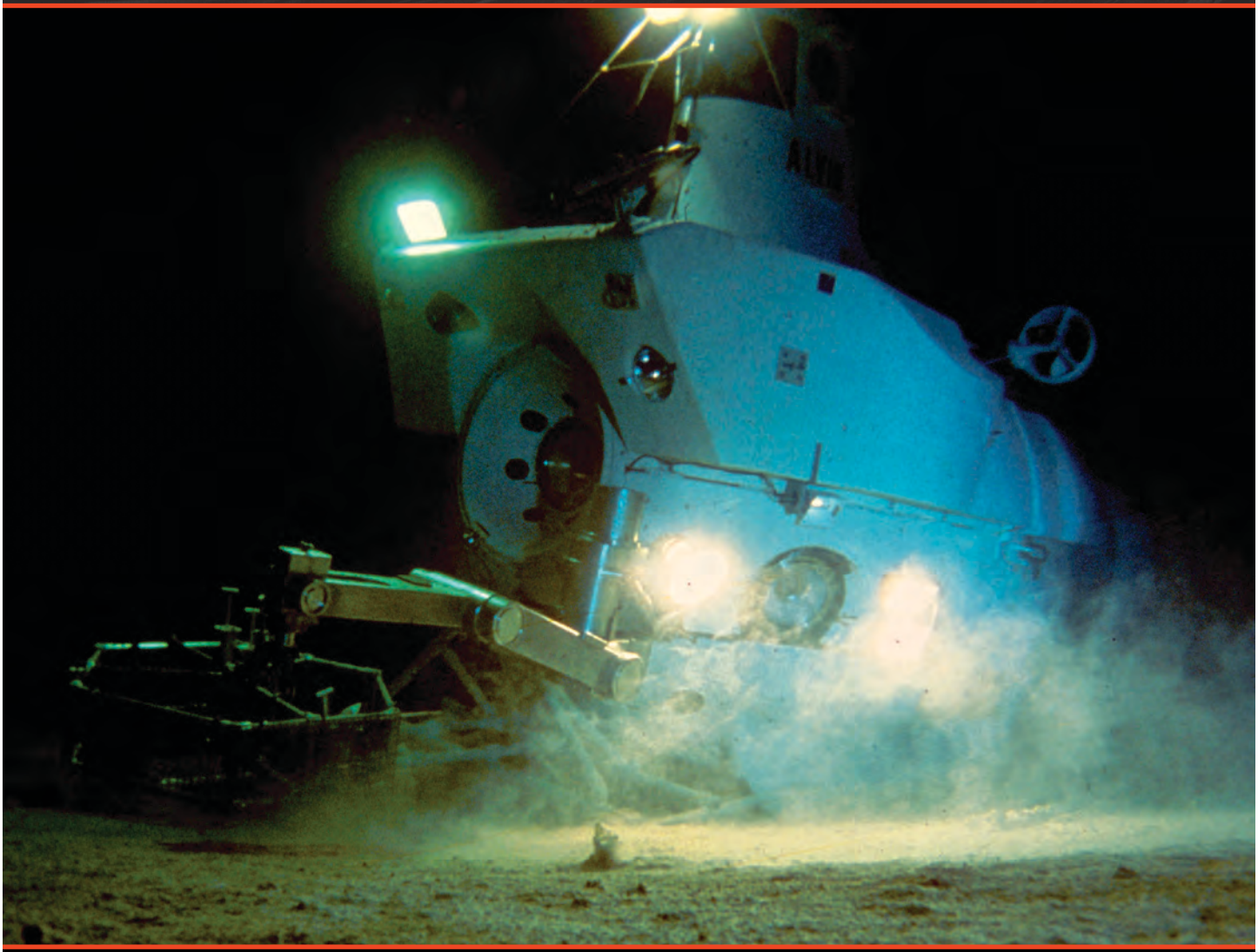
ALVIN

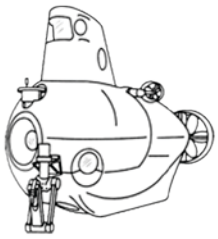
The nation's deepest diving research submarine

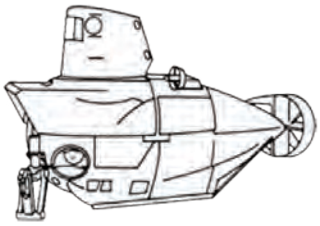
PAST, PRESENT, AND FUTURE



Woods Hole Oceanographic Institution

The EVOLUTION of *Alvin*





Alvin MILESTONES

1962

Woods Hole Oceanographic Institution contracts General Mills to build a small research submersible for $472,517. *Alvin's* sphere is shaped from a steel plate at Lukens Steel Co., Coatesville, Pa.

1964

On June 5, 1964, *Alvin* is introduced during a ceremony in Woods Hole.

1965

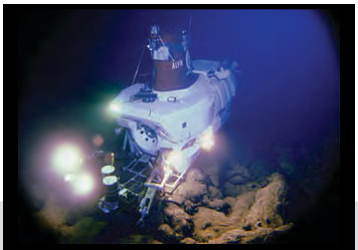
On July 20, 1965, researchers launch *Alvin* from the sub's first tender, the 105-foot catamaran *Lulu*. *Alvin* makes its first 6,000-foot dive to obtain Navy certification.

1966

The U.S. Navy called in *Alvin* to help find a hydrogen bomb accidentally dropped into the Mediterranean Sea. *Alvin* locates the bomb and, after the bomb skids down a slope on the first recovery attempt, it finds it again.

