SCIENTIFIC AMERICAN FRONTIERS PROGRAM #1503 "Going Deep"

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ALAN ALDA Hello and welcome to Scientific American Frontiers. I'm Alan Alda. It's said that the oceans, which cover more than two thirds of the earth's surface, are less familiar to us than the surface of the moon. If you consider the volume of the oceans, it's actually more than ninety percent of the habitable part of the earth that we don't know too much about. The main reason for our relative ignorance is simply that the deep ocean is an absolutely forbidding environment. It's pitch dark, extremely cold and with pressures that are like having a 3,000-foot column of lead pressing down on every square inch -- which does sound pretty uncomfortable. In this program we're going to see how people finally made it to the ocean floor, and we'll find out about the scientific revolutions they brought back with them. We're going to go diving in the Alvin, the little submarine that did so much of the work. And we're going to glimpse the future, as Alvin's successor takes shape in a small seaside town on Cape Cod. That's coming up in tonight's episode, Going Deep.

INTO THE DEEP

ALAN ALDA (NARRATION) Woods Hole, Massachusetts. It's one of the picturesque seaside towns that draw the tourists to Cape Cod each year. But few seaside towns have what Woods Hole has. For 70 years it's been home to the Woods Hole Oceanographic Institution — an organization that does nothing but study the world's oceans. While the tourists on Main Street are thinking about fried clams, all around them the folks at the Institution -- or WHOI, as it's universally known -- have other things on their minds. Like this, for instance. It's the submarine that's going to be exploring the world's oceans for the first half of the 21st century. The new sub is to replace this one — the Alvin. Arguably the most successful deep-diving sub ever built, Alvin's still at work after 40 years, but now getting hard to maintain. And, no — it's not named after a chipmunk, although oceanographers think it's just as cute. It's actually named for Allyn Vine, a WHOI scientist who championed the cause of ocean exploration. In the summer of 1964, Alvin made its first tentative dives in the shallow waters around Woods Hole — often with Allyn Vine on board. The essential component of any deep-dive sub is the part you can't see here — the massive pressure hull that protects the crew.

BOB BALLARD The first submarine ever built in America was the Turtle .

ALAN ALDA Oh, really?

ALAN ALDA (NARRATOR) Bob Ballard started working with Alvin at WHOI in 1967. This sister ship to Alvin has a pressure hull that's a steel ball, about 6 feet in diameter inside, hidden in the structure. There's a single small hole in the top of the ball.

BOB BALLARD This is the hatch. Two inches thick,

ALAN ALDA So, what keeps the water from going in here?

BOB BALLARD Well it's actually tapered. If you look at the hatch, it's like a porthole, the pressure pushes them down. In fact, you're most vulnerable at the surface. That's the most dangerous time because you don't have the pressure seating it. Alright, well let's get down inside here. So watch your step.

BOB BALLARD Absolutely a sardine...

ALAN ALDA Oh my God! It's tiny!

ALAN ALDA (NARRATION) In 1869, a hundred years before Alvin's launch, the French writer and ocean sailor, Jules Verne, published his classic story of the renegade scientist who travels the world's oceans in his fabulous submarine, Nautilus. None of Captain Nemo's technology existed at the time, of course, although in Hollywood's 1916 version the self-contained diving suits were a genuine technical advance. The adventures of Captain Nemo and his crew were an inspiration for generations of ocean explorers, including Jacques Cousteau and Bob Ballard. While some features of the Nautilus brilliantly foreshadowed later developments, Jules Verne did skip over the challenges of water pressure. Submarines, like the Nautilus, capable of accommodating large crews, developed rapidly during the Second World War. Yet water pressure limited the best of the German U-boats to a depth of about 700 feet, and today's large submarines can go no deeper than a thousand or so. It was Otis Barton, an engineer from Massachusetts, and his collaborator, William Beebe, who first solved the problem of how to reach extreme depths. The solution was to dive in a small, massive sphere — they called it a bathysphere. A spherical form offers the most effective resistance to the crushing pressures at depth. In a series of dives off Bermuda in the 1930s, they shattered the existing depth record of 525 feet, established by a diver in an armored suit. The bathysphere was simply lowered from a barge, a risky business since any fault in the cable would lead to a fatal plunge to the bottom. It was the peculiar subs called bathyscaphs, conceived by the Swiss balloonist Auguste Piccard in the 1930s, which finally reached the deepest part of the ocean — the 35,000-foot Challenger Deep off Guam. A huge tank of gasoline

provided flotation, so you didn't need a suspension cable. Bathyscaphs were safer, but very unwieldy, as Bob Ballard discovered personally.

