "demonstrable" was lacking.

For Snodgrass, however, the times were changing, and the MBT was an instrument in urgent need of change for the reasons noted. With the new possibility of an inexpensive electronic temperature sensor (thermistor) and electronic means of recording its output, there arose the key possibility of breaking the system into two parts – an expendable probe with its thermistor dropped into the water from the ship underway, and a permanent recording system inside the shipboard laboratory. A thin insulated wire connection from probe to ship, but one with its insulation free of pinhole leaks was needed; this proved feasible. Snodgrass urged this expendable approach to the Navy and to interested commercial firms. The primary result was the XBT, as built by Sippican Corp. (now Lockheed Martin Sippican).[25]

The fine insulated wire is wound on two spools, like fishing reels. One spool in the probe unwinds as the probe sinks. The other in the shipboard launcher unwinds as the ship continues to steam away from the point of launch. The part of the wire that enters the ocean at the launch point thus stays more or less still as the two unwinding spools move away from it. There is no pressure sensor. Depth is determined by the time the probe first contacts seawater and the known fall rate of the probe. The thin electrical wire is expendable and no longer a limiting factor, in contrast to the MBT where the mechanical wire must have the strength to recover the probe, so the XBT can routinely achieve much greater depths than the MBT, and at greater ship speeds. The overall survey economics, when both ship time costs and expendable probe costs are factored in, decidedly favor the XBT. Sippican has produced over 5 million XBT probes for research and military use since the 1960s. There are related expendable instruments for sensing ocean conductivity and temperature jointly (and thus computing salinity) and for sound velocity. Air-deployable versions with a radio link to the aircraft also exist (at greater unit cost) enabling even more rapid surveys if required. MBTs now reside only in museums. Both research uses: rapid reconnaissance of upper ocean variability to study its fundamental properties and dynamics and military ones, rapid reconnaissance of such variability and its acoustic consequences as an aid in submarine and anti-submarine warfare tactics, have been the clear beneficiaries of this early incorporation of electronic techniques in the arsenal of oceanographic instrumentation to observe ocean variability.

Concluding remarks

Space has not allowed this paper to give either a full history of Scripps Institution of Oceanography, or a complete survey of those occasions on which Scripps-related technological efforts have propagated into broader commercial or military impacts, let alone the more numerous occasions on which such efforts have fed back into crucial advancements in ocean research and observing capability. The companion paper by Dr. Russ Davis (see pages 18-31) discusses some of these other occasions, particularly ones enabled by the fundamental revolutions in electronics and digital systems of the last few decades. Here we have simply noted two somewhat eclectically chosen and historically earlier examples – wartime wave forecasting, and the application of early postwar electronics to shift from the MBT to the XBT – as illustrative of the ingenuity that Scripps people have brought to the task of understanding the ocean and revealing its behavior through any and all technologies that could be brought to bear. In these two cases the uses of the technological developments have spread well beyond research purposes alone. As the second century of Scripps unfolds this kind of seizing upon technological possibilities continues. The core incentive remains to create new instruments and measurement systems that will help peel back the darkest layers of the unknown sea for the scientists who seek to understand it – to render the *mare* less *incognitum.* Both the enhanced understanding and some of the new devices doubtless will continue to open up new advantages and new economic possibilities to sectors of society well beyond the confines of Scripps Institution and the ocean research community.

The aerial view of Scripps about one century later than on page 8. The original "Old Scripps" building is the building south of the pier at the cliff's edge, partly obscured by a group of trees, and bounded on its north, west and south sides by more recent buildings.

Courtesy Scripps Institution of Oceanography Archives, UC San Diego Library

Notes

1 http://sio.ucsd.edu/ (accessed Oct. 24, 2011).

2 Helen Raitt and Beatrice Moulton, *Scripps Institution of Oceanography – First Fifty Years,* The Ward Ritchie Press, 1967.

3 Ibid., 5.

4 Ibid., 17. The initial input of funds from E. W. Scripps was only the first of several crucial contributions from him and other members of the Scripps family. Ellen B. Scripps, relying on her half-brother's financial advice, underwrote the purchase of the 170 acres on which the Institution is now located and the construction of the first building, shown on page 12, both for under $20,000. When the solitary research vessel *Scripps* was lost in an explosion in 1936, Robert P. Scripps purchased the yacht *Serena*, had it refitted and modified, and donated it to the Institution as the *E.W.Scripps.* In this century the new Robert Paine Scripps Forum, with major Scripps family donations, has become a conference and meeting focal point, and an architectural landmark along the La Jolla coast. More complete mention of the Scripps family generosity and impacts in the early decades can be found throughout *Scripps Institution of Oceanography – First Fifty Years* [fn. 2].

5 Ibid., 16.

6 Ibid., appendix B.

7 Ibid., 184.

8 Peter J.S. Franks, "A Century of Phytoplankton Research at Scripps," *Oceanography,* 16(3)(2003), 60-66.

9 H. U. Sverdrup, Martin W. Johnson and Richard H. Fleming, *The Oceans – Their Physics, Chemistry and General Biology,* (Englewood Cliffs: N.J., Prentice-Hall, Inc., 1942, 13th printing 1964).