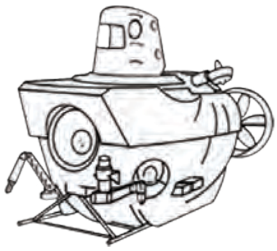
1977

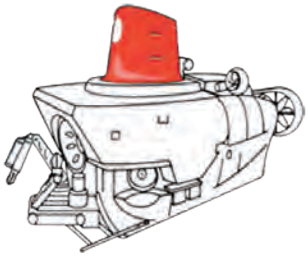
Scientists diving to the Galápagos Rift in *Alvin* explore seafloor vents gushing shimmering, warm, mineral-rich fluids into the cold, dark depths. Amazingly, the vents are surrounded by extraordinary, unexpected life forms.



1979

Armed with special instruments to collect samples, a second manipulator arm, and a new basket in front, *Alvin* returns to the Galápagos to examine how animals thrive in the extreme environment near hydrothermal vents.





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.

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 spot *Alvin* more easily when it surfaces.

1986–2010

Four aft thrusters replace 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.

Future

Researchers expect to install a larger personnel sphere, new batteries, and new foam, which will allow the sub to stay down longer, and eventually, dive to 6,500 meters.

1968

On Oct. 16, 1968, two steel support cables snap at the start of a dive. The pilot and observers scramble to safety. But *Alvin* then sinks 5,000 feet to the seafloor.

1969

Alvin is recovered a year after it sank. There is little structural damage, and lunches left on board are soggy but edible. The discovery opens up new areas of biological and chemical research.

1974

A new titanium sphere nearly doubles *Alvin's* diving capacity from 6,000 to 10,000 feet. With its new capabilities, *Alvin* participates in a project giving scientists their first chance to make firsthand observations of mid-ocean ridges.

1986

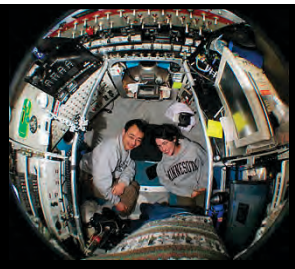
Alvin explores the *RMS Titanic*, accompanied by a small, remotely operated vehicle named *Jason Jr.* The vehicles conducts detailed photographic surveys and inspections of the *Titanic's* wreckage.

2004

Alvin makes its 4,000th dive, with WHOI Biologist Tim Shank (left) and pilot Bruce Strickrott aboard.

2007

On Jan. 26, 2007, WHOI biologist Tim Shank, diving in *Alvin*, has a conversation with NASA astronaut Sunita Williams, who is orbiting Earth on the International Space Station.



2008

In 46 years, *Alvin* has executed 4,637 dives, taking 9,270 passengers in its three-person sphere. *Alvin* pilot Mark Spear snapped this photo shot as the sub returned to the surface of the Pacific in 2008.

Alvin's Pilots

A tight-knit group with the 'right stuff'

WHOI Archives

▲ **Bill Rainnie, one of the first *Alvin* pilots, stands aboard R/V *Lulu*, *Alvin*'s former tender, in the late 1960s.**

Forty-five summers ago off the Bahamas, two men climbed inside a 23-foot white submarine named *Alvin* and drove it to a depth of 1,829 meters (6,000 feet), a dive that certified them as the first pilots of the world's deepest-diving research sub.

Bill Rainnie and Marvin McCamis never became household names the way astronauts Buzz Aldrin and Neil Armstrong would four years later when they rocketed into space. In 1969, when newspaper headlines heralded the moon landing, *The New York Times* called *Alvin* "a curiously shaped midget submarine, [that] somewhat resembles a chewed-off cigar with a helmet."

But as of October 2010, *Alvin* has safely transported 9,270 passengers on 4,637 dives to some of the blackest, coldest, and most remote places on Earth—to depths of 4,500 meters (14,764 feet).

While the United States has maintained a small fleet of space shuttles since 1981, *Alvin* is the country's sole research submarine capable of diving to such depths. Some 75 space shuttle pilots have flown missions, but since 1965, the job of driving *Alvin* has gone to just 38 men and one woman. Mechanically minded and adventurous, *Alvin* pilots are the ocean's equivalent of astronauts.

Their skills have allowed scientists worldwide to explore the ocean depths, map undersea volcanoes and valleys, examine previously unknown ocean life, gather water, rock, and biological samples, and see firsthand the ruined decks of the *Titanic*. They view sights that—though still on Earth—are nevertheless extraterrestrial, and they bear witness to revolutionary scientific discoveries.

Larry Shumaker, now in his 70s, was a pilot in 1977, the year scientists first identified hydrothermal vents on the seafloor near the Galápagos Islands. Their finding changed ideas about where and how life could exist.

"I felt like *Alice in Wonderland*," Shumaker said. "I remember the shimmering water coming from the vents and the unusual animals that humans had never seen before. Of course, now scientists have identified many of these animals [including tubeworms, white shrimp, and giant clams]. But at the time it was all so weird and new."

Former pilot Tom Tengdin was amazed by the tall seafloor rock formations, called black smoker chimneys, that were discovered in 1979. Belching black, scalding, mineral-rich fluids into the ocean, the smokers transformed scientists' understanding of the Earth's crust and the ocean's chemistry.

"Video doesn't capture the black smokers," he said. "When you're down there among them, you can almost hear them roar."

Pilots are more than deep-sea bus drivers who ferry scientists from surface to seafloor. Most have engineering degrees, and their certification with the U.S. Navy includes drawing—from memory—dozens of the sub's intricate hydraulic, ballast, electrical, and mechanical components and systems. They are solid swimmers; every launch and recovery requires assistance in the water. They are all mechanics as well as pilots; if anything breaks during an expedition, there are no fix-it shops at sea.

Just maintaining the sub's electronic and mechanical components requires at least five hours of work daily. Every three months, or every 25 to 30 dives, *Alvin* undergoes maintenance and inspection. And every three

Mark Spear, WHOI

▲ ***Alvin* has safely transported 9,270 passengers on 4,637 dives.**

to five years, *Alvin* undergoes a six-month overhaul and modernization at Woods Hole Oceanographic Institution. The pilots help clean, examine, and reassemble every component of the sub.

