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2023-07-15 underwater ears everywhere

Programming note: the subscribe link was broken for a while because I am bad at computers (yet another case of "forgot to enable the systemd unit"). It's fixed now. The unsubscribe link was also broken and is now fixed but, you know, maybe that was a feature. Did wonders for reader retention.

You may have seen some recent press coverage about events surrounding the *Titanic* and another notable loss at sea. I'm not going to rehash much of anything around the *Titan* because it's sort of an exhaustively covered topic in the mainstream press... although I will defend the Logitech controller by noting that Playstation-style controllers are extremely popular interfaces in robotics and 3D navigation (two symmetric analog sticks, unlike other major game controllers), and considering the genuine PS4 controller's terrible Bluetooth pairing UX with non-Playstation devices, the Logitech is probably a more reliable choice. And they did have spares on board!

I actually want to talk a bit about remote sensing, but of a rather different kind than I usually mention: hydrophones and wide-area sonar. This little-discussed military surveillance technology played a major role in the saga of the *Titan,* and it's one that seems poorly understood by both journalists and internet randos. I've seen a lot of Bad Takes about the Navy's involvement in *Titan* and I want to suggest a few things that might cause you to interpret the situation differently.

Submarines are very difficult to detect. This is a bad property for tourist ventures to the deep sea, but a very useful property to the military. Further, radio communications underwater are extremely difficult. Salt water attenuates radio signals very quickly, and while the effect decreases as you go to lower frequencies, it never goes away. Even the US Navy's sophisticated VLF systems require submarines to be relatively close to the surface (or rather use a wire antenna relatively close to the surface) for reception---VLF signals only penetrate seawater by up to about 40 meters. ELF offers better penetration into hundreds of meters, but ELF facilities are extremely expensive to build and operate and the receive antennas are formidably large, so the US Navy retired its ELF infrastructure in 2004.

For this reason, submersibles like *Titan* communicate with their surface support vessels via acoustic modems. This method is surprisingly reliable but produces a very low bitrate, thus the limitation of text messaging. Similar technology is used in deep-sea oil exploration, *Titan* likely used a commercial product for the data link.

The thing that propagates best underwater, in fact far better than above water and even better as you get deeper, is sound. The potential of sound for detecting and locating submarines is well-known. The first prominent use of this approach, widely called sonar, came about during the First World War when an anti-submarine surface ship successfully

detected a submarine directly below it via reflected sound. This type of sonar works well for locating nearby submarines, but it is an *active* technique. That is, an active sonar must *emit* a sound in order to receive the reflection. This is actually quite undesirable for many military applications, because emitting a sound reveals the presence (and with sufficient receiving equipment, location) of the sonar device. Anti-submarine ships stopped using active sonar on a regular basis fairly quickly, since it prominently advertised their presence to all of the submarines in the area.

Much more appealing is *passive* sonar, which works by listening for the sounds naturally created by underwater vehicles. With a sensitive directional hydrophone (an underwater microphone), you can hear the noise created by the screws of a submarine. By rotating the directional hydrophone, you can find the point of peak amplitude and thus the bearing to the submarine. This basic submarine hunting technique remains the state of the art today, but the receiving equipment has become far more capable and automated.

There is an arms race here, an arms race of quietness. I am resisting here the urge to quote the entire monologue from the beginning of *The Hunt for Red October,* but rest assured that [the Americans] will tremble again, at the sound of [the Soviet's] silence. In practice the magnetohydrodynamic propulsion technology depicted on the *Red October* has never proven very practical for submarines, although it was demonstrated in one very futuristic surface vessel built by Mitsubishi and called *Yamato 1* (fortunately it fared better than the battleship by that name). Instead, the battle of submarine silence has mostly revolved around obscure technical problems of fluid dynamics, since one of the loudest noises made by submarines is the cavitation around the screw. I don't know if this is true today, but at least years ago the low-noise design of the screw on modern US submarines was classified, and so the screw was covered by a sheath whenever a submarine was out of the water.

