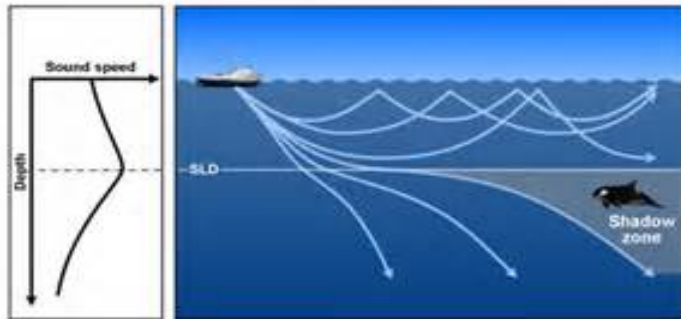


Acoustics at the Woods Hole Oceanographic Institution (WHOI) 1930-1960

Jim Lynch
Art Newhall
Bob Frosch

Sound in the Sea
Shadow Zone

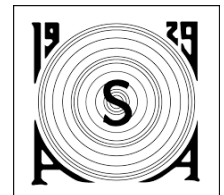


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WHOI 1940



169th Meeting of the Acoustical Society of America
May 19, 2015

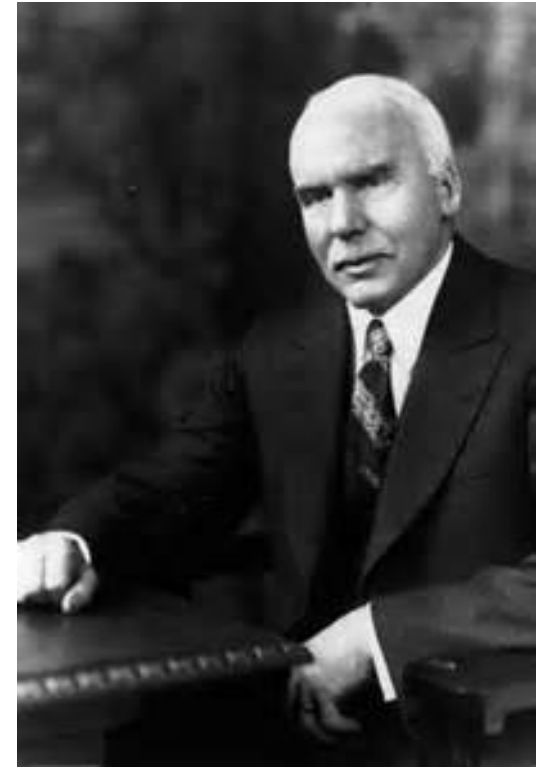


In the beginning....



Henry Bryant Bigelow piloting US Bureau of Fisheries vessel *Grampus* in 1914.

- The story starts with visionaries Henry Bryant Bigelow and Frank R. Lillie (MBL)
- Their vision was an oceanographic lab on the Atlantic that did all types of oceanography and had a full-ocean capable ship!
- Previously, researchers typically used vessels of opportunity (often less capable).



Frank Lillie (Marine Biological Laboratory)

1930-31... vision starts to come true

The entire “Oceanographic” was housed in the Bigelow Building in Woods Hole...



Bigelow building in 1945

The *Atlantis*, WHOI's first fully devoted, deep sea research vessel



Atlantis in 1931

1930-35...Hot fun in the summertime, but no acoustics...until this guy shows up

Chief Scientist Maurice Ewing
on *Atlantis* in 1949



- William Maurice “Doc” Ewing
- Young Lehigh Univ. physics professor looking for a good ship to do geophysics from ...hmmm



Deck of *Atlantis*
and often typical
working conditions

“Doc” Ewing – The Soul of the Enterprise



Doc Ewing (right) 1940

- From large Texas farming family – hardworking and resourceful
- BS, MS and PhD from Rice University
- Worked many side jobs, including Houston “oil patch”
- At Lehigh, developed unique interest in air/liquid/solid/ice interface seismics; blew up lots of NJ lakes, ponds, quarries and marshes.
- Two geologists (Bowie and Field) ask him if he can do similar research at sea to look at seafloor, and help get him \$2,000 GSA grant.
- From 1935-40, Ewing’s troupe works East Coast, with summer *Atlantis* trips being a premier at-sea opportunity.
- In 1940, Ewing moves his students to WHOI for duration of war.

