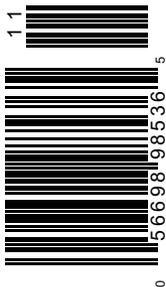
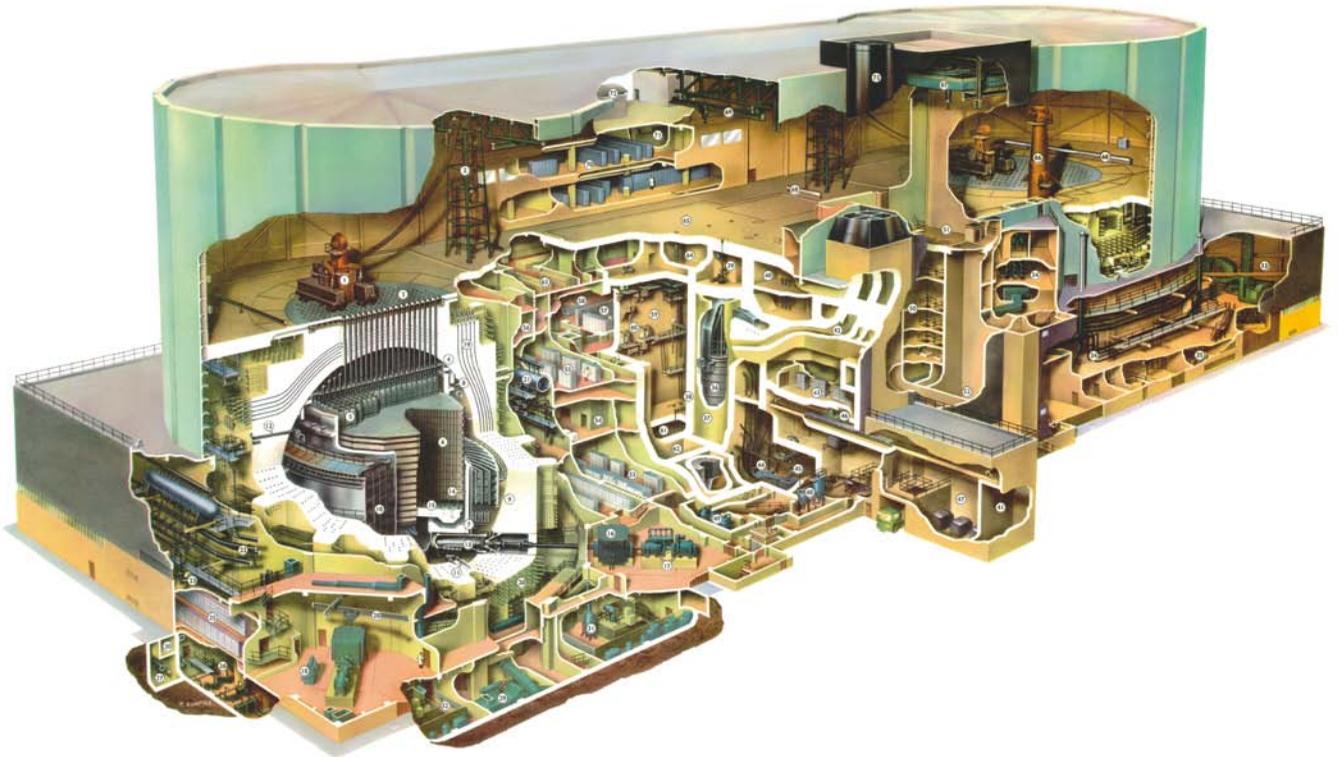


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AUTONOMOUS BIOLOGICAL SENSOR PLATFORMS

ETIENNE BENSON

Late in 2010, the *Journal of Geophysical Research* printed a report under the title “Narwhals Document Continued Warming of Southern Baffin Bay.”¹ The research described by the report was heavily promoted by the US National Oceanic and Atmospheric Administration, which had partially funded it, and the story was picked up by a number of newspapers and blogs, one of which praised the narwhals as “excellent field techs.”²

Who were these narwhals? How had they gotten into the business of not merely responding to or communicating among themselves about Arctic climate change but actually *documenting* it?

Not surprisingly, while it may have been narwhals who documented Baffin Bay’s shifting temperatures, it was a team of humans, led by marine biologist Kristin Laidre, who were responsible for sharing the documents with the world. Laidre’s team had gathered the narwhals’ records, fed them into modeling and mapping software, cogitated over the results, and written the report. And, indeed, it was they who had wired sensors and satellite transmitters to the dorsal ridges of fourteen narwhals captured off the coasts of Greenland and Arctic Canada between 2005 and 2007, making it possible for the cetaceans to “document” the water temperatures they encountered.