Passive sonar can be performed from ships and even aircraft-deployed buoys, but for the purpose of long-term maritime sovereignty it makes sense to install permanent hydrophones that function as a defensive perimeter. Just such a system was designed in the 1950s by (who else?) AT&T. AT&T had the expertise not only in acoustic electronics, but also undersea cable laying, a key component of any practical underwater surveillance system. Large arrays of hydrophones, spaced along cables, were laid on the ocean floor. The sounds detected by these hydrophones were printed on waterfall diagrams and inspected by intelligence analysts, who relied on experience and no small amount of educated guessing to recognize different types of marine life, geological phenomena, and vessels at sea.

This system, called SOSUS for Sound Surveillance System, remained secret until 1991. The secrecy of SOSUS is no great surprise, as it was one of the most important military intelligence systems of the Cold War. It presented a problem as well, though, as few in the Navy were aware of the details of the system and ship crews sometimes felt the abbreviated, zero-detail intelligence messages from SOSUS to be confusing and unreliable. They were being told of likely submarine detections, but knowing nothing about the system they had come from, they didn't know whether or not to take them seriously.

By the 1960s, SOSUS consisted of hundreds of individual hydrophones installed in long, cable-tethered arrays. Cables connected the hydrophone arrays to highly secured terminal facilities on the coast, which the Navy explained with a rather uninspiring cover story about undefined survey work. Over the following decades, computers were applied to the task, automatically detecting and classifying acoustic signatures. This early automation work inspired significant research and development on signal processing and pattern matching in both the military and Bell Laboratories, creating early precedents for the modern field of machine learning. Additionally, computer and telecommunications advancements allowed for remote control of the arrays, significantly reducing the staff

required for the program and leading to the eventual closure of many of the terminal naval facilities.

In 1984, SOSUS was renamed to IUSS, the Integrated Underwater Surveillance System. This new name reflected not only the increasing automation, but also the inclusion of several surface vessels in the system. These vessels, initially the USNS *Stalwart* and USNS *Worthy*, functioned as mobile IUSS arrays and could be moved around to either expand coverage or provide more accurate locating of a suspected target.

The existence of IUSS was finally declassified in 1991, although it was well known before that point due to several prominent press mentions. Since the declassification of IUSS it has enjoyed a dual-use role with the scientific research community, and IUSS is one of the primary sources of hydrophone data for marine biology. Today, IUSS automatically detects and classifies both submarines and whales.

The potential of passive sonar systems to detect submarine accidents is well-known. The 1968 loss of Soviet submarine *K-129* was detected by SOSUS, and the location estimate produced by SOSUS facilitated the recovery of *K-129* by the *Hughes Glomar Explorer,* one of the most fascinating naval intelligence operations of American history. 1968 was a bad year for submarines with four lost with all hands, and SOSUS data was used to locate at two of them (Soviet *K-129* and US *Scorpion*. French *Minerve* and Israeli *Dakar* would not be found for decades).

This all brings us to the modern era. *Titan* was lost on, presumably, the 18th of June. It was not located on the sea floor until the 22nd, four days later. Press reporting after the discovery included a Navy statement that IUSS had detected and located the implosion.

This has lead to a somewhat common internet hot take: that the Navy had definitive information on the fate of *Titan* and, for some reason, suppressed it for four days. I believe this to be an unwarranted accusation, and the timing of the location of the wreck and the statement on IUSS are readily explainable.

First, we must consider the nature of remote sensing. Remote sensing systems, whether space-based or deep underwater, produce a large volume of data. The primary source of actionable information in modern real-time remote sensing are computer systems that use machine learning and other classification methods to recognize important events. These computer systems must be trained on those events, using either naturally or artificially created samples, in order to correctly classify them. A major concern in naval intelligence is the collection of up-to-date acoustic signatures for contemporary vessels so that IUSS can correctly identify them.

A secondary method is retrospective analysis, in which human intelligence analysts review historic data to look for events that were not classified by automation when they occurred. Retrospective analysis, particularly with new signature information, can often yield additional detections. Consider the case I have previously discussed of the Chinese spy balloons: once signature information (almost certainly RF emissions) were collected, retrospective analysis yielded several earlier incidents that were not detected at the time due to the lack of signatures.

Like the RF spectrum, the ocean contains a lot of noises. They come from wildlife, from geological processes, and from commercial shipping, all besides naval operations. The Navy does not rigorously investigate every sound underwater, it can’t possibly do so.