He also dragged along some bright students... one of whom stayed at WHOI



Allyn "Al" Vine in 1940



Al Vine as we knew him

Alvin - his brainchild of later years

1964



2014



And a few other “no-names”

Doc Ewing produced many stellar students!



Joe Worzell



Frank Press

“**Joe**” **Lamar Worzel** (Associate Director at Lamont Geological Observatory, Director of Marine Science Institute Geophysics Laboratory) and **Frank Press** (President of US National Academy of Sciences, science advisor to four US presidents).

Ewing, Worzel and Vine energized acoustics (and much other) research at WHOI during 1935-40

- Ewing (in his car, “Floosey Belle”) and his students track back and forth from Lehigh to WHOI to test gear and grab data at sea
- Cars loaded with dynamite and delicate gear careen down hills without brakes, outrun hurricanes, and teach Car Repair 101 to students
- Ewing and his students set a 24/7/365 work ethic and enhance a ‘can-do’ attitude at WHOI



Doc Ewing (on right) checks his Floosey Belle (with help from his brother John)!

The Pre-War Years 1935-40 as seen by an undergraduate student (Worzel)



Ewing and Worzel assembling an 'Ash Can' explosive device.

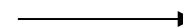
- Worzel is entrained after selling a camera to Vine and Ewing... and a fun jaunt to NJ to shoot some seismic lines. Cuts a class to do so, and finds a career.
- Learned how to create and repair equipment “on the job” – no COTS gear back then! Ewing, Vine, Webster and Worzel devised their own.
- 1936-38, they created and used seafloor seismic gear to be hung off *Atlantis*. Deep explosions were a new development, and geophones were homemade. Data was a photo record of the seismic trace!
- Deep-sea camera technology, magnetometer technology, pressure case technology, and mooring/deployment technology are all greatly advanced during this “quiet” pre-war era.



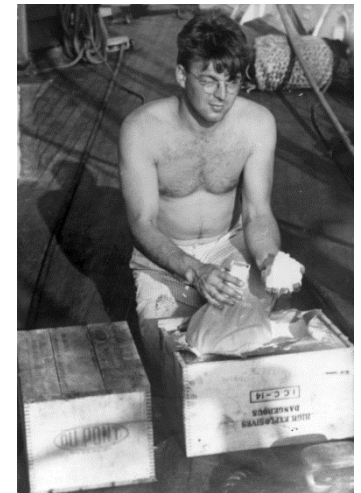
Student Joe Worzel
deploying an 'Ash Can'
from the *Atlantis*



Student Allyn Vine
whipping up more
explosives on deck.



Note “High Explosives
dangerous” label on box

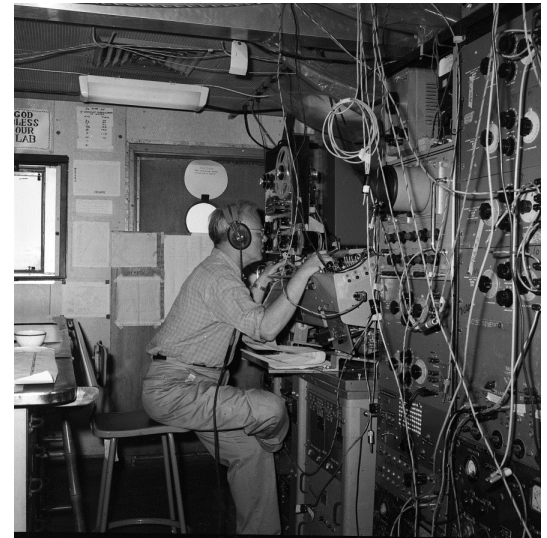


1940...Change is in the wind

- Worzel is accepted as a Lehigh grad student, and Vine is finishing up his PhD.
- Ewing is huddling with WHOI Director Columbus Iselin about ASW research directions...mainly the physics of sound transmission in top 100 fathoms of ocean.
- Vine and Ewing work on Bathythermograph (BT) improvements for the Navy.
- Bubble pulse is “rediscovered” and explained with help of “Doc” Edgerton “strobotron” photos.
<http://video.mit.edu/watch/underwater-explosion-phenomena-2626>
- NDRC established Jan 1, 1941. WHOI receives first Division 6 (Underwater Sound) contract, and “Sound Transmission in Sea Water” work done to date by Ewing et al. is first publication. Becomes a Navy manual.
- Ewing moves Vine and Worzel to WHOI for duration of war. “The Rectory” becomes a lively bachelor quarters. Newbie Brackett Hersey stays behind at Lehigh.