The *Journal of Geophysical Research* study represented a first attempt to deploy narwhals as components of a global infrastructure of environmental surveillance, and it required Laidre and her colleagues to overcome a number of difficult and even dangerous challenges. But it was only an incremental advance in a broader field of animal-borne sensing that had grown rapidly since the early 1990s, when improvements in microprocessors and satellite systems first made the remote retrieval of data from wildlife tags feasible. Before narwhals took their turn, penguins, albatrosses, seals, turtles, and tuna had all served as “platforms for oceanographic sampling,”³ “autonomous ocean profilers,”⁴ “oceanographic data collectors,”⁵ and even “oceanographers” *tout court*.⁶ The recruitment of the one-toothed, one-horned species (*Monodon monoceros*) classified by Herman Melville among the Octavoos, or “whales of middling magnitude,” merely expanded the menagerie.⁷

The idea of using electronically enhanced animals as tools for oceanographic and climatological

research, moreover, preceded this recent boom by several decades. Its roots lay in the 1960s and 1970s, when a small network of marine mammalogists began experimenting with electronic methods for tracking their elusive research subjects by adapting cold war gadgetry to cetological and oceanographic exigencies.⁸

As in most cases of invention, the longer one looks the more founders one finds, but William E. Evans, who died in 2010 at the age of 80, stands out among his peers. Although an illustrious career in marine mammalogy and environmental policy lay ahead of him, in the early 1960s Evans was still a young engineer at the Lockheed Aircraft Corporation’s offices in Burbank, California, where as part of a psychoacoustics research group he studied the effects of aircraft noise on humans and animals and the impact on naval sonar operators of spending long periods of time listening to ocean noise.⁹

Evans’s interest in psychoacoustics soon bloomed into a full-fledged passion for creatures of unusual sonic interest: dolphins. Taking inspiration from the cornucopia of space-age gadgets then flooding out of companies like Lockheed and from the evidence of cetacean intelligence being put on daily display at Marineland of the Pacific, a nearby theme park, he began searching for better ways to study dolphin communication in captivity and in the wild. For this project, the community of defense bioacousticians, naval engineers, academic cetologists, and theme-park entrepreneurs that had emerged in postwar Southern California—one might as well call it the military-cetological complex—proved to be a crucial resource.¹⁰

In 1962, Evans presented his latest ideas at the American Museum of Natural History in New York as part of a conference on “Bio-Telemetry” planned and funded by the Office of Naval Research, then the main supporter of US marine mammal research. The conference brought together an eclectic mix of biologists and engineers, including the cybernetician Warren McCullough, the cognitive ethologist Donald Griffin, and the neurophysiologist José M.R. Delgado, who would later become infamous for advocating “psychocivilization” through remote brain control.¹¹

To this accomplished and ambitious group Evans proposed two systems for enhancing humans’ access to dolphins’ underwater worlds. In one, a small radio transmitter attached to a dolphin’s head by suction cup would make it possible to record the individual’s vocalizations; in the other, a remote-controlled skiff equipped

opposite: A gray whale named Gigi with transmitter affixed to her back, awaiting release into the sea near San Diego in March 1972. Photo J. S. Leath-erwood. Courtesy of US National Oceanic and Atmospheric Association.



Being infrastructure is hard work. Narwhals, after a long day on the job, surfacing to catch a breath off of Baffin Island, Nunavut, Canada. Courtesy Paul Nicklen / National Geographic.

with television cameras would allow researchers to get a close-up view of dolphins in their natural environment. Inevitably, perhaps, Evans and fellow Lockheed engineer William Sutherland had dubbed the latter the “Motorized Observation Biotelemetry Yacht–Data Integration and Control,” or MOBY-DIC.¹²

Today, the proceedings of the Bio-Telemetry conference have an almost quaint feel, pervaded as they are by cybernetic tropes and space-age optimism about the power of technology. In subsequent years, the visions so enthusiastically presented by its participants proved difficult to realize, particularly for those, like Evans, eager to study animal life outside of the laboratory. In the open ocean, well-tested devices succumbed to water pressure or corrosion or simply failed for mysterious reasons. When the signal from a tagged dolphin disappeared, it was often impossible to tell whether the battery had been exhausted, the antenna had snapped off, the electronics had short-circuited, the animal had been eaten by a shark, or the researchers had simply failed to search in the right place at the right time.¹³

