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From Surveillance to Global Warming:
John Steinberg and Ocean Acoustics

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I would like to offer two scenarios separated by time and place but linked by both an individual and a historically significant perspective on the expansion of human knowledge.

In this initial product taken from a study in progress, I shall discuss the significance of the revolutionary work in ocean acoustics done by John Steinberg of Bell Telephone Laboratories. A physicist and acoustician, Steinberg made a second career for himself at the Institute of Marine Science at the University of Miami after his retirement from Bell in 1957.

The historically significant perspective to which I refer emerged from my work on the history of the Navy's involvement in the ocean sciences. In my book An Ocean in Common, published in 2001, I suggested that the demands of war, the availability of unprecedented talent and resources, and the relentless application cultural translation between 1940 and 1945 transformed the uncertain relationship between civilian ocean scientists and the U.S. Navy into a regular professional dialogue, a fluid partnership that served both human knowledge and the considerable discrete ambitions of both civilian science and the Navy.[1]

In linking the following two episodes, I shall illustrate the dynamics of this early postwar naval-scientific dialogue, highlight John Steinberg's unheralded discoveries, and demonstrate the ease with which scientific revelations about the world ocean passed from pure discovery, to military application, to civilian applied science, and back again. This amazing fluidity permitted knowledge, the associated technology, and a full appreciation of possible application to flow across significant and culturally formidable professional boundaries with great ease.

Exactly one year ago I sat in a hotel room across from a man who smiled frequently, regularly displaying a shining gold tooth, a distraction I had never before encountered while doing an oral history. While his tooth flashed in the hotel room light demonstrating one of the attractive attributes of that precious metal, his words proved infinitely more valuable. This interview took place in the Sheraton Hotel in Moscow, and across from me sat an experienced Soviet submarine driver.[2]

Roughly forty years earlier, Captain Second Rank Nikolai Shumkov, then commanding officer of the Soviet Foxtrot class diesel submarine B-130, found himself in a truly unenviable position. On 25 October 1962, off the American coast and barely one hundred feet below the surface in uncomfortably warm tropical waters, he realized the game had ended. Immediately above his head sat the American ASW carrier USS Essex and her entire task group. A secret Soviet naval operation codenamed Anadyr brought Shumkov and his crew to this fateful meeting. For the crew of Essex and their shipmates in the task group, this was the Cuban Missile Crisis.

When asked how he felt the Americans managed to track his progress and discover his position, Shumkov cited a number of technical problems his boat had experienced and its geographic proximity to the center of east coast American naval power. He also mentioned a disturbing American radio message. His communications officer intercepted an order broadcast in the clear from a shore facility to a Navy P-2V Neptune ASW aircraft authorizing an anti-submarine prosecution and giving B-130's coordinates with astonishing accuracy. At that point, I did not have to ask the obvious question. He stared at me for a moment, his smile fading along with his tooth. Then this experienced submarine commander looked me in the eye and in his heavy Russian accent said, "SOSUS."[3]

He had heard of the newly installed American network of deep ocean acoustic sensors and their possible capability. In 1962 he knew nothing more; very few people on either side of the Cold War did. Only one year earlier the U.S. Navy and the Western Electric and Bell Laboratories components of AT&T had completed the installation of the first generation acoustic arrays off the east coast of the United States. It fell under the codename Project Caesar. The system had yet to work out all of its technical flaws and few could then imagine its future capability.[4] Shumkov knew from experiences after 1962 that this network had probably tracked him for days, given his proximity to the American coast. With a depleted battery and significant technical failures, B-130 soon came to the surface on that October day in 1962 to the great satisfaction of the Essex Task Group commander and the U.S. Navy. To this day, Shumkov vividly remembers the humiliation of the experience. At the time, he could not know the extent of his acoustic vulnerability.[5] However, John Steinberg knew.

Almost thirty years later, as the Cold War began to loose much of its heat, a group of scientists conducted an experiment at Australia's Heard Island in the Indian Ocean. Driven by a desire to better understand the progress of global warming, in January 1991 these international experts sought to examine, over global distances, the range and behavior of powerful acoustic signals introduced into the ocean at Heard Island.

During World War Two American submarine commanders used the newly introduced bathythermograph to measure the temperature of the water outside the hull. Familiarity with temperature, depth, and, to a lesser degree, salinity, could make the difference between life and death. The ocean's temperature and depth would bend and direct the active sonar signals used by Japanese destroyers to hunt American submariners. With this knowledge in hand, American boats could evade by seeking acoustic shadow zones; areas missed by the active sonar because of the bathymetry of the water. The characteristics of the ocean all around them often became their greatest ally.