Doc Edgerton working with his camera on the WHOI dock in 1959



Brackett Hersey 1960

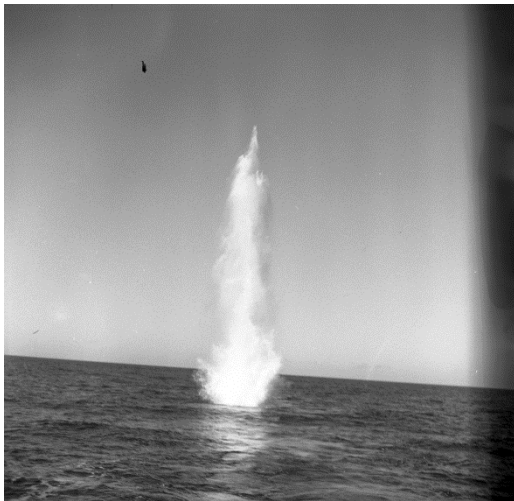
WWII at WHOI

Many Navy Projects! Deal with them!

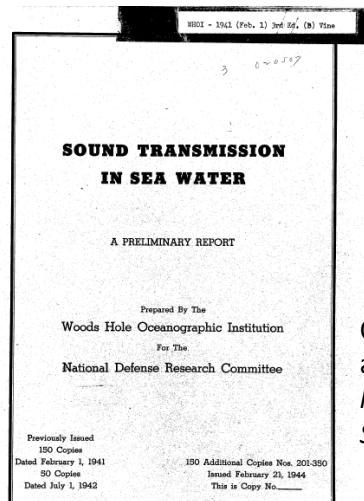


Joe Worzel and helpers unloading seismic charges

- First WHOI war project was anti-fouling paints. Mundane sounding, it saved the Navy ~10% on fuel, increased ship speeds, and reduced maintenance time! (“Navy 1”)
- Second project was “Sound transmission in Seawater” (“Navy 2”)
- Seventh project listed was “development and application of underwater explosives.” (“Navy 7”)
- Many other non-acoustics projects, but with relations to acoustics (hydrography, biology, etc.)



Seismic charge photo taken from *Atlantis*



Oceanography by Columbus Iselin, physics by Maurice Ewing, assisted by Allyn Vine, Joe Worzel and Alfred Woodcock
http://acoustics.who.edu/WHOI_acoustics_history/SoundTransmissionInSeaWater.pdf

Submarines and Mines



Al Vine assembling his underwater camera

- Underwater camera is developed to help divers assess wreck damage, navigation hazard potential (but PI's were not given charts of where wrecks or other hazards were, due to "need to know", and so occasionally traversed mine fields.)
- Big 1943 project was Shallow Water Acoustics! WHOI was asked (at first blindly) to totally understand 10-20 fathom propagation, all frequencies, all bottoms. Soon found why...
- Germans could set off (disable) entire acoustic mine field remotely using the ground wave from an explosive shot.
- Ground wave arrives first, sounds like a ship! Remedy – wait for the water wave to verify whether is a shot or a ship!

