

# Trailblazer in the Ocean Depths

ALVIN CELEBRATES 50 YEARS OF PIONEERING ACCOMPLISHMENTS *by Kate Madin and Lonny Lippsett*



Draped in bunting and with a Navy brass band playing, the new research submersible *Alvin* was commissioned at the Woods Hole Oceanographic Institution dock on June 5, 1964.

This year marks the 50th anniversary of two of America's most iconic, cutting-edge vehicles: the Ford Mustang, and another vehicle that was hardly sleek or stylish and didn't have a bold, jazzy name. Three years after President John F. Kennedy committed the nation to the goal of "landing a man on the moon and returning him safely to the Earth"—and five years before we did so—a stubby white submersible was built with the goal of taking people to the bottom of the ocean and returning them safely to the surface: *Alvin*.

Owned by the Navy and operated by Woods Hole Oceanographic Institution (WHOI), *Alvin* was officially commissioned June 5, 1964, in a ceremony attended by hundreds at the

WHOI dock. Over its first half century, it responded to national crises, recovered a lost hydrogen bomb and investigated the impacts of the Deepwater Horizon oil spill. It helped document the world's most famous shipwreck. It revealed seafloor terrain that scientists never imagined. It discovered unexpected deep-sea life thriving without sunlight, revolutionizing our understanding of where and how life could exist on Earth and other planetary bodies. It inspired the development of new generations of deep-submergence technology and vehicles, as well as generations of future scientists, engineers, and explorers.

Much has already been written about *Alvin*, but a brief retelling of its story seems appropriate to celebrate the sub's 50th birthday.



Scientists convene in Washington, D.C., to discuss how to study the ocean depths. WHOI scientist Allyn Vine suggests building a submersible. Participants draft a resolution that the U.S. should develop manned undersea vehicles.

1956



WHOI contracts with General Mills to build a small research submersible capable of diving to 6,000 feet. Cost: \$498,500.

1962



The newly formed WHOI Deep Submergence Group starts using the name *Alvin*, after Allyn Vine. *Alvin* is commissioned on June 5 on the WHOI dock.

1964



*Alvin* makes its first 6,000-foot dive, to obtain Navy safety certification.

1965

## Vine and Darwin

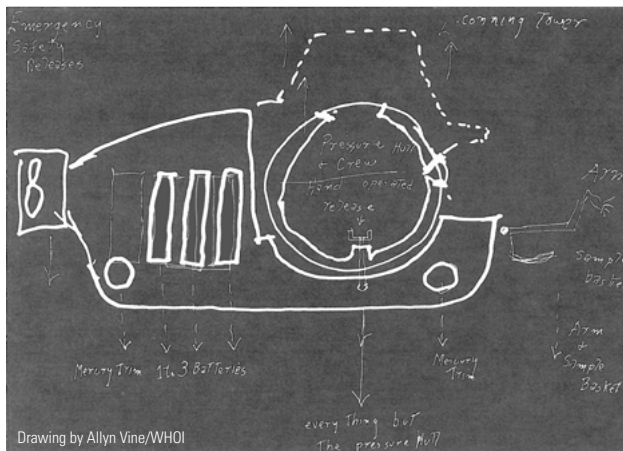
In the mid-1950s, the deep seafloor was literally a black hole. Scientists had little idea what was down there and little access to find out. Submarines existed, but they did not go so deep, and they lacked windows. Auguste Piccard had built the bathyscaphe *Trieste*, a windowed sphere suspended under a blimp-like structure filled with thousands of gallons of gasoline. But it was unwieldy and had no sampling capabilities.

In 1956, the National Academy of Sciences and National Research Council convened a symposium in Washington, D.C., to discuss how to study the deep ocean. Among the 103 oceanographers present was WHOI scientist Allyn Vine, who later wrote: “A small group of oceanographers at the Woods Hole Oceanographic Institution and elsewhere felt that it was preferable to look at this exciting ‘last frontier’ directly from small deep-diving manned submersibles rather than with remote viewing systems.”

At the symposium, Vine made this famous statement, which seemed to stir the participants: “I believe firmly that a good instrument can measure almost anything better than a person can if you know what you want to measure. ...

But people are so versatile, they can sense things to be done and can investigate problems. I find it difficult to imagine what kind of instrument should have been put on the *Beagle* instead of Charles Darwin.”

Symposium participants enthusiastically passed a resolution to develop a national program to develop “vehicles capable of transporting men and their instruments to the great depths of the ocean.”