Such challenges meant that Evans had few serious companions or competitors in the quest for an

effective cetacean-tracking system. In 1964, he left Lockheed to begin graduate studies in marine mammalogy at UCLA and to take a part-time position with the US Navy’s new Marine Mammal Program.¹⁴ There, while putting sea lions and bottlenose dolphins to work in the nation’s defense, he had access to plentiful research subjects, generous funding, and the latest in naval technology. By the end of the 1960s, in partnership with engineers at a small oceanographic instrument firm called Ocean Applied Research, Evans had developed the two essential components of a dolphin-tracking system. One was a robust tag; the other was an “automatic direction finder” that could localize a radio signal even when it was detectable only for those few seconds that the antenna of a coursing dolphin’s tag might break the water’s surface.¹⁵

In Southern California’s tight-knit cetological community, advances made in the context of national defense were quickly disseminated to academic research and theme-park management, and vice versa. In 1972, SeaWorld asked Evans to develop a radio tag that could be used to track Gigi, a young gray whale (*Eschrichtius robustus*) who had been captured as an



Scientists attach a satellite tag to a male narwhal. Courtesy Paul Nicklen / National Geographic.

infant in one of the calving lagoons of Baja California and subjected to a year's worth of scientific tests before SeaWorld determined that it would be too expensive to maintain her permanently in captivity. Evans's tag would make it possible to continue studying Gigi even after her release, while helping SeaWorld reassure an increasingly whale-mad public that the experience had done her no lasting harm.¹⁶

Evans would later recall being deeply skeptical of the scientific value of SeaWorld's adventure in gray whale captivity, but he leaped at the unique opportunity to advance his radio-tracking work.¹⁷ Unlike the tagged dolphins who had preceded her, Gigi would be a tool *for* research as well as an object *of* research. More precisely, she would be an entirely unprecedented form of "Mobile Marine Environmental Survey Vehicle."¹⁸

In practice, this meant that Gigi's tag would not only signal her location as she migrated northward but would also transmit information about dive depth and water temperature, just as the narwhals tagged by Laidre and her colleagues would some three decades later. NASA, in the midst of its post-moon-shot search for a *raison d'être*, pitched in funds and

engineering expertise for the project. The idea was that satellite-borne instruments might eventually gather data from an armada of cetacean sensor platforms, autonomous probes for a Mission to Planet Earth.¹⁹

In the event, Gigi's erratic diving behavior and damage sustained by the tag almost immediately after her release prevented Evans from collecting much useful data. But it was a start, a "Phase I" of something bigger. Phase II, carried out while Gigi was still making her way up the California coast, transformed a Pacific common dolphin (*Delphinus delphis*) into a tool for mapping fish populations. This time, Evans's team managed to collect seven hours of data by airplane before the signal was lost. Although the scientific goal was different than in Gigi's case, the infolding of figure and ground was much the same. From using tags to study animals, Evans and his colleagues had graduated to using tagged animals to study the environment. Instruments had become components, animals "oceanographic survey platforms."²⁰

Evans continued to play a key role in the development of cetacean radio-telemetry through the end of the 1970s. When he subsequently shifted his attention to

other research methods and to matters of policy, others picked up where he left off, including a new generation of marine mammalogists for whom the cold war configurations of their discipline epitomized in the Southern California of the 1960s were, though hardly irrelevant, no longer central.

By the mid-1990s, this new generation had woven together a set of technologies and infrastructures that made the space-age dream of collecting data from far-ranging oceanic animals a reality. These included attachment techniques that kept tags affixed to animals for months or years, energy-dense batteries that powered ever smaller and more powerful transmitters, satellite systems capable of collecting data from any location on the Earth's surface, and powerful computers that could analyze thousands of data points per tagged animal. Meanwhile, the specter of global climate change gave biologists new reasons to consider wild animals not just as fascinating and threatened subjects of research in their own right but also as sources of environmental data.²⁰¹

It is easy, perhaps all too easy, to figure Gigi, the fourteen narwhals used by Laidre et al., and animals in other such studies as a kind of found infrastructure that requires only the slightest of modifications to become a rich source of environmental data, just as we might describe navigable rivers as a found infrastructure of transportation. But if it is an easy figuration, it is also a restless one that oscillates with the equally compelling figures of sensor-bearing animals as oceanographers or as subjects of research.

Although the subject position of the satellite-tagged narwhal is unique, this oscillation, I would argue, is not. More and more of us carry compact radio transmitters equipped with a wide array of sensors and networked into a global telecommunications infrastructure. It is increasingly common to find oneself individuated through a global infrastructure of communications and surveillance, then subsumed into that infrastructure as a tool for making other actors visible, then separated out once again as a "documenter" of the world, then instrumentalized once again, and so on *ad infinitum*. These days, infrastructure is a role that comes and goes.