Employing this process conversely, signals introduced into the ocean and carefully examined would reveal, through their behavior, temperature variations as well as other physical attributes of the ocean over time and distance. Concentrating on critical characteristics of the sound related to phase, acoustic signal processing could both reveal, and provide a means to accurately monitor, many critical characteristics of the ocean. Since seawater covers seventy percent of the Earth's surface, ocean temperature would provide an excellent measure of the extent and variation of warming on a global scale. The Heard Island Feasibility Study called for monitoring stations in Asia, Africa, on the ocean surface in the Atlantic and Pacific, and on both American coasts to gather data on signals sent at regular times and at particular frequencies.[6]

The results of the 1991 experiment confirmed acoustic signal processing as an effective tool to monitor global warming. This experiment provided the foundation for the Acoustic Thermometry of Ocean Climate [ATOC] project, sponsored by the Office of Naval Research [ONR], the National Science Foundation, the Department of Energy, and the National Oceanographic and Atmospheric Administration [NOAA]. While his name rarely appears in the constellation of physicists and acousticians whose reputations rest in part on the origins and results of the Heard Island Feasibility Test, John Steinberg realized the potential of sound as an ocean monitoring tool thirty years before Walter Munk and his colleagues conducted their experiment in the Indian Ocean. Steinberg's discoveries while conducting SOSUS-related experiments in the Straits of Florida in the early 1960s made ATOC possible.[7]

Born in Lakota, Iowa on 21 June 1895, John Christian Steinberg returned from aviation duty during the Great War to the doctoral program in physics at the University of Iowa, completing his degree in 1922. He joined the Western Electric Company that same year, moving to a position at Bell Laboratories in 1925.[8] Another World War and twenty-five years later, Steinberg became part of the Project Jezebel team at Bell Labs led by Charles Wiebusch. Jezebel emerged as the cover name for SOSUS-related low frequency acoustic research.

When the Navy identified advanced German submarine design and technology captured and possibly exploited by the Soviets as the primary naval threat to the United States in 1950, deep ocean submarine surveillance suddenly became very desirable and assumed a very high priority. Prewar low-frequency acoustic propagation research by

Lehigh University's W. Maurice Ewing and his student John Lamar Worzel had already elevated this approach to ASW from desirable to theoretically possible. Ewing and Worzel discovered the deep sound channel, a layer of ocean that regularly permitted sound propagation over thousands of miles with minimal attenuation. After confirming their initial 1937 hypothesis, wartime research displayed the potential captive in this natural condition of the ocean. In 1945 a victorious Navy still showed little interest, but the Coast Guard authorized the creation of a rescue station in Hawaii based upon a system Ewing called SOFAR [Sound Fixing and Ranging]. This technique employed a small explosive charge set off in the deep sound channel by ships or individuals in distress. While the sound of the small explosion crossed entire oceans trapped in the channel, a process of triangulation enabled rapid response and rescue.[9]

Steinberg worked for seven years on Project Jezebel, the low frequency acoustic research that made the Sound Surveillance System [SOSUS] possible. For SOSUS, Soviet submarines would provide the noise that would propagate in the sound channel as they moved into the Atlantic Ocean from the Barents and Norwegian Seas or into the Pacific from Petropavlovsk. The system would listen silently for the telltale sounds of an operating submarine and report the boat's activity for ASW prosecution. As a senior Bell Labs physicist, Steinberg regularly attended meetings with the Navy that addressed the nature of the hydrophone arrays, their position, and every fundamental acoustic problem confronted by the project as the system deployed in the 1950s.

When he left Bell Labs for retirement and a research post at the University of Miami's facility on Virginia Key between Miami and Key Biscayne, Steinberg's interest in SOSUS continued. He received funding from the Office of Naval Research to explore seasonal variations in the sounds made by the marine life resident in the Florida Straits. Nature constantly provided a challenge for the SOSUS array operators who had to identify sounds and frequencies peculiar to submarines as opposed to marine life. Familiarity with the latter would assist in personnel training and the development of filtering techniques necessary to help them determine the particular acoustic signature of a hostile submarine. Naval ASW experts needed the various sounds made by operating submarines to emerge clearly from the ocean's ambient noise on the paper trace produced by the Low Frequency Analysis and Recording [LOFAR] system used for submarine surveillance at SOSUS shore facilities.[10]

Steinberg created sites at Fowey Rocks Light House, which marked the entrance to Biscayne Bay just off Miami, and on Bimini Island in the Bahamas about 48 miles distant for conducting active and passive acoustic measurements relative to SOSUS bioacoustics. William Cummings, a graduate student in biology at the University, assisted Steinberg as did a number of technicians who took responsibility for the equipment. By 1963 Steinberg and his team installed a continuous wave 420 Hz transmitter at Fowey Rocks that put a single tone into the ocean. They also placed receivers for both active and passive detection at ranges of eight and forty-seven miles from that source as well as a third actually on Bimini.[11]

Working from the National Museum of Natural History's Lerner Marine Laboratory on Bimini, Steinberg began to listen to noises in the region generated by various fish and mammals, paying special attention during the full and new phases of the Moon as well as across seasonal changes. He made scores of recordings, especially of the "clicking chorus" that took place during particular portions of the lunar cycle, a phenomenon that drove the SOSUS operators mad. Steinberg even experimented with using a vacuum tube driven television camera to observe marine life in the area, seeing if he could actually identify his swimming soloists by sight.