WHOI scientist Allyn Vine helped design the sub named after him. He sketched *Alvin's* many safety features, including a way to release the sphere containing people (which never was necessary).

## From the makers of Cheerios

Charles “Swede” Momen Jr., chief of undersea warfare at the Office of Naval Research, was a proponent of a deep research sub. He had seen plans for a small submersible vehicle called *Seapup* developed by Harold “Bud” Froelich, an engineer at General Mills Corp. (whose products once ranged way beyond cereals).

In 1962, with Navy backing, the newly formed Deep Submergence Group at WHOI requested bids to build a submersible based on *Seapup*. But the WHOI group had already started calling the proposed sub *Alvin* to honor Allyn Vine. Despite its lack of gravitas (and a cartoon chipmunk popular at the time), the name stuck and became official.



The U.S. Navy calls in *Alvin* to help find a hydrogen bomb that was accidentally dropped into the Mediterranean Sea. The *Alvin* team finds and helps recover the bomb.

1966



Steel support cables holding *Alvin* snap at the beginning of a dive. The pilot and observers scramble to safety, but *Alvin* sinks 5,000 feet to the seafloor.

1968



*Alvin* is recovered after 10 months under water, transported to WHOI, and repaired. Lunches left on board are saturated but not decayed. This discovery leads to new ways to study deep-sea microbes.

1969



*Alvin* dives with Ruth Turner aboard, the first dive with a woman scientist.

1971



With a \$498,500 bid, General Mills won the contract to build a submersible capable of carrying three people to a depth of 6,000 feet. In 1962, Lukens Steel Co. in Coatesville, Penn., made 6-foot-diameter steel plates and shaped them into hemispheres. Hahn & Clay in Houston, Texas, welded them together to make three spherical pressure hulls—for *Alvin* and for the Navy's deep-submergence vehicles *Sea Cliff* and *Turtle*, both now retired from service.

"We had tried to think of almost every conceivable situation that might imperil human life, and devised ways to avoid

For its first 20 years, *Alvin* traveled on and was launched from a tender ship *Lulu*, named after Vine's mother. The catamaran was built out of two surplus Navy pontoons.



such crises," Vine later wrote in *Oceanus* magazine. "*Alvin's* major safety feature was the crew's ability to return to the surface by releasing the pressure hull ... from the sub's underbody and chassis. In that way, the crew could escape if, say, the sub's arm or other projection became entangled in debris on the bottom."

During the two years of *Alvin's* construction, General Mills sold its fabrication division to Litton Industries. Froelich remained with Litton, and the sub was delivered in May 1964 and commissioned in June. Later that summer, Vine, Froelich, and *Alvin's* first pilot William Rainnie baptized *Alvin* in Woods Hole Harbor. Its first year or so was largely given over to test dives.

### Along came *Lulu*

The sub soon acquired its first "tender" ship. In the spirit of innovation and tight budgets that often characterizes oceanography, the ship that *Alvin* would travel on for two decades was built on Cape Cod

from two surplus Navy pontoons, making a catamaran, with an easy entrance and exit for the sub in the middle. The tender was named *Lulu*—Vine's mother's name.

Rainnie was first in a line of only 39 *Alvin* pilots. (By contrast, there were 74 space shuttle commanders from 1977 to 2011.) He and the first three relief pilots, Marvin McCamis, Valentine Wilson, and Edward Bland, were all ex-Navy submariners.

Rainnie and McCamis made increasingly deeper dives, many in the Bahamas where the deep water of Tongue of the Ocean is close to shore. There, the submariners inspected the Navy's ARTEMIS underwater listening array, fulfilling one of the objectives Momsen had promoted to secure Navy funding for the submersible project. Testing included one tethered, unoccupied, twelve-hour test dive to 7,500 feet, for safety trials. *Alvin's* first piloted dive to 6,000 feet, its original depth rating, took place with Rainnie and McCamis aboard on July 20, 1965, earning the sub Navy certification.

### Accidents and incidents

Soon after, in January 1966, two U.S. Air Force planes collided over Spain, dropping a hydrogen bomb into the Mediterranean Sea. The Navy called on the *Alvin* Group to help find it.

In a two-month search, the *Alvin* team located the bomb on the seafloor and helped recover it, making the Navy very happy, cementing *Alvin's* name and reputation in the public and press, and affirming even to skeptics its usefulness as an undersea vehicle.