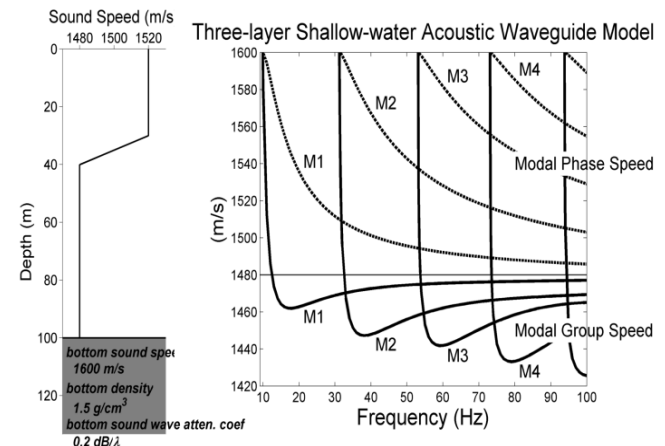
Shallow Water Acoustics

- Ala the minefield example, there was a need to understand acoustics on continental shelves
- So, Ewing and Worzel trucked all over East Coast getting data. Saw ground and water waves, and the other dispersion features of broadband pulses in SW.
- Sent their (unique!) data to a fellow at Columbia who had a theory of SW propagation, but no data – Chaim Pekeris. The rest is history.
- Had the fun (?) of chasing a German sub with SUS charges while taking data. Dangerous? Nah, Uboats weren't going to waste a torpedo on a small research vessel.



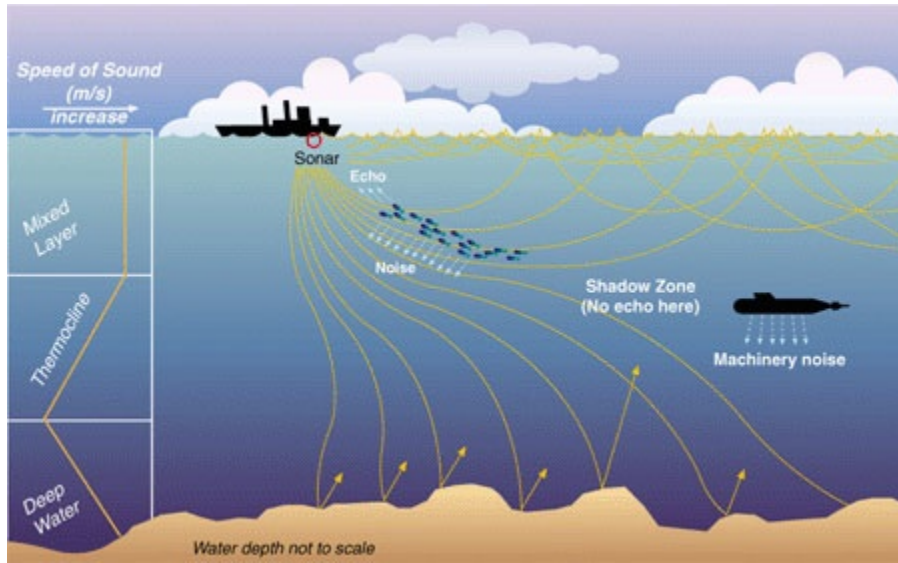
Chaim Pekeris

Worzel, Ewing, Pekeris (1948). *Propagation of Sound in the Ocean*, Contribution #415 from the Woods Hole Oceanographic Institution.



Acoustic modal dispersion vs frequency

The Afternoon Effect



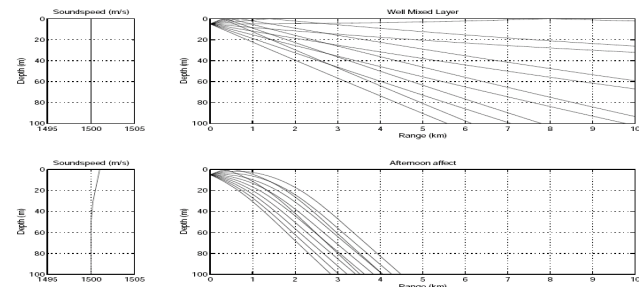
Bathythermograph (BT)

http://acoustics.whoi.edu/WHOI_acoustics_history/BT_A_Historic_Review.pdf

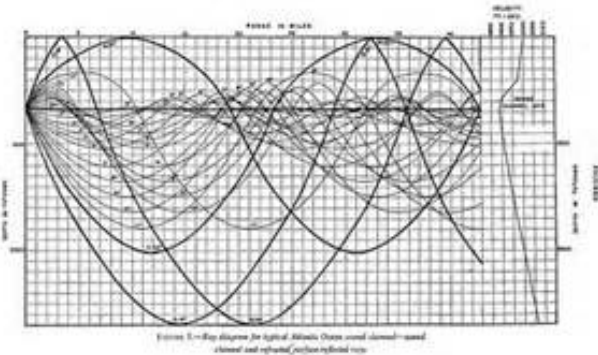
- Detection of subs was good in the morning, but deteriorated as the day went on. First looked at by WHOI in 1937.
- Surface heating, and thus downward refraction, create a shadow zone where subs can hide!
- BT (left) gives profile needed to hide or detect submarine.
- “God Bless Allyn Vine” from submariners...