"Not to make it sound too dramatic—because the sub is very solid—but we're constantly working hard to make sure that the sub comes back up to the surface," said former pilot Anthony Tarantino.

At sea, daily chores begin before dawn, when the entire group rises to check the submersible's equipment and ensure that the batteries are charged. They test electronic gear, from radios to temperature gauges and depth-readers. They make sure *Alvin*'s cameras work and video recorders are loaded with tape. They add a total of 377 kilograms (832 pounds) in ballast weights—stacks of steel plates—to each side of the sub. These make *Alvin* heavy enough to sink to the seafloor.

Then the glory begins, when two scientists slip into the sub's 2-meter (6-foot) sphere, huddle against tiny view ports, and turn to the day's pilot who will take them to the seafloor. When the sub resurfaces in the evening, another pilot hoses corrosive salt water off *Alvin* and its components. Meanwhile, tomorrow's pilot meets with scientists to plan strategies for the next day's mission.

Piloting *Alvin* comes with modest fame. Children's books describe the team of six or seven *Alvin* pilots and pilots-in-training that accompanies the sub on each expedition. Teenagers send e-mail messages to their support ship, the research vessel *Atlantis*, asking about the two- to four-year, at-sea training process (see Page 12). Strangers on airplanes and parties who ask "What do you do?" grow wide-eyed at their response.

"People have two reactions," said Anthony Berry, a former pilot. "They are either impressed, or they think I'm crazy. They say, 'Why would you want to go to sea for months at a time and go into the pitch black sea in a tiny sub?' "

For every 40 applications to the *Alvin* group, one person is accepted into the pilot training program, which requires worldwide travel and up to eight months a year at sea. But for all the work involved in getting into the pilot seat, piloting *Alvin* isn't a career. Some of today's pilots may not be around when *Alvin* takes its latest incarnation as a new submersible that can dive to 21,320 feet (6,500 meters).

Most stay an average of five years before family, other job opportunities, or the lure of driving something smaller than a 15,875-kilogram (35,000-pound) submarine beckons from shore. Still, every pilot has a story of why he or she went to sea and what happened during their time inside *Alvin*.

"We've all gone through the same path, and the guys who make it are definitely solid," Tarantino said. "You're looking at a bunch of guys who rely on each other. I'd place my life in any of their hands."

—Amy E. Nevala

Dave Gallo, WHOI

▲ **Current and former *Alvin* pilots (from left) Anthony Berry, Mark Spear, Patrick Hickey, Bruce Strickrott, Anthony Tarantino, and Gavin Eppard muster in front of the submersible on the deck of the research vessel *Atlantis*.**

Bruce Strickrott

Amy Nevala, WHOI

Becoming an *Alvin* pilot:

Bruce Strickrott, who hails from Maryland and New York, earned his sea legs in the U.S. Navy. After joining at age 20, he participated in the Gulf War, where he operated radars, monitored surface-to-air missile defense, and provided anti-aircraft warfare support on a naval vessel. After six years, he went back to college for a degree in ocean engineering from Florida Atlantic University. During his job search, he found WHOI's Internet advertisement seeking *Alvin* pilots. "When I went to Woods Hole for the interview, I saw the research vessel *Atlantis II* there. Then I saw *Alvin*. And at that moment I said, "Man, I want this job.' "

Have you ever been scared in the sub?

Every once in a while I'll jump or get startled, like when the sub bumps into something. Otherwise, we do everything possible to keep us out of dicey situations.

What three skills must every *Alvin* pilot possess?

Attention to detail is probably the most important skill. Piloting the sub is about moving up and down safely, dealing with atmospheric pressure in the sub, doing science, checking systems, making sure data are being collected properly. With all that to do, the second skill is keeping your wits about you, staying calm, and making decisions in a logical way. The third? Keeping a sense of humor. Of course, the technical skills are obvious, but without humor down there, we're doomed.

Of the 39 people who have piloted *Alvin*, only one has been a woman. Few have been minorities; there has never been a black *Alvin* pilot. Why do you think there aren't more women and minority pilots?

I don't think it's a hiring philosophy; we have had minorities. I think it's a reflection of a larger problem of not having enough women and minorities in science and engineering fields.

What do you do when you are not on the ship?

We usually get 10 days to three months off at a time for vacation. In the winter I ski as much as possible. Otherwise I do normal things that people do. I go to weddings, visit family, and spend time at the office in Woods Hole.

What person, dead or alive, would you most like to invite on a dive in *Alvin*?

Jules Verne [author of *Twenty Thousand Leagues Under the Sea*]. Tell me he wouldn't get the biggest kick out of it.

—Amy E. Nevala

Like many boys who spend their youth throwing baseballs in Massachusetts parks, Anthony Tarantino dreamed of playing for the Red Sox. When not pitching, he liked to take apart his toys and put them back together, which ultimately led to a career in engineering. After graduating from Wentworth Institute of Technology in Boston, he worked for seven years at two engineering firms. In 1999 he went to Hawaii for a snorkeling and scuba vacation. "There were all sorts of interesting things in the water," he said. "I remember thinking on the flight home, 'Gee, it would be kind of interesting to do something where I would see some cool stuff in the water.' Being from Massachusetts, I knew a little bit about *Alvin*. As a shot in the dark, I pulled up WHOI's Web page, saw a job ad, looked at the skills they were looking for, and said, 'I can do all that stuff.' " We interviewed Tarantino in 2005, shortly after he became an *Alvin* pilot.

Tell us about the *Alvin* pilot training program and the skills you need.