In its second year, *Alvin* settled into scientific operations around the western North Atlantic seafloor. As with any new endeavor in the deep ocean, a few odd events occurred. In July 1967, near the Bahamas, a swordfish impaled *Alvin's* skin (not the personnel sphere). The fish was damaged far more than the sub and made for a hearty dinner back on deck. In September 1967, the sub's manipulator arm came off during a rough recovery and sank—but was soon found on the seafloor, recovered, and reinstalled.



A new titanium personnel sphere installed in 1973 allows *Alvin* to dive to 3,000 meters and to participate in Project FAMOUS. The French-American expedition used subs to investigate the mid-ocean ridge for the first time and revealed a seafloor that scientists had not imagined.

1974



Scientists in *Alvin* at the Galápagos Rift explored previously unknown and unexpected communities of deep-sea organisms that thrive in the absence of sunlight, sustained not by photosynthesis but by chemosynthesis. The discovery transformed conceptions of how and where life can exist.

1977



*Alvin*, now with a second manipulator arm and upgraded sampling equipment, returns to the Galápagos Rift to collect animals. Later, on the East Pacific Rise, scientists in *Alvin* discover the first "black smoker" hydrothermal vents, with extremely hot, chemical-rich water gushing from vent chimneys.

1979



Scientists diving in *Alvin* in the Gulf of Mexico discover cold-seep animal communities, habitats sustained by cold, chemical-rich fluids seeping from the seafloor.

1983

Then in 1968, on the continental shelf south of Woods Hole, just before a dive, steel cables that supported the sub on *Lulu* snapped. With just enough time to react, pilot Ed Bland and the scientists aboard got out of the sub just before it slipped off its platform and sank in 5,000 feet of water.

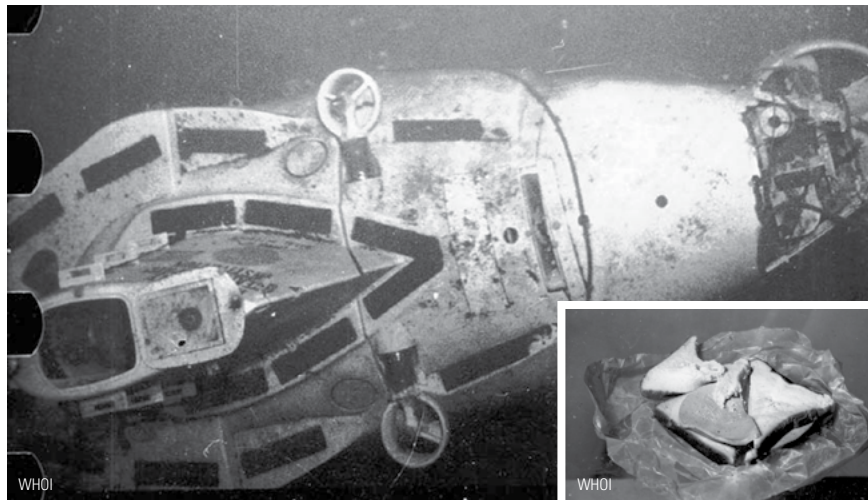
A debate ensued on whether to recover the sub, because of the possible cost. But in September 1969, the submarine *Aluminaut* and the Navy research ship *Mizar* found and lifted *Alvin*. The only damage was to *Alvin's* sail, which had to be broken to insert a hoist bar. *Alvin* was repaired and soon back at work.

### Dunked apples

One unforeseen outcome of *Alvin's* ten-month immersion sent ripples through the ocean science community. Lunchbags abandoned at the sinking were still in the sphere. After nearly a year in seawater 5,000 feet deep, the bologna sandwiches were sodden and the apples wet. But they were not decayed. They would still have been edible (though not likely palatable).

WHOI microbiologist Holger Jannasch wasn't too surprised; he had expected decomposition to be slow at cold temperatures in the deep sea. "It was not the well-preserved quality of the foodstuffs that startled us," he wrote, "but the utterly simple means of overcoming the decompression problem, used in this involuntary experiment." The decompression problem was this: When scientists brought bacteria adapted to the high pressure of the deep ocean back to the surface, the rapid decompression killed the very microbes the scientists wanted to study.

Suddenly, Jannasch saw that instead of bringing the microbes up, they could do experiments *in situ* in the deep sea—by putting culture media in sample containers on the seafloor and allowing in seawater with ambient bacteria that would grow there. This insight "broke a roadblock," he said, and led to new experiments, new sampling and culturing instruments, and a blossoming of deep-sea microbiology that has yielded unfathomed biochemical discoveries, some with commercial and pharmaceutical applications.