In most cases, scientists engaged in performing specific work under contract or on a grant would certainly accomplish the tasks necessary to satisfy their sponsor, but they would also use spare time and any available equipment to do some work of particular interest to themselves. Steinberg followed this model and while working on the bioacoustics project for ONR, he also studied basic sound propagation across the Florida Straits. Unfortunately, the transmission qualities of his 420 Hz sound source fell far below expectation. The Fowey Rocks signals barely registered at Lerner Labs in Bimini due to a poor selection of fabrication materials for the transducer's parabolic mounting frame. Lacking the funds to install another source, Steinberg needed to improve the reception gain from the existing source. [12]

Very interested in both Steinberg's primary line of investigation and his secondary interest, Marvin Lasky of ONR asked one of his program managers, Phillip Stockland for assistance. A veteran of the underwater acoustics branch at the Navy's David Taylor Model Basin in Carderock Maryland, Lasky arrived at ONR in 1957 to work for Aubrey Price in Code 411 supervising contracts related to ocean acoustics, both in pure research and in applied projects.[13] Stockland brought Lasky's attention to a University of Michigan mathematician then supported by ONR for his work in acoustic signal processing. Theodore Birdsall, at Michigan's Cooley Electronics Laboratory, received a quick and unexpected telephone call from Marvin Lasky suggesting very strongly that he put aside his current work and fly down to Miami. As an ONR fellow working with Steinberg in the summer of 1963, Professor Harry DeFerrari now of the University of Miami, recalled colleagues remarking that Lasky told Birdsall, " . . . to get down to Miami and find those guys [at Lerner] another 10 dB of gain or don't bother writing another [funding] proposal."[14] Apparently the argument proved immediately persuasive.

Choosing a technique also under study by Bell Labs, Birdsall found the solution in phase coherent demodulation. This technique employed a very narrow band filter that permitted the examination and manipulation of the amplitude and phase of the acoustic signal. Working together with ONR sponsorship, Birdsall and Steinberg improved the quality of the transmitted signal by 40 dB at the Lerner Laboratory receiver, surpassing Lasky's demand by 30 dB.

Once applied, this technique drew Steinberg's attention to the variation of the signal's amplitude and the unexpected regularity of its phase. Current wisdom resigned the phase to a random variable, not a steady, regular component of the signal's nature. In this case, Steinberg and Birdsall observed that the phase barely varied. After a few days, an astonished Steinberg concluded that the seemingly minor variation that he did observe reflected the natural action of the tides. Nearly forty years later, Harry DeFerrari recalled Steinberg's reaction and the significance of his conclusions,

It immediately occurred to Steinberg that you could make all kinds of measurements relative to the *whole ocean* by just looking at acoustic signals. That was the birth of tomography and acoustical oceanography and everything right there; it also gave the signal processing people on submarines a new way to process and to get new gain out of it, using the phase as a variable in detection. It was a major breakthrough and carried that group for another ten years.[15]

The potential resident in this effort immediately made partners out of the Universities of Miami and Michigan and the project adopted the name "MIMI," using the first two letters of each school name.[16]

In October 1965, Steinberg and Birdsall submitted their results to the Journal of the Acoustical Society of America under the title, "Underwater Propagation in the Straits of Florida," with Steinberg observing that,

Investigations of the acoustic characteristics of the Straits and of the requirements for a system suitable for measurement on a continuous basis were carried out over a 3-year period. Recently, an acoustic system and a limited environmental system were realized.

While the article focused primarily on the propagation issues, the stability of the phase, the application of phase coherent demodulation, the unexpected diurnal regularity of the phase variation, and the possible opportunities for environmental research and monitoring emerged clearly. Steinberg turned seventy just four months before submitting the article.[17]

MIMI consumed his attention for the balance of his years at Miami.[18] When John Steinberg retired for the second time in 1972, the seventy-seven year old acoustician joined Palisades Geophysical Institute's Miami Division as a senior scientist. J. Lamar Worzel and some of his colleagues at Columbia University's Lamont-Doherty Geological Observatory created Palisades Geophysical Institute as a commercial spin-off venture to absorb some of the defense contracts that many universities no longer found attractive or politically safe as shadow of American involvement in Southeast Asia lengthened. The Vietnam War and the policies of the Robert McNamara Defense Department did much to challenge the dialogue that emerged from World War Two. Worzel's company represented one solution to that challenge that Steinberg and many other acoustics specialists used to continue their work.[19]