It helps if you have an engineering background, because the sub is very complex. You start off as an *Alvin* technician, and your job is basically to help out and do as much as you can. In the meantime, you're looking and listening, gathering as much information as possible, and trying to learn about how the day-to-day operations go, as well as what makes the sub work. The first couple of months you're here, you're feeling it out.

What do you mean by "you're feeling it out"?

The lifestyle. This job has a few unusual features. Being out here for eight months of the year. Dealing with the fact that the people you work with are the people you live with and the people you play with is another big factor. Being away from your family for so long. I don't have a house or an apartment. I have my stuff in my sister's house in boxes. When I'm on vacation, I'm either traveling or bumming a room in my sister's house, or even my parents' house. So it's a nomadic lifestyle. None of us is married. It can be very difficult to hold a relationship.

Assuming you like the lifestyle, what happens next?

Well, while you're trying to decide whether you fit into the program, the *Alvin* group is doing the same thing with you. If you've proven yourself, one day they come up to you, and they say, "We've talked about it, and we think you're ready. You're a PIT now."

A PIT?

Pilot-in-training. Every fifth dive, there's a pilot-in-training dive. A PIT will go down with a pilot and one observer. We accomplish the day's science mission, and at the same time, train our pilots. There's no simulator for *Alvin*. There's really no other way to learn. I made 16 PIT dives before I made it to pilot. Some people have more.

the training program

Anthony Tarantino

Amy Nevala, WHOI

What are the next steps?

There's a checklist of systems on *Alvin* that you have to learn. There are probably 200 electrical, electronic, and mechanical systems—from the system that scrubs out carbon dioxide from the air in the sphere to the variable ballast (VB) system that allows you to control the sub's buoyancy. You have to be able to draw a mechanical diagram of each system and know it thoroughly. Then you have to go in front of a pilot and display your knowledge of each system—how it works, why it works, and how to maintain it. Once you've completed all the systems, you begin the process.

The process is just beginning?

The process includes four oral examinations. The first one is with three to five scientists who ask you about safety and about your ability to complete scientific dive objectives. After that, you have a review board with all the *Alvin* pilots on board. You stand in front of a whiteboard, and everyone else sits around the table asking you questions. They'll say, "OK, draw the VB system." You draw it out, and then they start asking you all sorts of questions about it. I think I was in there two days, for four to five hours at a time. That was tough.

And then?

After that, there are two more reviews. They send you back to Woods Hole, and you have the same type of oral examination with the deep-submergence engineers back at the office. These are the guys who know all the technical bits about the sub that you might deal with on a daily basis. They expect you to have dug into them and know them. They just grill you. These guys have been around for years. They know the history of *Alvin*, and they expect you to know that, too. They'll ask questions like "Why is this *Alvin* system the way it is?"

Once you get past that, you still have one more hurdle to jump?

You have to go before a Navy review board. You get sent to the Navy's deep-submergence facility in San Diego and sit down in front of an admiral and a group of submarine captains, and they grill you on a bunch of situations. Once you get past them, you're blessed, and you get to dive. You've earned your Navy deep-submergence dolphin [an insignia pin], and you've made it. You do your first solo dive, and it's fantastic, and you get out of the sub, and the guys dump a bunch of goop on you. It's sort of a traditional initiation rite.

Is there a big celebration?

When you get into port after the cruise is done, it's traditional for the new pilot to throw a party for everyone on board. I did mine in Manzanillo, Mexico, and it was a load of fun. You get roasted by the guys, and they give you gag gifts.

—Lonny Lippsett

Amy Nevala, WHOI

▲ **The WHOI-operated research vessel *Atlantis* serves as support vessel for *Alvin* operations. During each recovery, two certified swimmers help bring the submersible back to the ship.**

Building the Next-Generation *Alvin*

Plan offers a roadmap to extend sub's diving capacity to 6,500 meters

Illustrated by Megan Carroll, WHOI

Three times geologist Adam Soule has climbed inside the deep-diving submersible *Alvin* and headed to the seafloor. Geochemist Susan Humphris stopped counting after 30 dives. Dan Fornari, who studies deep-sea volcanoes, has descended more than 100 times.

Yet for all of them, the deepest seafloor depths have remained out of reach. *Alvin* is not designed to withstand pressures beyond a depth of 4,500 meters, or 2.8 miles.

"Right now, *Alvin* allows us to see 63 percent of the ocean," Fornari said. "We want to see 98 percent." That would require descending to 6,500 meters, or more than 4 miles.

In the late 1990s, ocean scientists steered toward that goal as they began planning to replace the stalwart *Alvin*, which made its first dive in 1964 and as of October 2010 has carried 9,270 passengers safely to the depths in 4,637 dives. They proposed a next-generation vehicle that could go deeper, spend more time on the bottom, have more interior room, and have more and bigger windows, or viewports.

In 2004, the National Science Foundation (NSF) agreed to the plan and awarded $22.91 million to Woods Hole Oceanographic Institution (WHOI), which manages the National Deep Submergence Facility. The NDSF is a federally funded center that operates, maintains, and coordinates the use of deep-sea exploration vehicles for the U.S. research community, including its only human-occupied submersible, *Alvin*.

A tradition of bringing people deep

But initial estimates for design, construction, and testing of the new vehicle nearly doubled, and material costs soared. The cost of titanium to forge a new personnel sphere for the sub rose fivefold.

"As detailed planning progressed, it became clear that we couldn't afford the full costs to implement the 6,500-meter, top-of-the-range vehicle in a single hit," said Chris German, chief scientist for deep submergence at WHOI. "Consequently, we developed a new plan, still aiming to achieve the same endgame, but via a longer-term, two-stage approach."