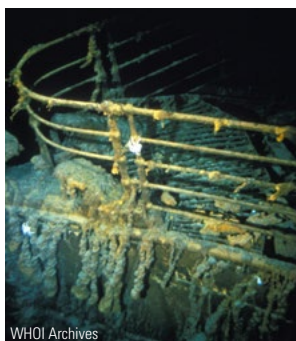


In a 1968 mishap, *Alvin* sank 5,000 feet to the seafloor. Its occupants got out safely, but the sub was not recovered for 10 months. A sandwich left in the sub was found sodden but edible. The discovery inspired new ways to study deep-sea microbes.

### FAMOUS dives

In 1973, *Alvin* was proposed to participate in the French-American Mid-Ocean Undersea Study ("Project FAMOUS") along with two French submersibles. The mission was to take scientists 3,000 meters (nearly 10,000 feet) down to the Mid-Atlantic Ridge—the great mountainous seam that runs down the center of the Atlantic—for the first time.

To reach these depths, *Alvin's* variable ballast system was modified and its steel personnel sphere was replaced with a titanium sphere. After testing, the sub was officially certified to 12,000 feet (3,658 meters) depth, twice its original range. The upgrade was costly, and some scientists thought the money should be spent on other research. A godfather of ocean sciences, Maurice Ewing, infamously shook his finger in the face of WHOI scientist Bob Ballard and "threatened to melt *Alvin's*



*Alvin* explores the wreck of the RMS *Titanic*, with a small remotely operated vehicle, *Jason Jr*. The vehicles take images of the ship that capture the public imagination.



Scientists in *Alvin* explore another kind of chemosynthetic community living off decaying whale bones: "whale falls."



Cindy van Dover becomes the first and only (so far) female *Alvin* pilot.



*Alvin* proves it can safely dive to 4,500 meters (14,764 feet) to reach 20 percent more of the seafloor.

1986

1987

1990

1994



sphere into titanium paper clips if FAMOUS wasn't worthwhile," wrote Victoria Kaharl in *Water Baby, the Story of Alvin*.

But it was. "One of the major accomplishments of the project was the technical feat itself," according to a 1975 article in *Science* magazine. "FAMOUS established—according to James Heirtzler of the Woods Hole Oceanographic Institution, head of the U.S. team—that 'it is now relatively easy for oceanographic scientists to work at the bottom of a deep ocean.' Another was the discovery that, as Tjeerd van Andel of Oregon State University put it, 'the ocean floor is disturbingly different from what we had imagined.'"

The gnarly, diverse landscape of rock and lava that *Alvin* revealed was hardly muddy and uniform as scientists had assumed from ship-based studies and dredging hauls, and FAMOUS helped confirm the nascent theories of seafloor spreading and plate tectonics.

In the mid-1970s, *Alvin* was certified to depths of 4,000 meters (13,124 feet), opening more of the seafloor to human observation. Its greatest discovery lay just ahead.

### Life as we didn't know it

In 1977, *Alvin* transited the Panama Canal for the first time so that scientists could use the sub to study geology in the Galápagos Rift in the Pacific Ocean off the coast of South America. Geologists and chemists had detected chemicals in the area that suggested volcanic activity. They hoped to verify that when seawater percolated through cracks in the seafloor, it was heated by volcanically hot rocks below. They thought the hot water leached chemicals from rocks, rose buoyantly, and vented back up through the seafloor, carrying chemicals into the ocean.

Scientists diving in *Alvin* found these so-called hydrothermal vents. But, to their astonishment, they also found large aggregations of big clams, worms, and mussels never seen before. Until they saw the vents, scientists had thought that animals living in the deep depended for food on sparse organic matter sinking



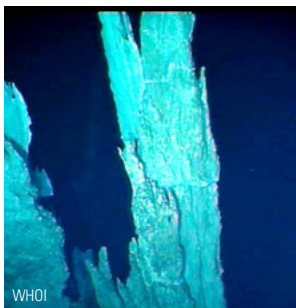
In the late 1970s, *Alvin* explored hydrothermal vents harboring unexpected deep-sea life: tubeworms, mussels, and other animals sustained by energy from chemicals from the seafloor, instead of sunlight.

from the sunlit surface. Instead, these organisms were thriving without sunlight, the energy source for almost all life on land.

"The scientists who made the surprising discovery of teeming life around hydrothermal vents of the Galápagos Rift in 1977 were geologists and geochemists," wrote former WHOI biologist Fred Grassle. "They had not expected to find spectacular colonies of previously unknown, large animals on the deep seafloor."