Afternoon Effect (change of 3deg C)

Comparison of Sound Propagation when surface heats up 3 degrees C



Deep Water – The SOFAR Channel



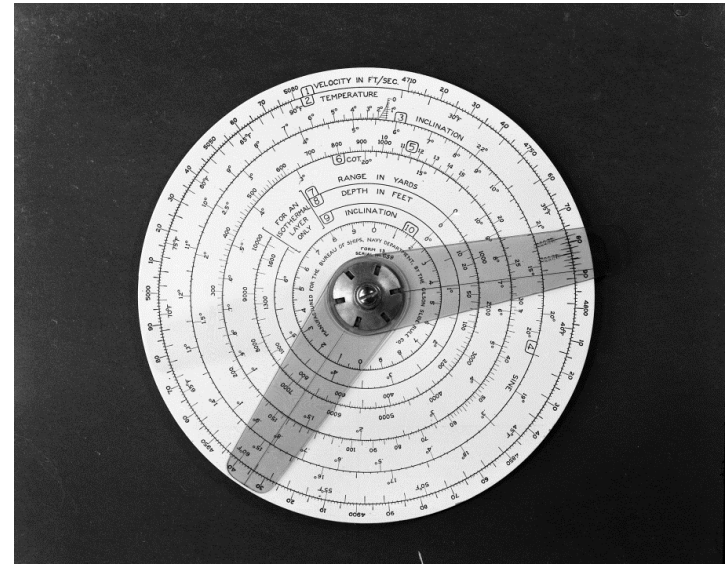
Worzel and Ewing assembling charge for submarine SOS location signal.

- Ewing had predicted the deep sound channel in the “Sound Transmission in Sea Water” memo
- In 1943, he proposes SOFAR propagation as useful for locating downed fliers.
- Prediction is tested off Bahamas with 4 lb TNT charges. Find out it works, and likely could be heard halfway around the world!
- However, fliers didn’t want SUS bombs on their planes... (!?)
- Brekhovskikh finds SOFAR axis independently via experiment, not by prediction.

If only we had more time....

Additional notable topics addressed at WHOI during the WWII era

- Deep scattering layer – Diel migration of organisms that created variable reverberation
- Deep sea detonators - Worzel came up with the state of the art detonator by grabbing the formula from kids cap pistols!
- Bottom profiling – Ewing was first and foremost a geophysicist, and this was the geological meat!
- Developed circular refractive slide rule for quickly calculating sound rays – Please raise your hand if you've ever used a slide rule. ;-)
- Effects of turbulence, bubbles, and vessel wakes on bottom hydrophones



Calculation of sound waves using a WHOI Refractive Slide Rule
http://acoustics.whoi.edu/WHOI_acoustics_history/refractive_slide_rule_manual.pdf

Other acoustics pioneers at WHOI

Arnold Arons



- Arnold was a staff member of the WHOI Underwater Explosives Research Laboratory, the "Navy 7" group, conducting explosives research for the U.S. war effort.
- He served as the WHOI research group leader that made shock wave measurements on the first atomic bomb tests at Bikini Atoll in 1946.
- Lured to the "Dark Side" (Physical Oceanography) by Hank Stommel, where he did quite well.