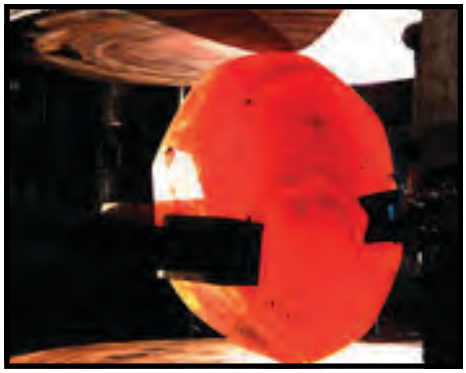
Instead of replacing the entire vehicle, engineers will build several new, key components that will be integrated into the existing *Alvin* in mid-2011 during the submersible's next regularly scheduled major overhaul and modernization, which it undergoes every three to five years. (Over more than four decades of service, nearly every component in the sub has been replaced at least once.)

During stage 1, *Alvin's* frame will be modified to integrate a larger, more pressure-resistant personnel sphere with larger viewports that will increase scientists' field of vision of the deep ocean and seafloor. In stage 2, as funding becomes available, other *Alvin* systems will be modified to increase the sub's depth capacity to 6,500 meters. In addition, a different battery type—most likely involving lithium-based chemistry—will be fully developed to increase the sub's energy capacity so that it can dive for longer periods.

"While we may not get everything according to this plan—at least not in

Ben "BK" Miller, Southwest Research Institute)

▲ **Titanium used to forge the new personnel sphere started out as barrel-shaped ingots fabricated by a mill in Pennsylvania. The two larger ingots, each weighing 17,000 pounds, were shaped into hemispheres that were joined to create the crew compartment. The third ingot, weighing 7,000 pounds, will be used to make viewport and hatch inserts.**



Courtesy of the Advanced Imaging & Visualization Laboratory, WHOI

▲ **At a forging plant in Wisconsin, the titanium ingots were heated to 1,700°F and "edge rolled" to get it them as close to circular as possible. Next, they were paddled to flatten them and to reduce their thickness to about 6 inches.**

the next five years—what this plan does ensure is that the U.S. research community will have access to a much improved, bigger and better *Alvin* from 2012 onward," German said.

A new personnel sphere

Many goals of the upgraded submersible will be met by a new $10-million titanium personnel sphere currently under construction, which will carry a pilot and two passengers. The sphere maintains sea level atmospheric pressure inside for its occupants, while it resists increasing pressure from the increasing volume of overlying water as the sub dives deeper—up to 6,500 meters.

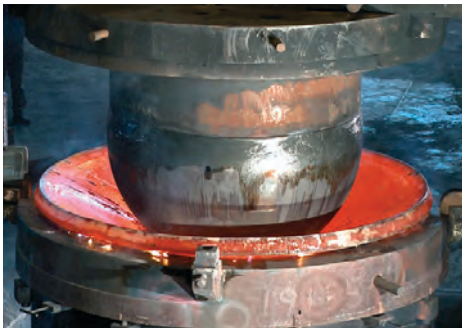
Deep-sea explorers often make crew compartments spherical. Because a sphere has no edges, its geometry distributes external forces evenly over its structure, making it the strongest possible shape. At depths of 6,500 meters, pressure will reach nearly 5 tons per square inch, said Pat Hickey, operations manager for the *Alvin* Group. Hickey has piloted 636 dives in the sphere—more than any *Alvin* pilot.

"Other shapes, such as a cylinder, can also be made to withstand such pressure, but at a severe weight penalty because they need to be much thicker than a sphere to go to the same depth," Hickey said. The new sphere will weigh more than 11,000 pounds and its walls will be nearly 3 inches thick, up from *Alvin's* current 2 inches.

"This sphere was definitely the biggest technical challenge of the project," said Anthony Tarantino, a former *Alvin* pilot who is part of a team of engineers at WHOI overseeing the development of the upgraded submersible. The sphere, he said, must be nearly flawless—free of any deformities that could weaken its structure and potentially cause it to crumple under pressure. Engineers will run dozens of tests at all stages of its fabrication to insure its reliability.

To make the sphere, engineers needed titanium, more than 34,000 pounds to be exact, about the weight of a large school bus. Two huge, barrel-shaped ingots were fabricated by a mill in Morgantown, Pa., and reshaped into two giant hemispheres by Ladish Forging in Cudahy, Wisc., by pressing them like huge pieces of dough into huge 11-foot discs and then successfully forming them into their cup-like shapes.

Forging Photos Courtesy of the Advanced Imaging & Visualization Laboratory, WHOI



▲ One of the forged hemispheres cools. Material from the hemisphere's interior and exterior was later removed to reduce its thickness to 3 inches.

◄ The heated titanium disc is shaped into a hemisphere.

Tom Kleindinst, WHOI

▲ Anthony Tarantino holds a model of the new personnel sphere, which will measure 7 feet in diameter.

Increasing visibility, reducing fatigue

In August 2009, another milestone was reached when STADCO, Inc. in Los Angeles, Calif., successfully joined the two hemispheres using high-energy electronic beam welding. The technique eliminates the need for additional welding material that would add weight, minimizes the amount of heat needed to be applied to the parts, and reduces the chances that the sphere will be distorted. The sphere has spent the last year undergoing treatments to ensure its reliability.

STADCO has also cut inserts for the hatch, electrical and fiber-optic connections between components inside and outside the sphere, and five viewports through which pilots and scientists can view the depths.

Alvin now has three viewports, one in front and one on each side, each about the size of a dinner plate. But because the viewports are funnel-shaped through the sub's thick walls, the actual view is more like looking through a window the size of a teacup saucer.

With more viewports, pilots will have more visibility to guide the sub and use *Alvin's* manipulator arms to conduct sampling and experiments. And easy-viewing computer monitors will replace switchboards and gauges that pilots continually keep their eyes on to check power, communications, propulsion, and alarm systems.