Acoustic monitoring of global warming, ATOC, and other related projects find their roots in ASW and deep ocean surveillance. The policies of the Office of Naval Research and the Bureau of Ships in the two decades after World War Two demonstrated that both the ocean science community and the U.S. Navy had largely come to the conclusion that new insights into the environment writ large naturally addressed the individual curiosities, needs, and interests of both groups. After all, the naval battlespace defined by a particular set of coordinates had surface, air, and subsurface aspects. Research conducted by experienced and trusted investigators designed to enhance general human knowledge by objectively studying the jet stream, ocean currents, the deep sound channel, or the ocean bottom might easily produce critical defense insights and new capabilities. In the case before us, ONR recognized the expertise of an old Bell Labs veteran, encouraged the continued application of his talents to SOSUS and submarine detection, funded his research for many years, certainly addressed perceived defense requirements, but in the process recognized and sponsored a diversion that may possibly emerge as the best way to monitor an environmental threat to the future of humankind.

Participants in the professional dialogue that emerged from the effort to subdue the Axis understood and accepted the notion that discoveries and insights, regardless of the motive for finding them, often have useful and necessary applications beyond the limited vision of patron or scientist. For roughly twenty years after 1945, ONR, BuShips, and many scientists who worked on naval problems realized the limits of an *initial vision* or the *requirements of the moment* and money flowed for both the tantalizingly possible as well as the immediately practical. Thus there exists an unlikely but very important, and direct link between tracking Soviet submarines during the darkest days of the Cold War and our current effort to appreciate and control the damage we have done to our environment. That link rests with John Steinberg and a historically significant perspective on knowledge.

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[1] Gary E. Weir, An Ocean in Common: American Naval Officers, Scientists, and the Ocean Environment (College Station: Texas A&M University Press, 2001).

[2] Oral History with Captain First Rank Nikolai Shumkov by Gary E. Weir, Moscow, 14 February 2002. The oral history is in the possession of the author.

[3] Shumkov Oral History, 14 February 2002.

[4] Weir, An Ocean in Common, 298-315.

[5] Shumkov Oral History, 14 February 2002.

[6] Walter Munk and Arthur Baggeroer, "The Heard Island Papers: A Contribution to Global Acoustics;" Walter H. Munk, Robert C. Spindel et. al., "The Heard Island Feasibility Test," The Journal of the Acoustical Society of America (96, No. 4, October 1994), 2327-2329; 2330-2342.

[7] Walter H. Munk, Robert C. Spindel et. al., "The Heard Island Feasibility Test," The Journal of the Acoustical Society of America (96, No. 4, October 1994), 2330.

[8] "John Christian Steinberg," American Men and Woman of Science, the Jacques Cattell Press, ed., Twelfth Edition, Volume 6, St-Z "The Physical and Biological Sciences," (New York: Jacques Cattell Press/R.R. Bowker Company, 1973), 6092.

[9] Weir, An Ocean in Common, 298-315

[10] Oral History with Professor Harry DeFerrari, RSMAS, Miami, conducted by Gary E. Weir, 21 January 2000, Contemporary History Branch, U.S. Naval Historical Center.

[11] DeFerrari Oral History, 21 January 2000; http://lib1.nippon-foundation.or.jp/1998/0857/contents/020.htm

[12] The source was mounted in a parabolic frame that would help direct the sound toward the receivers at Bimini. When the frame was built the aluminum tubes used received a coat of copper-based anti-fouling paint. The frame was also expected to improve reception at Lerner by 14 dB. When installed, the copper in the paint reacted chemically with the seawater and the "boiling" action on the surface of the tubes caused many of them to flood. The entire episode resulted in a dampened signal and much diminished directivity.

[13] Statement of Personal History: Marvin Lasky, box 8, Marvin Lasky Papers, RC 21-5, Navy Laboratories Archive, David Taylor Research and Development Center. These

records now reside at the U.S. Naval Historical Center's Operational Archive, Washington D.C.

[14] DeFerrari Oral History, 21 January 2000.

[15] DeFerrari Oral History, 21 January 2000.

[16] John C. Steinberg and T.G. Birdsall, "Underwater Sound Propagation in the Straits of Florida," Journal of the Acoustical Society of America (vol 39 No.301, 1966), 301.

[17] Steinberg and Birdsall, "Underwater Sound Propagation in the Straits of Florida," 301-315.

[18] See also, J.C. Steinberg and M. Kronengold, "Fixed System Acoustic Measurements in the Straits of Florida," Journal of the Acoustical Society of America (Vol 51, No. 1 [part 1], 1972), 86.

[19] John Steinberg died in Miami in 1988 at the age of 93.

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