BOB BALLARD The front of the submarine came down and I'm looking at it, and it's just the metal and everything, its just twisting in my eyes, like a giant... just slowly, just very slowly, taking the submarine and just ripping it open. And then I see av gas coming out.

ALAN ALDA What's that?

BOB BALLARD That's the flotation gasoline. We ruptured our tank.

ALAN ALDA How did this turn out? Did you live?

BOB BALLARD Well here's what happened. We then, he dropped the whole... then you could drop the whole door and he dropped ten tons. When he saw that, I said "av gas!" When I yelled "av gas," he dropped the doors open and we dropped ten tons. Now we're at 20,000 feet. It's a six hour trip home and here's what happens. You're leaking your gasoline and you start decelerating and then you start back down. Well, they had in the sub a little calculator, you know one of those little LED displays? Freezes up on a number? And so every few seconds, it was telling you your ascent rate. Well ,there was enough uncertainty in the calculation that it depended upon whether you were an optimist or a pessimist. You could get whatever you wanted out of those numbers.

ALAN ALDA You didn't know whether you'd make it to the top before you lost your gasoline which gave you the buoyancy?

BOB BALLARD Exactly. And then you'd go negative. No one spoke. The most silent experience I've ever had, and we all looked at those numbersÉ

ALAN ALDA For six hours?

BOB BALLARD For six hours. And we were decelerating, because we were losing flotation. But we had enough to get home.

ALAN ALDA (NARRATOR) Although Alvin has done some great science — as we'll see later — it was originally built for the US Navy, and operated by WHOI. Its first deep dive, to 6,000 feet, was to check out a secret listening array off the Bahamas. Soon after that Alvin was brought here, off the coast of Spain, to play a starring role in a famous Cold War incident. In the 60s, B-52 bombers loaded with live H-bombs, were always in the air. One such patrol, returning to North Carolina, had a catastrophic collision with its aerial refueling tanker. Seven crew members died, and four H-bombs plunged to earth. Mercifully, they did not

explode, and three were recovered on land. The fourth, though, was 2,000 feet down in the Mediterranean. Alvin found the bomb, after 19 dives, by following a long gouge in the sea floor, spotted by the WHOI crew. The gouge led to the bomb's parachute. This film has never been shown before, by the way. Alvin's remote control arm couldn't recover the bomb, but it did help guide a secret new Navy robot to snag the parachute and haul the bomb up. There had always been doubts whether Alvin would really turn out to be useful — but not anymore. The incident showed that people could routinely reach unprecedented ocean depths — and so could robots. This tension between manned and unmanned deep diving has continued to this day. A unique ship made from these surplus Navy pontoons was to cause a near disaster for Alvin, as well. Alvin was carried to dive sites on Lulu, then lowered into the water between the pontoons, suspended on steel cables. In 1968, this was the result. A suspension cable on Lulu had snapped, and Alvin had fallen into the sea with the three crew members inside, and the hatch open. The sub sank in 60 seconds, but not before the crew scrambled or were pulled to safety. After seven months, a secret Navy camera system -- towed by this ship, the Mizar -- found the wreck. Another deep-dive sub, the Aluminaut, was brought in. The plan was for the Mizar to dangle a nylon rope down to the Alvin. Then the Aluminaut would use its remote control arm to hook the rope to the wreck. It took two trips over three months, but they finally did it, and Alvin was winched up 5,000 feet from the floor of the Atlantic. In our next story, we'll look at some of the important science results that Alvin went on to achieve over the next three decades. But first, take a look at the famous sandwich that came up in the Alvin — in perfect shape after a year on the bottom. It led WHOI scientists to look closely at slow decomposition at depth, and then argue against the idea of deep-ocean disposal of waste. It was a great service performed by one sunken sub, and one baloney sandwich.

DEEP SCIENCE

ALAN ALDA (NARRATOR) We're in the eastern Pacific, near the Galapagos Islands. We're going to go on a typical deep science dive, into the Galapagos Rift. The Alvin's made thousands of such dives over the last three decades.

TECHNICIAN Have a good one. Sealing the hatch.

RALPH HOLLIS Hatch is secure.

ALAN ALDA (NARRATOR) But this dive, which our cameras filmed a few years ago, is in many ways the classic Alvin dive. It was here in 1977 that people, for the first time, gazed out from the sub at a kind of life we never knew existed.

RALPH HOLLIS Hatch is closed, oxygen on, CO2 scrubber on, ID light on. Request permission to dive.

CONTROLLER Roger. You're clear to dive. Depth of the target 2485. Clear to dive.

RALPH HOLLIS Roger Alvin diving.

ALAN ALDA (NARRATOR) We're going down 8,000 feet, although the metal ball that's protecting us can safely reach 15,000. It will take two hours to reach the bottom.

RALPH HOLLIS My depth is 1620, one six two zero. 1620 one six two zero.