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4 Barbara A. Block, "Physiological Ecology in the 21st Century: Advancements in Biologging Science," *Integrative and Comparative Biology*, vol. 45, no. 2 (2005), p. 305.

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6 Jean-Benoît Charrassin, Young-Hyang Park, Yvon Le Maho, and Charles-André Bost, "Penguins as Oceanographers Unravel Hidden Mechanisms of Marine Productivity," *Ecology Letters*, vol. 5, no. 3 (2002), p. 317.

7 Herman Melville, *Moby-Dick; Or, the Whale* (New York: Penguin, 2001), pp. 153–154.

8 This history is partly told in my *Wired Wilderness: Technologies of Tracking and the Making of Modern Wildlife* (Baltimore: Johns Hopkins University Press, 2010), pp. 139–188; see also Amy Samuels and Peter L. Tyack, "Flukeprints: A History of Studying Cetacean Societies," in Janet Mann, Richard C. Connor, Peter L. Tyack, and Hal Whitehead, eds., *Cetacean Societies: Field Studies of Dolphins and Whales* (Chicago: University of Chicago Press, 2000), pp. 9–44.

9 For these and other details on Evans's career, see William E. Evans, *Fifty Years of Flukes and Flippers: A Little History and Personal Adventures with Dolphins, Whales and Sea Lions* (Sofia: Pensoft, 2008).

10 On military-academic-entertainment links, see Gregg Mitman, *Reel Nature: America's Romance with Wildlife on Film* (Cambridge, Mass.: Harvard University Press, 1999), pp. 157–179; D. Graham Burnett, "A Mind in the Water," *Orion*, vol. 29, no. 3 (May–June 2010), pp. 38–51.

11 Lloyd Slater, ed., *Bio-Telemetry: The Use of Telemetry in Animal Behavior and Physiology in Relation to Ecological Problems* (Oxford: Pergamon, 1963); José M. R. Delgado, *Physical Control of the Mind: Toward a Psychocivilized Society* (New York: Harper & Row, 1969).

12 William E. Evans and William W. Sutherland, "Potential for Telemetry in Studies of Aquatic Animal Communication," in Lloyd Slater, ed., *Bio-Telemetry: The Use of Telemetry in Animal Behavior and Physiology in Relation to Ecological Problems* (Oxford: Pergamon, 1963), pp. 217–224.

13 For examples of many such difficulties, see William A. Watkins and William E. Schevill, *The Development and Testing of a Radio Whale Tag*, Woods Hole Oceanographic Institution Technical Report WHOI-77-58, September 1977.

14 On the Marine Mammal Program, see William E. Evans, "A Short History of the Navy's Marine Mammal Program," *Aquatic Mammals*, vol. 34, no. 3 (2008), pp. 367–380.

15 William E. Evans, "Orientation Behavior of Delphinids: Radio Telemetric Studies," *Annals of the New York Academy of Sciences*, vol. 188 (1971), pp. 142–160.

16 William E. Evans, "Telemetry of Temperature and Depth Data From a Free Ranging Yearling California Gray Whale, *Eschrichtius robustus*," *Marine Fisheries Review*, vol. 36, no. 4 (1974), pp. 53–58; Eleanor Coerr and William E. Evans, *Gigi: A Baby Whale Borrowed for Science and Returned to the Sea* (New York: Putnam, 1980); William E. Evans, op. cit., note 9, pp. 71–72.

17 Evans expressed his skepticism in the Senate nomination hearing for his chairmanship of the US Marine Mammal Commission. See *Nomination—Marine Mammal Commission, Hearing Before the Committee on Commerce, Science, and Transportation*, 12 March 1984, US Senate, 98th Congress, 2nd session, pp. 12–13.

18 William E. Evans, "Mobile Marine Environmental Survey Vehicle: Phase I Report," Naval Undersea Center Technical Note 758, April 1972.

19 On NASA's involvement in satellite-based wildlife tracking, see Paul Sebesta and Roger Arno, *Wildlife Monitoring Program Plan*, April 1979, NASA Technical Memorandum 78578.

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21 Charles H. Greene, Barbara A. Block, David Welch, George Jackson, Gareth L. Lawson, and Erin L. Rechisky, "Advances in Conservation Oceanography: New Tagging and Tracking Technologies and Their Potential for Transforming the Science Underlying Fisheries Management," *Oceanography*, vol. 22, no. 1 (2009), pp. 210–222.