> "This sphere is definitely the biggest technical challenge of the project."
>
> — WHOI engineer Anthony Tarantino

"The goal was to reduce fatigue," Tarantino said. "It's mentally draining for pilots to be constantly sweeping their eyes to different gauges, then looking outside through the viewports, then sweeping the interior again. A pilot does this dozens and dozens of times during each dive."

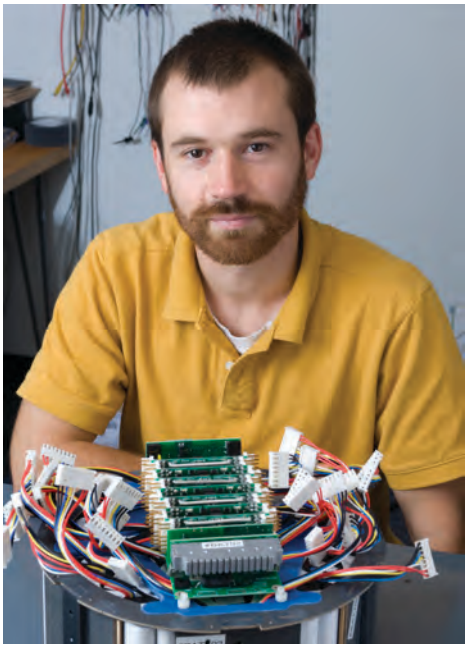
Stage 1 improvements also include better ergonomics (see Page 6), a new command-and-control system, enhanced lighting and imaging, increased data logging capabilities, fiber-optic penetrators, and better interfaces with science instruments.

The quest for more battery power

Alvin works from the 274-foot research vessel *Atlantis*. On the ship, before each *Alvin* dive, engineers recharge 3,500 pounds of lead-acid batteries that power every aspect of the vehicle, from its exterior lights to its six reversible thrusters: three that move the submersible backward and forward, two for up and down movements, and one for turning.

The battery power provides scientists with 10 to 11 hours of time in the water. About three to four of those hours are taken up by descending and then returning to the sea surface.

"That time is so valuable, so precious," said Soule. "When we're down there, we're squeezing out every moment of energy. When we see the power get low, we start turning off lights and working with a real sense of urgency. So to me, the biggest benefit of the new submersible will be the longer time on the bottom."



Tom Kleindinst, WHOI

▲ WHOI engineer Daniel Gómez-Ibáñez is designing small, powerful, and safe batteries to give *Alvin* more power to allow the sub to stay down longer on each deep-sea dive.

To get more time, researchers need more power. In the past 10 years, with the development of cell phones and computers, small, powerful lithium-ion batteries have become common. Those types of batteries could power the new submersible. But instead of one or two thumb-size batteries typically used in a cell phone, it would take about 10,000 to power *Alvin*, said WHOI engineer Daniel Gómez-Ibáñez, who is designing custom-made batteries for *Alvin's* replacement.

Not only do the batteries need to produce more power than the existing batteries, they must be smaller and lighter—under 3,000 pounds—to offset the weight of the new larger and heavier personnel sphere. Gómez-Ibáñez has helped design batteries for two WHOI-operated, unmanned deep-sea vehicles, *Nereus* and *Sentry*. But *Alvin*'s battery requirements are unique because it carries people. Safety and reliability are crucial to their design, Gómez-Ibáñez said. To ensure their reliability engineers must investigate dozens of possible ways for the batteries to fail and plan for them, so that any failure cannot possibly endanger human lives.

The stuff that keeps *Alvin* afloat

Another critical and expensive component of the sub is the material that keeps it floating: syntactic buoyancy foam, a matrix of billions of microscopic hollow glass spheres embedded in epoxy resin. The resulting material is hard enough to resist crushing under extreme pressure, yet it is lighter than water and thus provides buoyancy to lift a 36,000-pound vehicle, said Rod Catanach, a WHOI engineer overseeing the foam's development.

The new *Alvin* will require syntactic foam that can withstand pressure at depths of 6,500 meters. Catanach is working with Teledyne Technologies Inc., which created the 4,500-meter-depth foam now used in *Alvin*.

▲ WHOI engineer Rod Catanach is overseeing the development of new syntactic foam, the material used to provide buoyancy that allows *Alvin* to float back to the surface. The foam is made of a matrix of billions of microscopic hollow glass spheres embedded in a hard epoxy. It must withstand the crushing pressure at depths of 6,500 meters, or 4 miles.

A tricky part to manufacturing the new syntactic foam is perfecting the ratio of the light material, the microspheres, and the heavy "glue" material, the resin, Catanach said, so that a minimum amount of foam can provide maximum buoyancy. Otherwise, too much is needed, and that would make the sub too bulky.

—Amy E. Nevala

Funding to upgrade the submersible comes from the National Science Foundation's Division of Ocean Sciences and the Woods Hole Oceanographic Institution.

Alvin Gets an Interior Re-design

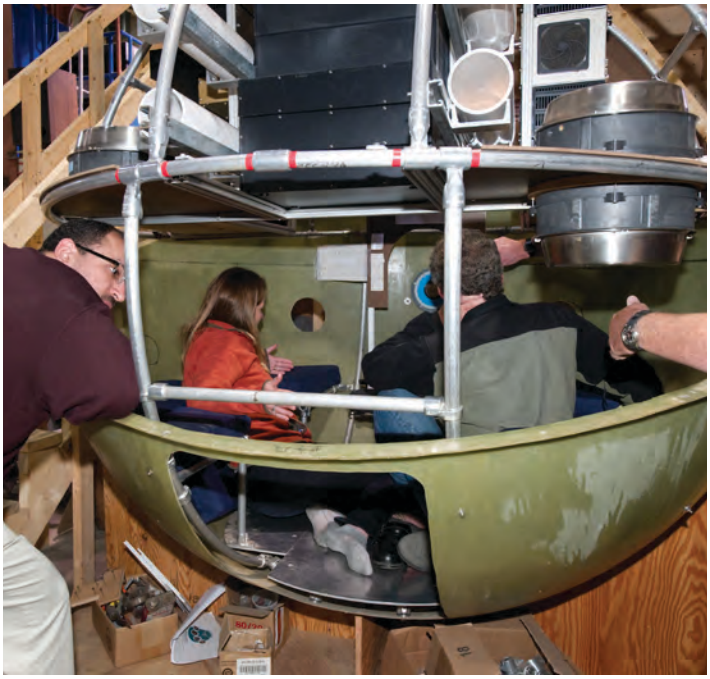
Sub's new sphere to offer a little more room to add a bit of comfort