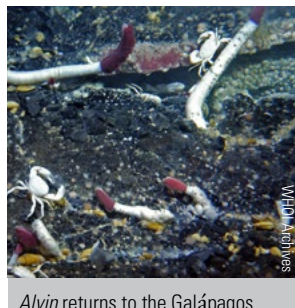
A return to the Galápagos Rift, with biologists, was planned, but first, *Alvin* needed upgrades. In 1978 the sub got a new titanium frame for strength, a new sample basket to bring back samples and specimens, and a new starboard manipulator arm, making it two-armed for the first time.

In 1979, *Alvin* returned to Galápagos, where biologists confirmed that microbes—with the biochemical machinery to extract energy from chemicals coming from beneath the seafloor—formed the base of the food chain. Many of the larger animals had no mouths or digestive systems. They harbored in-



*Alvin* discovers "Lost City" in the Atlantic, a previously unknown environment where seawater reacts with mantle rock to produce unusual kinds geological structures and chemosynthetic communities.

2000



*Alvin* returns to the Galápagos Rift for the 25th anniversary of the discovery of hydrothermal vents. It finds old animal communities wiped out by fresh lava flows and newly colonized post-eruption communities.

2002



*Alvin* celebrates its 4,000th dive in January with WHOI biologist Tim Shank (left) and *Alvin* pilot Bruce Strickrott on the Nootka Fault off British Columbia, Canada. It celebrates its 40th anniversary in June.

2004



In November, *Alvin* pilot Pat Hickey completed his 600th *Alvin* dive, at 9° North in the Pacific Ocean.

2006

ternal symbiotic bacteria that made food for them in exchange for a safe haven to live. These previously unimagined ecosystems, chemosynthetic rather than photosynthetic, were some of the most profound scientific discoveries of the 20th century.

### More life in unexpected places

Later in 1979, *Alvin* dove at 21° North, on the East Pacific Rise, discovering the first black smokers humans had seen. These tall, chimney-like rock formations gushed high-temperature, chemical-rich, toxic, acidic black fluids.

“It looks like an Old West locomotive at full throttle,” wrote pilot Dudley Foster, “the smoke rising and diffusing in the currents. ... I pick up our temperature probe and insert it into the searing gusher. We watch the datalogger excitedly as the temperature soars through ... 358 degrees Celsius ... more than 678 degrees Fahrenheit! ... We’re only a few feet away. But we dare not go any closer because our acrylic plastic viewports would start to soften.”

The discovery of such unexpected life in such extreme environments further expanded concepts of where life could exist. It expanded astrobiologists’ views on where to search for life elsewhere in the solar system. It also inspired scientists, students, and the public and made a strong argument to continue exploring the deep sea in *Alvin*.

During *Alvin*’s 1982 upgrade, its sail was changed from white to orange-red to make it easier to spot when it surfaced. The next year, it said farewell to *Lulu* and hello to a new tender, *Atlantis II*.

Around this time, scientists in *Alvin* discovered vent-like animals on the Florida Escarpment, a large, stepped, rocky platform off Florida’s West Coast made of long-dead corals, mollusks, fish skeletons, and other organic matter that accumulated over geological time. Through cracks and fissures in the carbonate bulwark, waters rich with hydrogen sulfide, methane, and other chemicals seep into the ocean and sustain chemo-

synthetic communities. Over the years *Alvin* explored similar habitats, called “cold seeps,” in the Guaymas Basin off Mexico, the Gulf of California, and the Gulf of Mexico.

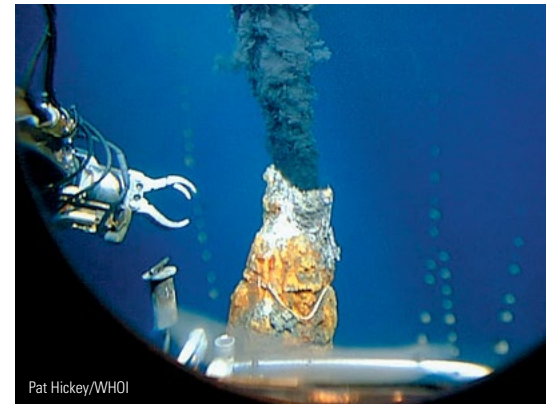
### Curious creatures and *Titanic* adventures

In 1985 scientists in *Alvin* found the first hydrothermal vents on the Mid-Atlantic Ridge. They saw no tubeworms, the iconic animals of Pacific vents, but instead found thousands of shrimp swarming around the vents. The shrimp were eyeless in the lightless deep sea, a development also seen in some cave-dwelling animals.