ALAN ALDA (NARRATOR) The acoustic radio echoes through the ocean.

RALPH HOLLIS Everything looks normal, Jim, so far.

JIM CHILDRESS OK. We'll be on the bottom before long.

RALPH HOLLIS 600 meters to go.

ALAN ALDA (NARRATOR) We're diving on a part of the ocean ridge system — an enormous undersea mountain range that snakes around the globe. In the 1960s we realized the mountains are actually volcanoes, which create the earth's crust. Then in the 70s, deep-diving subs like the Alvin began to visit the ocean ridges.

RALPH HOLLIS A2, this is Alvin. At the bottom. Depth is 2507, two five zero seven, ambient temperature, two point zero four nine.

ALAN ALDA (NARRATOR) First, we're gliding over lava fields. Then the water begins to warm up. And we seeÉ giant clams. They were first glimpsed in 1976, by a remote camera system from the Scripps Institution of Oceanography. The next year, in a WHOI expedition led partly by Bob Ballard, Alvin came down and found the clams, found hot water vents -- and found a whole new kind of life on earth. Clustered around the underwater volcanic springs -- called hydrothermal vents -- was an array of unknown life forms, thriving in the warm currents. Tube worms, clams, mussels, crabs and fish. At first, scientists couldn't figure out how these things survive. Up above, all life depends on sunlight and photosynthesis — but here there is no sunlight. It turned out that life here depends on kinds of bacteria that were new to science. They live on the energy of the earth itself, consuming hydrogen sulfide gas that's dissolved in the water that flows from the vents. This may be how life on earth began. The scientist on our dive, Jim Childress from UC Santa Barbara, does not always look out the window, as you might expect. Instead, he's watching a TV monitor while the pilot, Ralph Hollis

from WHOI, collects the samples Jim wants. It makes sense for professional pilots to run the sub's systems, but it can be frustrating for the scientists not to see directly what's happening.

JIM CHILDRESS Where are you, sort of right where the tube comes out of the rocks?

RALPH HOLLIS Well, I'm up to the yellow mark, into the fissure where the tube worms are.

ALAN ALDA (NARRATOR) How pilots and scientists can best work together on the ocean floor is going to change in Alvin's replacement.

RALPH HOLLIS A2, Alvin. Request permission to surface. Request permission to surface.

CONTROLLER Roger.

ALAN ALDA (NARRATOR) To surface, the Alvin drops a thousand pounds of steel ballast — maybe right on top of a biology sampling area.

RALPH HOLLIS Both weights away.

ALAN ALDA (NARRATOR) Later on we'll talk about plans for new working conditions, and ballast, in Alvin's replacement. The objective, though, will remain the same — take scientists down, and get them back, with their amazing finds. In 1979, Alvin made another historic find, in an area called the East Pacific Rise, off Baja, California. They called them Black Smokers — chimneys spewing out clouds of mineral-rich water, so hot that it must have come from deep in the earth's crust. This explained why the sea is so full of minerals.

BOB BALLARD The seawater, which is under pressure, goes right down into those cracks, goes down into the magma chamber. The magma chamber is hot -- 1400 degrees, 1200 to 1400 degrees centigrade. And so it heats up the water, and then the water begins to interact with the magma chamber, and it changes its chemistry.

ALAN ALDA Now does the water turn to steam?

BOB BALLARD No, it can't because of pressure. It turns into superhot water.

ALAN ALDA Superhot water which means it stays É

BOB BALLARD Liquid. ALAN ALDA Liquid, but it's really...

BOB BALLARD Really hot. And its now full of chemicals that it didn't have before. And its those chemicals that are coming out of the black smokers that are responsible for the chemistry of the world's oceans. In fact we now realize that the entire volume of the world's oceans is going inside the earth and out, every six to 8 million years.

ALAN ALDA Every six to eight million years.

BOB BALLARD The entire volumeÉ

ALAN ALDA All the oceans in the worldÉthey all go down...

BOB BALLARD Through this system.

ALAN ALDA Under the floor of the ocean.

BOB BALLARD Into the mountain range, and come up in the form of black smokers.

ALAN ALDA And it takes eight or ten million yearsÉ

BOB BALLARD For the whole ball game. That's a lot of water.

ALAN ALDA Well, of course.

BOB BALLARD And that's what's caused the chemistry of the world's oceans. And we didn't know that.

ALAN ALDA (NARRATOR) Diving in Alvin is not the only way we've discovered how the oceans and their inhabitants work, but it's been an amazingly successful way. Next we'll see how the folks at WHOI think they can make a better Alvin.