For more than four decades, scientists have foregone a few creature comforts to see animals, or volcanoes, or shipwrecks at the bottom of the sea.

On a typical dive in the research submersible *Alvin*, a pilot and two scientists climb through a narrow hatch into an equipment-filled, 6-foot-diameter titanium sphere. Once sealed inside, they have no room to stand up, no seats, and no bathroom. For up to eight hours, they sit on thin pads on the floor and peer out windows, or viewports, the size of teacup saucers. The pilot drives while perched on a small metal box.

"It sort of equates to sitting in a phone booth with two of your closest friends, all day long," said Patrick Hickey, *Alvin* operations manager at Woods Hole Oceanographic Institution (WHOI), who has logged 636 dives as the sub's pilot.

"Being on the smaller side is definitely a plus when you dive in *Alvin*," said Bruce Strickrott, who, at 6 feet 3 inches, is currently *Alvin's* tallest pilot.



Tom Kleindinst, WHOI

▲ **Scientists test a mock-up of the new *Alvin* sphere constructed by engineers at Woods Hole Oceanographic Institution. They offered feedback on ways to make the sphere more comfortable and effective.**

But now engineers at WHOI have begun planning a multimillion-dollar overhaul that will ultimately allow *Alvin* to stay down longer (up to 12 hours) and dive deeper (6,500 rather than 4,500 meters). To withstand greater pressures at greater depths, a new, stronger titanium sphere has been forged (see Page 2). It is 3, rather than 2, inches thick, with an interior diameter that is 4.6 inches wider than *Alvin's* current sphere. That increases the interior volume by 18 percent, from 144 to 171 cubic feet, and that additional space has opened up a range of new possibilities.

"The buzzword is ergonomics," said Anthony Tarantino, a former *Alvin* pilot. He is part of a team of marine engineers at WHOI who have donned the hats of interior designers to make *Alvin*, a workhorse of the oceanographic community, a little more comfortable.

Space constraints

Even before thinking of a redesigned interior, engineers on the project considered the shape and weight of every item that must fit inside the submersible on each dive. All told, the list includes about 300 items. Every power, navigation, and alarm system panel, storage shelf, camera control device, ethernet switch, emergency flashlight, and even the pilot's small seat must be weighed to ensure that *Alvin* has enough buoyancy material to keep the submersible upright and stable during a dive.

Once all the equipment is inside, what space remains goes to the pilot, the scientists, and the small bags of items that they bring down with them (typically, a snack, notepads or other recording devices, and extra warm clothing).

Fitting it all inside the sphere is like piecing together an enormous puzzle inside a big ball. In a laboratory on a dock in Woods Hole, engineers created a prototype fiberglass version of the new sphere to give people a sense of the available space and help them figure out where everything might go.

To represent each item that will go into the sphere, engineers designed and built cardboard mock-ups of computer monitors, video displays, handheld cameras, and dozens of other pieces of equipment to help work out how to fit people and components harmoniously together.

In spring 2010, Chris German, chief scientist for deep submergence at WHOI, distributed a 20-question survey to *Alvin* users, seeking their opinions on changes they would most like to see in the new sphere's interior. More than 110 biologists, geologists, microbiologists, geochemists, and engineers responded.

◄ The new sphere will have five, rather than, three viewports; the forward-looking viewports will be 7, rather than 5, inches in diameter. To withstand pressures at greater depths, the sphere will be 3, rather than 2, inches thick, with an interior diameter that is 4.6 inches wider than *Alvin*'s current sphere. That increases the interior volume by 18 percent, from 144 to 171 cubic feet.

Illustration by E. Paul Oberlander, WHOI

Seats, sights, and heights

The survey also asked people about their height and vision. German said the information will help make the interior set-up of the sphere more user-friendly, and when possible, adjustable to accommodate different needs.

Half of the respondents reported that they are nearsighted. "During the average dive, people are constantly looking out of a viewport then back to a computer screen or notepad to record what they are seeing, or to interior video screens showing live video feeds to areas around the submersible," German said. "It means they are constantly refocusing their eyes. That's important to know because it helps us decide where we are going to put key components like video monitors," especially in relation to where scientists will position themselves inside the sphere.

As to how they will position themselves, scientists will have more options. The new locations of the viewports necessitated changes in seating, which gave engineers an opportunity to build in some more comfort. Now, passengers often sit on the floor, with their heads on opposite sides of the sphere and their legs poking into shared space in the center, trying not to kick each other or the pilot's metal box seat. To get people off the floor, engineers have proposed adjustable benches that allow passengers the choice of kneeling, sitting, or lying flat.

Built for depth, not for comfort

With such an expensive and carefully crafted investment, why not make the new sphere really snazzy by adding reclining leather seats? a reporter suggested. How about a few cozy cashmere blankets and an Italian coffee maker, which would fight the chill that comes from the average temperatures of 55° to 65°F inside the sphere? Tarantino laughed and shook his head.