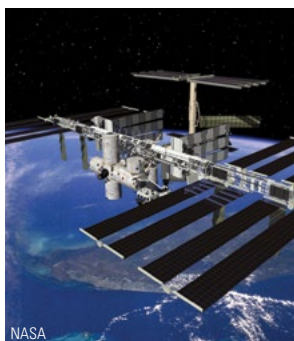
Cindy van Dover, the first and only woman to become an *Alvin* pilot, had subsequently enrolled as a MIT/WHOI graduate student. She discovered that the blind shrimp, which harbor chemosynthetic bacteria under their shells, carried another surprise—unique organs on their backs that contained light-sensitive “visual pigment” normally found in eyes. She hypothesized that hot vents might produce a faint glow, called black-body radiation, which the pigment on the shrimp could detect, allowing them to avoid the vents’ lethal superheated fluid. An experiment on the Juan de Fuca Ridge off Vancouver Island, conducted with *Alvin*’s lights off (not normal operating protocol), showed a faint clear glow from a vent.

Since then, this and other new shrimp species have been found at vents in the Atlantic and Indian Oceans and the Caribbean Sea, but not at Pacific vents. Biologists wonder about and

In 1979, scientists discovered black-smokers chimneys gushing like seafloor geysers and spewing hot chemical-laden black fluids.



Pat Hickey/WHOI



NASA

WHOI biologist Tim Shank has a telephone conversation in *Alvin* with NASA astronaut Sunita Williams aboard the International Space Station.

2007



BOEM & NOAA OER

*Alvin* responds to the Deepwater Horizon crisis, investigating impacts of the oil spill in the Gulf of Mexico.

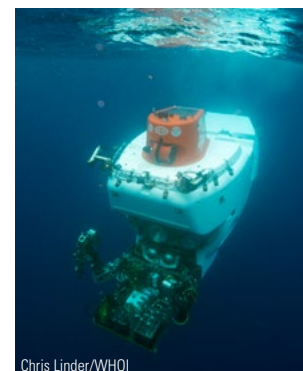
2010



Tom Kleindinst/WHOI

*Alvin* is disassembled and undergoes a \$41-million upgrade to enhance its systems.

2010-13



Chris Linder/WHOI

The upgraded *Alvin* resumes operations where it left off: investigating impacts from Deepwater Horizon in the Gulf of Mexico.

2014

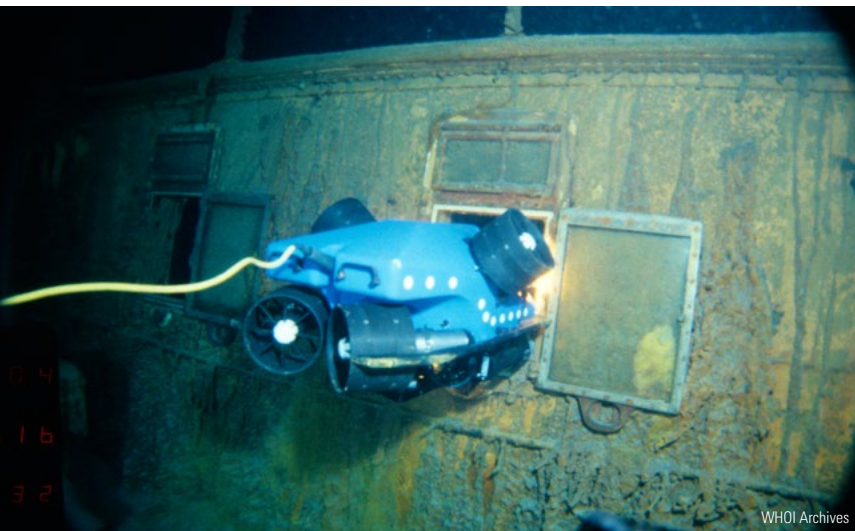


continue to study why vent communities differ from each other and how the animals get from one vent to another hundreds of miles away.

Amid these biogeochemical explorations, *Alvin* paused in 1986 to visit to one of the world's most famous ships: the wreck of the *Titanic* in 3,800 meters (12,500 feet) of water off Newfoundland.