Arnold Arons and Hank Stommel
in lab behind Bigelow Building

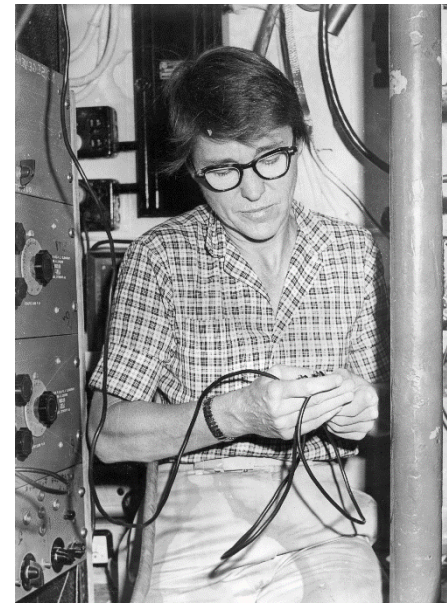


Arnold Arons (and colleagues) on Time Magazine
Cover, May 6, 1966

"As you obsolesce as a scientist, if you live long enough, you turn into a historian. I guess that's what's happened to me.", Arnold Arons, Oct. 2000, WHOI Ocean Acoustics Lab. (http://acoustics.whoi.edu/colleagues/arnold_aron.html)

Betty Bunce

- Betty was a member of the WHOI underwater explosives group starting in 1944.
- Betty's research included marine seismology, acoustic reflection and refraction, and underwater acoustics associated with seafloor studies.
- In 1959, she was the first woman to officially go to sea on a American research vessel for more than a daytrip.
- She was also the first woman ever to serve as chief scientist on an American oceanographic vessel.



Betty Bunce on *R/V Bear* 1951



Betty Bunce on *Atlantis II*



Betty and Dave Fahlgvist loading for sea duty

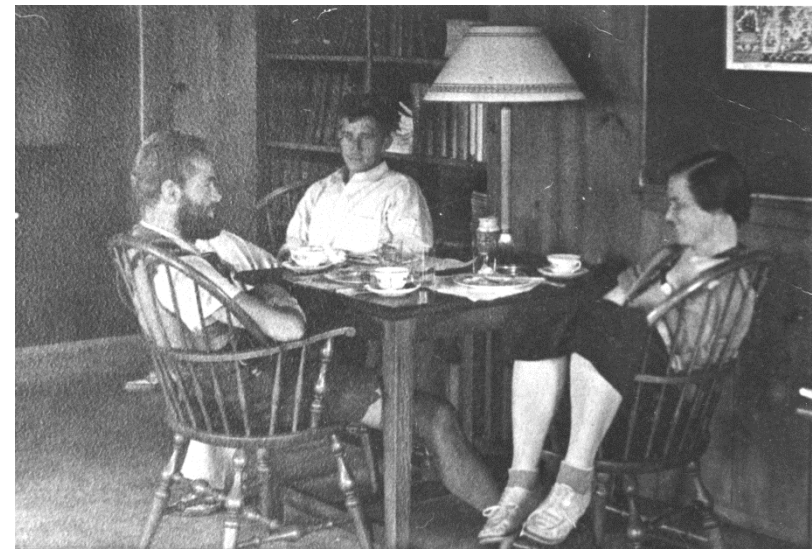
Mary Sears

- Mary worked summer appointments at WHOI in the 1930s and served on the WHOI scientific staff from 1940 to 1963.
- Also a Navy WAVE during World War II, she provided intelligence reports, “Submarine Supplements to the Sailing Directions,” which predicted the presence of thermoclines under which a submarines could hide to escape enemy detection by surface sonar.
- In 2000 the US Navy named a new naval research vessel, its sixth Pathfinder-class oceanographic survey ship, the *USNS Mary Sears*. This was the first time in its 225+ year history that the Navy named a research vessel for a woman.

USNS Mary Sears



Mary Sears in her Office in Bigelow Building Room 206.



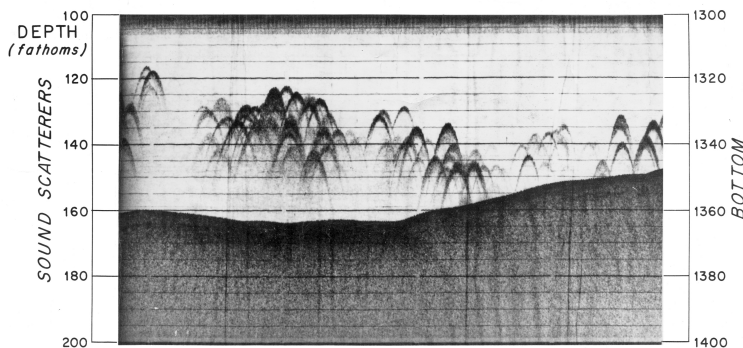
Mary Sears with WHOI colleagues relaxing in Bigelow Building Room 114.