When the Navy became aware of the missing *Titan,* analysts almost certainly began a

retrospective analysis of IUSS data for anything that could indicate its fate. They apparently detected loud noises and were able to locate the source as near the *Titanic* wreckage, probably fairly quickly after the *Titan* was first reported missing.

Here is the first challenge, though: the *Titan* was a new submersible of novel (if not necessarily well thought out) construction. The Navy has some familiarity with the acoustic signatures of imploding military submarines based on incidentally lost submarines and, in at least one case, the intentional torpedoing of a submarine to record the resulting acoustics (the *Sterlet*). This data is used to produce a signature against which new signals can be compared. Because of the significant differences in size and construction between *Titan* and military submarines, the Navy likely had very low confidence that known acoustic signatures of catastrophic losses were applicable. The total number of submarines to have ever imploded underwater is quite small, and none were of similar size and construction to *Titan*. The point is that while intelligence analysts likely *suspected* they had evidence of implosion, they probably had low confidence in that conclusion.

It is unwise, in the course of a search and rescue operation, to report that you *think* the vessel was irrecoverably lost. Doing so can compromise search operations by creating political pressure to end them, while making the situation of families and friends worse. It is customary to be very cautious with the release of inconclusive information in events like this. The problems are exemplified by the Coast Guard's announcement that another passive sonar system had detected possible banging sounds, which motivated a lot of reporting making wild conclusions based on acoustic signatures that were likely unrelated.

The more damning accusation, though, is this: did the Navy withhold information on the detection from searchers out of concern for secrecy? Setting aside that this makes little sense considering that SOSUS and its capabilities have been widely known to the public for decades, and the search site was well within historically published coverage estimates for SOSUS, this accusation doesn't align with the timeline of the search.

The first search vessel capable of deep undersea exploration, the ROV *Pelagic Odysseus 6k*, arrived on the scene on the morning of the 22nd. Just five hours later, *Odysseus* had located the wreckage. Considering that the descent to depth alone would have taken Odysseus over an hour, the wreckage was located extremely quickly in the challenging undersea environment. One reason is obvious: the wreckage of *Titan* was close to the *Titanic,* although the *Titanic* debris field is large and searching it all would have taken hours. The second reason became known shortly after: when *Odysseus* began its search, they had almost certainly already been tipped off by the Navy as to the location of the possible implosion.

The Navy did not withhold information on the detection for four days out of some concern for secrecy. Instead, the information was not known to the public for four days because that was when the search team was first able to actually investigate the Navy's possible detection.

Indeed, the idea that the Navy suppressed the information seems to come only from the rumor mill and internet repetition of half-read headlines. The original press coverage of the IUSS detection, from the WSJ, states that the Navy reported the finding to the Navy commander on-scene at the search effort immediately. It does include the amusing sentence that "the Navy asked that the specific system used not be named, citing national security concerns." This might seem like a huge cover up to those unfamiliar with intelligence programs, but it's perfectly in line with both normal military concerns around classified systems (which are often known by multiple names which must be kept

compartmentalized for unclassified contracting) and the specific history of IUSS, which during its period of secrecy had problems with being accidentally named in unclassified reports multiple times.

IUSS is now a smaller system than it once was, although with improving technology its coverage has probably expanded rather than contracted. It still serves as a principal method of detecting submarines near the US, an important concern since submarines are one of the main delivery mechanisms for nuclear weapons. IUSS is just one of several semi-secret underwater sensing systems used by the Navy.

A not totally related system that will nonetheless be of interest to many of my readers (who I suspect to be somewhat concentrated in the San Francisco Bay Area) is the San Francisco Magnetic Silencing Range. A small building in the parking lot of Marina Green, complete with a goofy little control tower from the era of manned operation, is the above-water extent of this system that uses underwater magnetometers to measure the magnetic field of Navy vessels passing through the Golden Gate. Since underwater mines are often triggered by magnetometers, the Navy ensures that the magnetization of vessel hulls does not exceed a certain limit. If it does, the vessel can be degaussed at one of several specially-equipped Navy berths---inspiration for at least one episode of The Next Generation. Similar arrays exist at several major US ports.

The building itself is long-disused, and the array is now fully remote controlled. When I lived in San Francisco it was abandoned, but I see that it has apparently been restored to function as the harbormaster's office. I appreciate the historic preservation effort but something is lost with the removal of the Navy's sun-faded signage.