*Alvin* now had new electric thruster motors, instead of its old bulky rear propeller, and the new maneuverability was useful. During this expedition, *Alvin* made twelve dives to carefully explore and photograph the debris field. It also worked in tandem with a small prototype tethered robotic vehicle, *Jason Jr.*, to explore inside the wreck. The dramatic, evocative images of *Titanic* received worldwide attention. The success of *Alvin's* deep-sea exploration and its technological progeny has spawned new generations of remotely operated and autonomous deep-submergence vehicles.

The small robotic vehicle *Jason Jr.* was designed at WHOI and controlled from *Alvin* via a tether. In 1986, scientists used the vehicles together to explore and photograph the wreck of the *Titanic*.



WHOI Archives

## New travels, new habitats

The next quarter-century took *Alvin* to work in the Gulf of Alaska, the Pacific, and Atlantic, discovering and documenting more new deep habitats. In the 1990s off California, *Alvin* encountered chemosynthesis-based communities living on the decayed bones of a whale and helped investigate other such “whale falls.” Scientists theorize that whale falls may serve as oases in food-poor regions of the ocean and steppingstones for animals between food-rich areas.

In 2000, exploring a new region of the Mid-Atlantic Ridge, *Alvin's* occupants saw 60-foot-tall white carbonate spires, crags, and chimneys looming out of the darkness where the sub's lights shone. They called the fantasy landscape the “Lost City.” Here lower-temperature methane- and hydrogen-rich, highly alkaline fluids react with mantle rock, depositing different minerals and creating another previously unknown environment and ecosystem.

*Alvin* also explored seamounts, ancient undersea volcano peaks that were found to harbor abundant life—concentrations of fish and unusual deep-sea corals that supported hundreds of species living with and on them.

In its final expedition before a major upgrade, *Alvin* once again responded to a national crisis. It returned to deep coral communities that it had previously explored to investigate impacts from the Deepwater Horizon oil spill. *Alvin* examined corals near the oil well in the Gulf of Mexico and documented dead and dying corals coated with dark material that later was identified as oil.

In December 2010, after 4,664 dives, after discovering hundreds of new animal species and untold new microbial species, *Alvin* was taken out of service to undergo a major upgrade funded primarily by the National Science Foundation. In 2014, the upgraded sub, with an array of new capabilities, picked up where it left off, returning to the Gulf of Mexico.

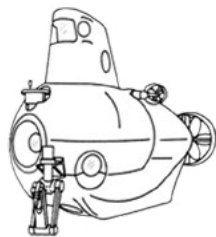
To date, *Alvin* has safely transported about 2,800 unique Alvinauts to the bottom of the sea. More people have been to the top of Mount Everest.

Happy 50th birthday, *Alvin*. Long may you dive. ▲

## The Evolution of

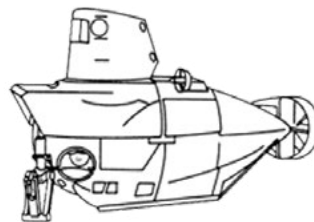
# Alvin

Illustrations by E. Paul Oberlander



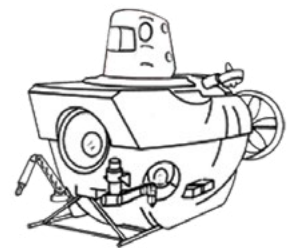
**1962**

The sub is named *Alvin* to honor the creative inspiration for the vehicle, Allyn Vine, a scientist at Woods Hole Oceanographic Institution.



**1973**

The original steel personnel sphere is replaced with a titanium sphere and more flotation is added, allowing *Alvin* to reach greater depths.



**1978**

To collect more rock and biological samples from hydrothermal vents off the Galápagos Islands, researchers add a second manipulator arm on the starboard side and a new sampling basket.

After the 2010 Deepwater Horizon oil spill, scientists in *Alvin* assessed the impacts on deep-sea communities and vulnerable deep-sea corals that were coated with oil.