GREATER DEPTHS

ALAN ALDA (NARRATOR) We're back at WHOI on Cape Cod. Every three years, Alvin has to break away from whatever ocean it's exploring, and return home. Then it gets torn apart and overhauled. They say there's not an original piece of the sub left. In 1973 the all-important pressure hull was replaced with a titanium version that could go twice as deep, to 15,000 feet. The white blocks are a special foam, made of microscopic glass bubbles, that can withstand the pressure of the deep ocean. It's what gets Alvin back to the surface — you just drop some weight, and the sub floats up. That's why the Alvin is so safe — no main ballast tanks needing pumps and valves to empty. Barrie Walden's group at

WHOI is responsible for designing Alvin's replacement. He's checking out the Sea Cliff, a US Navy sister ship to Alvin, retired in 1998. Sea Cliff could dive to 20,000 feet — 5,000 deeper than Alvin — but the basic design is the same. And inside the cramped pressure hull, the drawbacks are the same too.

BARRIE WALDEN When these submersibles were first designed, video was nowhere near as capable as it is today. So the designers purposely wished for the observers to have different views than what the pilot had, so that they wouldn't be wasting the human eyeball, essentially. So these viewports do not overlap. The observers can't see what the pilot is doing. The new Alvin is going to be different than that, in that the pilot viewport will still be in approximately the same position, but the observers' viewports will be pulled around to the front and raised a little bit, to give them the same sort of view that the pilot has.

ALAN ALDA (NARRATOR) This is the other way to explore the oceans. It's an ROV — remotely operated vehicle. Now that video is so capable, ROVs can send high quality pictures through a fiber optic cable, back to the control room on the ship. It's cheaper and safer than sending people down. They can take samples, remotely, too. Next will be AOVs -- autonomous vehicles that can find their own way out and back. So why build another manned deep submarine?

BARRIE WALDEN Whenever I find somebody that is a champion of the other methods of doing this kind of work, the easiest thing I can do to convince them that there is a place for manned submersibles is let them make a dive. There are some benefits that you get from actually being there, looking around in person, that you just don't get from a cable-controlled vehicle, or a vehicle that gives you data a week after it's recovered, kind of situation. Now, I'm not saying that we should have nothing but manned submersibles. My argument really is that we need at least one manned submersible.

ALAN ALDA (NARRATOR) In the belief that that view is correct, computer models and plywood and fiberglass are now getting together to create Alvin's replacement. This is a mock-up of the pressure hull -- although it won't be sliced in half. Bob Brown -- a former Alvin pilot -- heads up the design team.

BOB BROWN Here you see the pilot's seat. The pilot will sit -- will be a movable little chair. And he would sit like this, with his viewport here. The blue around here indicates the actual size of the viewport. The simulator viewport we have is much smaller. The actual one will be bigger. We have a small pilot's desk here in the middle, and this is something that he can look at by glancing down when he's looking out the viewport.

ALAN ALDA (NARRATOR) The hull diameter is about six inches larger than Alvin's, inside. Combined with touch screen controls and miniaturized electronics,

that will give a much roomier cabin. But there'll still be a few old-fashioned, clunky controls. BOB BROWN We do have, on the switches above here, we have switches for vital systems that are necessary for getting the submersible back to the surface.

ALAN ALDA (NARRATOR) The sub will use the same tough glass foam as Alvin, but it won't be dropping steel weights to surface. Instead it will pump water out of ballast tanks. In an emergency, it will still be able to jettison all kinds of parts to get back up. The biggest change though, is the two scientists having their own ports to look out front. All three people will be able to work cooperatively.

BRUCE STRICKROTT Put your head up there. We're not going to be fighting for space, are we?

ALAN ALDA (NARRATOR) Current Alvin pilots, like Bruce Strickrott, come in regularly to try out the mock-up. The new sub will go to 21,000 feet — 6,000 more than Alvin. To have reasonable working time on the bottom, it'll need to go down and up twice as fast. So this sub will be streamlined, and it'll almost fly up and down, at an angle.

BRUCE STRICKROTT What will this feel like at 20 degrees nose down in the descent?

BOB BROWN Yeah, we'll have to, er...

BRUCE STRICKROTT Make some sort of vertical backrest, or something BOB BROWN Well, probably a chair back here, probably not even sit on that, and he can have his chair back here for going up, and something else for going down, to be determined yet. And these things can be changed to allow for angles.

ALAN ALDA (NARRATOR) The goal is, in three years, to have all this carved in stone — or rather forged in titanium. The sub will give scientists routine access to 99% of the earth's ocean floor — in a whole new style.

BRUCE STRICKROTT I think it's like the difference between a Motel 6 and a Hilton. They're going to love it, are you kidding me? It's bigger, they got more viewports, they get to look out front -- they never get to look out front. They get benches to sleep on, on the way up and down. How could they not like it?