10 The importance of this book in its time can scarcely be overstated. It was as comprehensive as the authors could manage, although some reviews felt it left out some significant aspects of the subject. It influenced a generation of Scripps students and, through them, the establishment of oceanographic departments and curricula at new institutions that they went on to found. It had enough potential military use to be restricted to U.S. and Canadian circulation during its first years of publication. Good histories of the book and its impacts are referenced in fn. 11 and fn. 12 (below).

11 Deborah Day, "Scripps Before World War II: The Men, the Science and the Instruments," *Oceanography,* 16(3)(2003), 15-28.

12 John A. Knauss, "The Oceans as Educational Philosophy," *Oceanography,* 16(3)(2003), 29-31.

13 Sverdrup's Norwegian origins, and Munk's Austrian ones, cooked in the unholy cauldron of wartime fear and suspicion of foreigners, became ingredients for initiating loyalty investigations of both men and for retraction of their security clearances. Munk's clearance was later restored and he went on to an ongoing role as a key adviser to the Navy on all manner of highly classified topics and to the honor of a Secretary of the Navy Chair in Oceanography. Sverdrup's work on the wave problem

was not tripped up by his lack of clearance, but he was barred from some other work of possible military usefulness where he might have contributed much to the war effort. For a man who had lost a brother to the Nazis and who had had two sisters jailed by them, the wound must have been deep. After the war he returned to Norway and died there in 1957, never having learned the full story of the unfounded suspicions that had given rise to his clearance problems. Munk [fn. 17} recounts this sad history in short form. Day and Munk [fn. 18] give a much more complete account, including many details unearthed from FBI and military intelligence agency files via a Freedom of Information Act request in 1993. Tragically, some of the initial inputs of mere suspicion that triggered the investigations are traceable to Scripps colleagues of Sverdrup and Munk. As Munk and Day [fn. 18] have observed, "Wars, and the present included, awaken paranoid instincts." The Sverdrup clearance revocation stemmed not from malevolence on the part of the Scripps colleagues involved, but from the inherently risk-averse structure of the clearance machinery and its officials, with large incentives not to let any possibly-disloyal person through the filter. A consequence, as in the Sverdrup case, is that "in balance the true security of the country may well end up on the losing side."

14 Michael Longuet-Higgins (compiler), "Group W at the Admiralty Research Laboratory – Personal Reminiscences by Some of Its Members," in Anthony Laughton, John Gould, "Tom" Tucker and Howard Roe, *Of Seas and Ships and Scientists: The Remarkable Story of the UK's National Institute of Oceanography,* (Cambridge, The Lutterworth Press, 2010), 41-66.

15 H. U. Sverdrup and W. H. Munk, "Theoretical and Empirical Relations Between Wind, Sea and Swell," *Transactions of the American Geophysical Union,* 27(6), (1946), 823-827.

16 H. U. Sverdrup and W. H. Munk, "Empirical and Theoretical Relations In Forecasting Breakers and Surf," *Transactions of the American Geophysical Union,* 27(6), (1946), 828-836.

17 Hans von Storch and Klaus Hasselmann, *Seventy Years of Exploration in Oceanography: A Prolonged Weekend Discussion with Walter Munk,* (Heidelberg, Dordrecht, London, New York, Springer, 2010), 21-23. Hasselmann, a longtime colleague of Munk, is a key figure in the postwar science of ocean wave physics and dynamics that underpins postwar advances in wave forecasting.

18 Walter Munk and Deborah Day, "Harald U. Sverdrup and the War Years," *Oceanography,* 15(4)(2002), 7-29.

19 Blair Kinsman, *Ocean Waves,* (Englewood Cliffs: N.J., Prentice-Hall, Inc., 1965), 321.

20 Gary E. Weir, "Fashioning Naval Oceanography: Columbus O'Donnell Iselin and American Preparation for War, 1940-1941," in *The Machine in Neptune's Garden,* Helen M. Rozwadowski and David K. Van Keuren (eds.), (Sagamore Beach: MA, Watson Publishing, 2004), 65-91.

21 Elizabeth Noble Shor, *Scripps Institution of Oceanography: Probing the Oceans 1936 to 1976,* (San Diego, Tofua Press, 1978), 246. This book is the fundamental general history of Scripps for the period following that referenced in fn. 2, with some overlap.

22 Ibid., 247.

23 James M. Snodgrass, "Instrumentation and Communications," in John F. Brahtz (ed.), *Ocean Engineering: Goals, Environment, Technology,* (New York, London, Sydney, John Wiley & Sons, Inc., 1968), 397.

24 E. N. Shor, *op. cit.,* 89.

25 http://www.sippican.com/contentmgr/showdetails.php/id/312 (accessed Oct. 24, 2011).