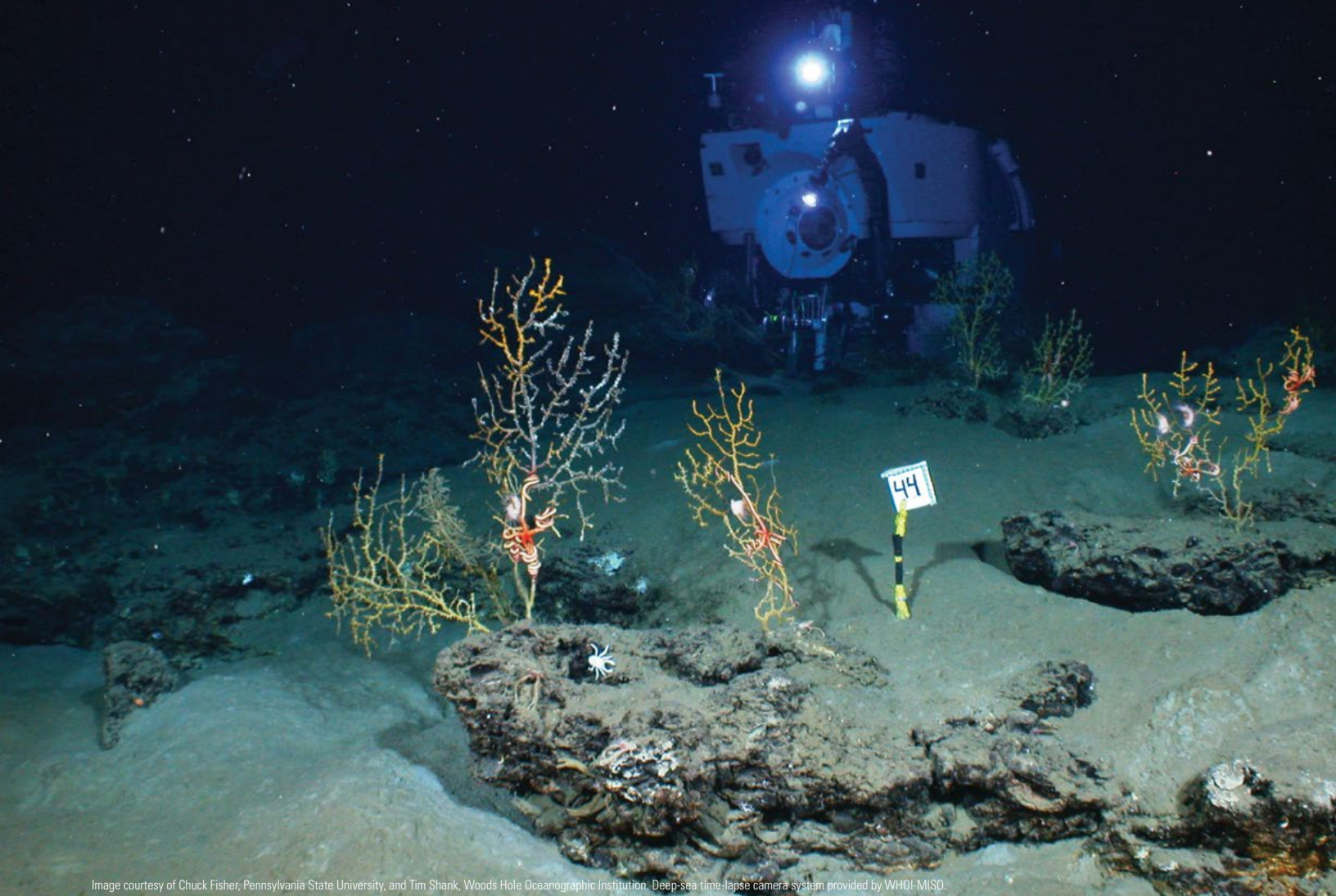
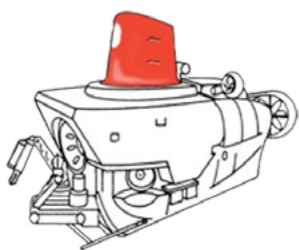
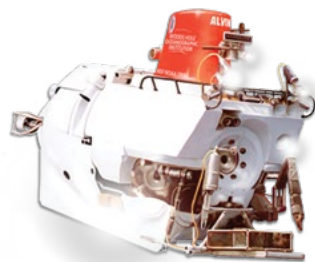


Image courtesy of Chuck Fisher, Pennsylvania State University, and Tim Shank, Woods Hole Oceanographic Institution. Deep-sea time-lapse camera system provided by WHOI-MISO.



## 1982

A lifting “T” is added behind the sail for a new launch and recovery system. The sail color is changed from white to red-orange to make *Alvin* easier to see when it surfaces.



## 1986–2010

Four aft thrusters replace the stern propeller to increase speed and maneuverability. The manipulator arm is upgraded to hydraulic power. More-powerful batteries are installed. Video cameras and pan-and-tilt units are added.



## 2014

A new personnel sphere is added with 18 percent more interior room and two new forward viewports. The new sphere was designed to reach depths of 6,500 meters. Also added were an auto-command-and-control system, high-definition imaging systems, LED lights, and a larger payload basket.