Brackett Hersey

- Hired in 1947 to run the underwater acoustics program.
- He was the first WHOI department chairman of Geology & Geophysics. (1963-1966).
- Hersey's research included solid earth geophysics, underwater acoustics, physical oceanography, sound scattering by marine animals and marine geology.
- He worked to pioneer the development and use of towed instruments at sea, and received patents for methods of the study and applications in marine seismology and underwater acoustics.
- The best known and most-widely applied of these is the Continuous Seismic Profiler (CSP) for measurement of layered sediment beneath the ocean floor.



Brackett Hersey in 1948



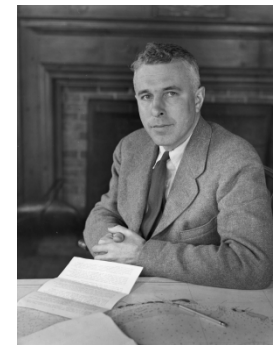
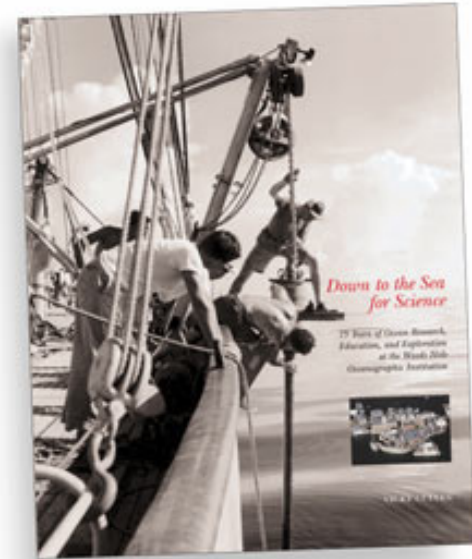
Hersey's recording of reflection patterns (1960)



Brackett Hersey in *Atlantis* lab in 1949

References and Thank You's

- “Down to the Sea for Science”, Vicky Cullen, 2005.
(<http://www.whoi.edu/75th/book/>)
- Autobiography, Joe Lamar Worzel, 2004. (
http://acoustics.whoi.edu/WHOI_acoustics_history/worzel-autobiography.pdf)
Highly recommended!
- “WHOI History During War Years, 1941-1950”, Columbus Iselin, 1955. (
http://acoustics.whoi.edu/WHOI_acoustics_history/WHOI_history_war_years_Iselin.pdf).
- WHOI Archives gets a very big THANK YOU
- All references can be found at
http://acoustics.whoi.edu/WHOI_acoustics_history.html



Columbus Iselin, 1949

And a thank you to our colleague and co-author Bob Frosch

Robert Frosch received his undergraduate and graduate degrees in theoretical Physics at Columbia.

1951-1963, Associate Director of Research at Hudson Laboratories where he was project manager of ARTEMIS, which developed active sonar for the Navy.

1963, Advanced Research Projects Agency in the US Department of Defense, serving as Director for Nuclear Test Detection and as the authority for the program of research and development as deputy director of the Advanced Research Projects Agency.

1966, Assistant Secretary of the Navy, in charge of all the research and development at the US Navy.

1973-1975, Assistant Executive Director of the United Nations Environmental Program

1975-1977, WHOI Associate Director for Applied Oceanography

1977-1981, NASA Administrator, Bob was the 5th Administrator and was overseeing development of the space shuttle program.

1981-1993, Vice President of Research and Development at General Motors.

He is still active in both scientific and technical policy activities today as: a Senior Research Fellow at Kennedy School of Government, Harvard University, a Guest Investigator in the WHOI Ocean Acoustics and Signals Lab, and WHOI trustee since 1975.



Frosch AIP Oral History Transcripts, http://www.aip.org/history/ohilist/28066_1.html (1 of 4)

Questions??