Weight limits prohibit too many frills, he said. Safety considerations also add constraints. To prevent a fire inside the submersible, electronics must meet strict criteria before they are allowed in. Fabrics covering the foam pads also must be fire-resistant and made from a material that would not emit noxious fumes.

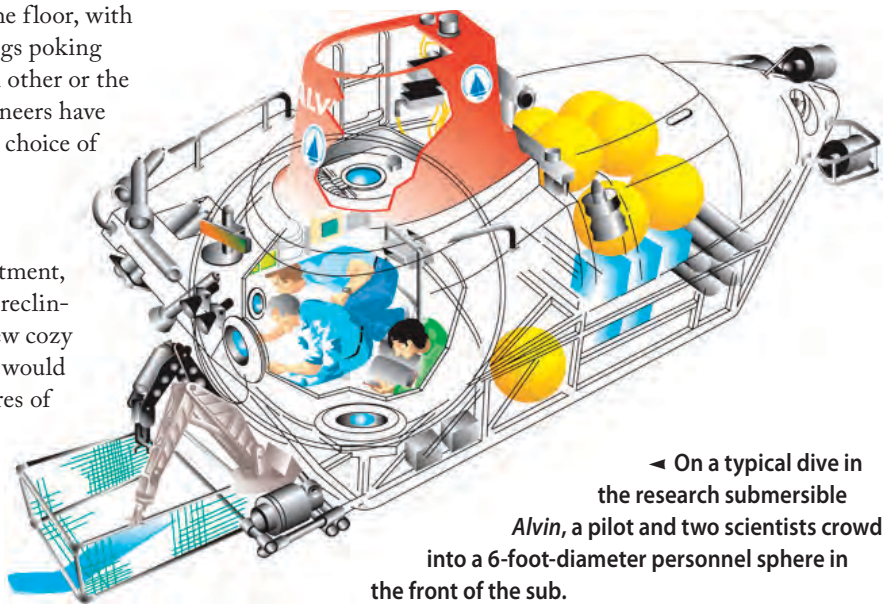
"We're never going to be able to provide luxury," said German. "It's not like flying business class."

But lack of comfort is part of the experience, he said. Sharing a ride in *Alvin* bonds people, he said, in the same way that people sometimes feel a shared experience after making an arduous car journey.

"People know that they have endured one of the more uncomfortable rides on Earth to be a part of a really special group," German said.

Hickey, *Alvin's* operations manager, was confident that people would enjoy improved creature comforts in the new sub. But he forewarned future passengers that they still won't find one thing on board: indoor plumbing.

—Amy E. Nevala



◄ On a typical dive in the research submersible *Alvin*, a pilot and two scientists crowd into a 6-foot-diameter personnel sphere in the front of the sub.

Illustration by E. Paul Oberlander, WHOI

FUN FACTS

Has *Alvin* ever gotten stuck?

Yes. Once in 1975, *Alvin* drove over a fissure wider than the submersible. It went in and the pilot proceeded slowly. Before the pilot could tell that the fissure's walls were narrowing, the submersible became wedged in the crack. Initial attempts to maneuver out failed. Finally, the pilot backed out, to the relief of *Alvin*'s passengers and the ship's crew.

What do you do on the way down?

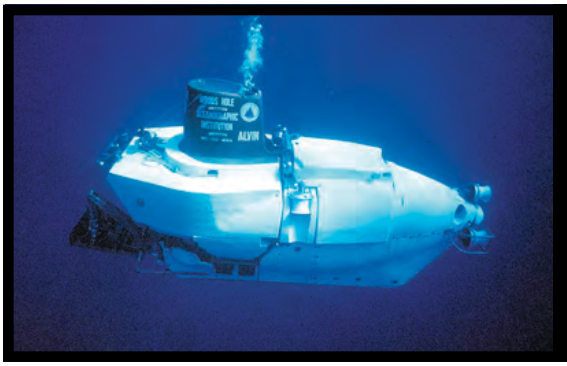
Prepare notes, data logging sheets, and tape recorders for logging research information. Layer on hats and sweaters; it gets colder the deeper you dive. Listen to music (typically chosen by the pilot).

How many people have been *Alvin* pilots?

Some 75 space shuttle pilots have flown missions, but since 1965, the job of driving *Alvin* has gone to just 38 men and one woman.

Has anyone famous traveled in *Alvin*?

Yes. Walter Cronkite (the late broadcast journalist); Rita Colwell (former director of the U.S. National Science Foundation); William Broad (Pulitzer-prize winning writer for *The New York Times*); Gary Comer (founder of the Lands' End clothing company); Vinod Khosla (venture capitalist); Ann Curry (television news journalist).



Do *Alvin* pilots have any special traditions?

Most people receive flowers or a card to honor a special achievement. Seagoing folks have their own, sometimes quirky, rituals. When Mark Spear stepped out of *Alvin* after becoming WHOI's newest deep-sea pilot, a fellow pilot greeted him with a traditional baptism on the deck of the research vessel *Atlantis*.

What about marine life?

In 1967, an 8-foot long, 196-pound swordfish lodged its bill into a joint on *Alvin*'s hull during a dive off the east coast of Florida. Members of the *Alvin* team removed the swordfish, with minimal damage to *Alvin* (the fish, however, was turned into steaks).

How did *Alvin* get its name?

The submersible is named for Allyn Vine, a WHOI engineer and geophysicist who helped pioneer deep submergence research and technology.

What is the temperature in *Alvin*?

The average temperature outside the submersible is usually around 35°F. Inside the sub with all the electronics, and three people's body heat, it gets down to 45° to 50°F.

Where is the bathroom in *Alvin*?

There is no bathroom. On a wall inside its support vessel, *Atlantis,* there is a sign that reads "PB4UGO." Experienced divers urge newcomers to take the sign seriously. If there is an emergency, divers have to use a bottle.