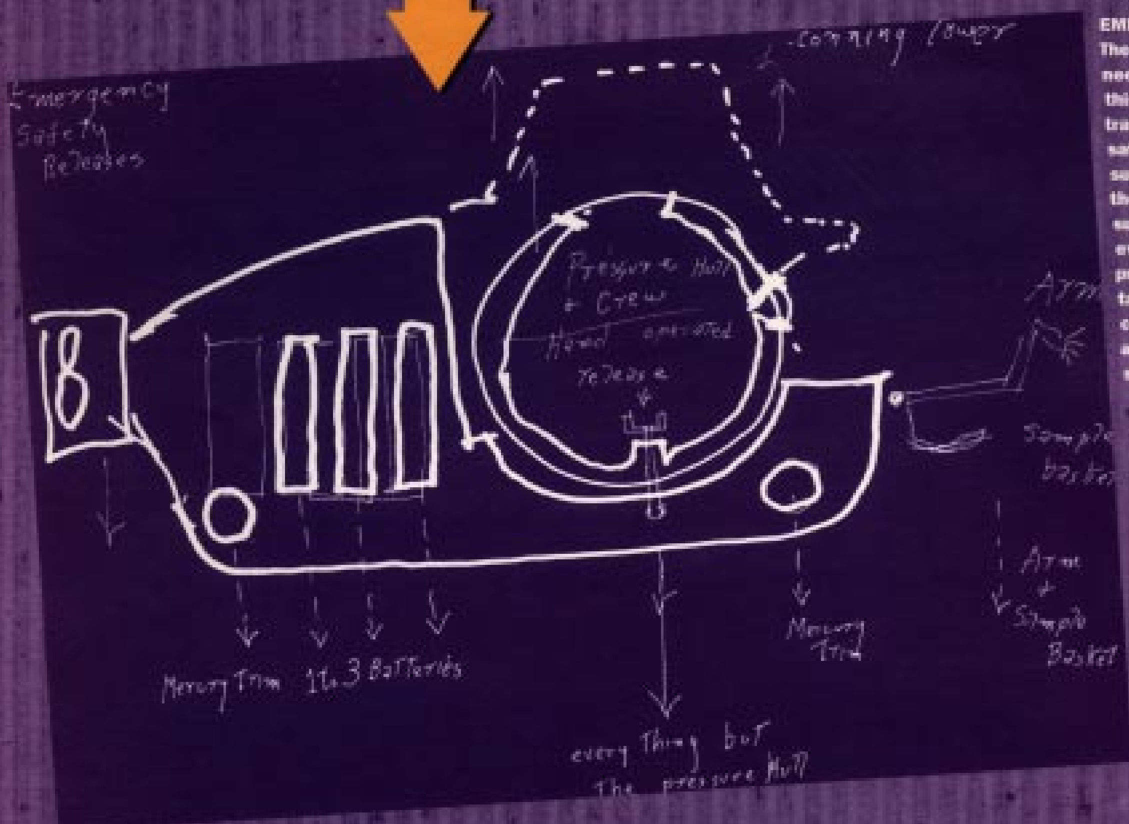
OCEAN explorer

For the Young Associates of Woods Hole Oceanographic Institution Vol. 4 No. 1 September 1994



EMERGENCY EXIT
The late WHOI engineer Allyn Vine made this sketch to illustrate an important safety feature of the submersible *Alvin*. If the sub could not surface normally, everything but the pressure hull containing the divers could be dropped to allow the hull to surface.

NECESSITY IS THE MOTHER OF INVENTION

We humans are not creatures of the sea. For us to spend more than a very limited amount of time on the open water has required a series of inventions throughout history. Beginning with simple rafts and canoes carved from the trunks of trees, these vessels progressed to today's complex computer-controlled ships.

Few people are more aware of a human's need for tools and technology on the sea than oceanographers. Their work depends on finding ways to outsmart furious waves, predatory creatures that snap buoy cables with their sharp teeth, and many other calamities.

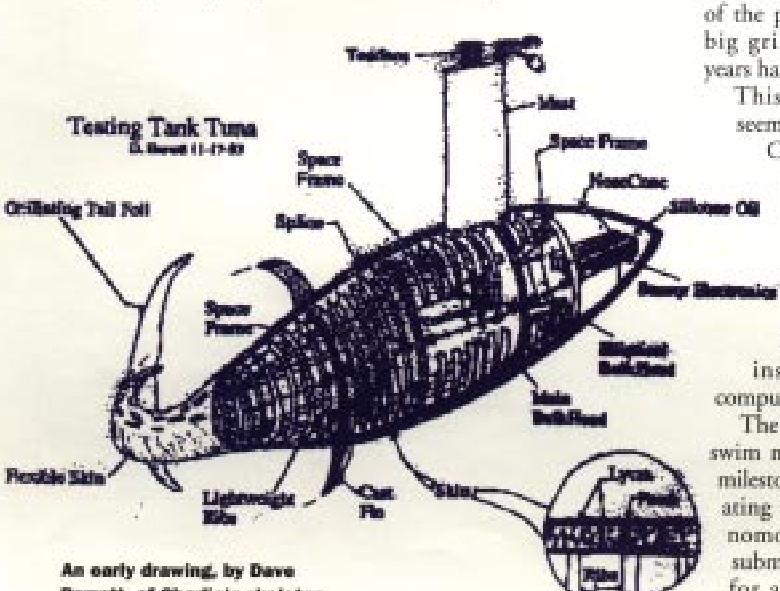
In this issue of *Ocean Explorer* you will meet a number of inventors who have dedicated themselves to solving some of the problems of studying the sea. You'll meet researchers involved in brand-new inventions. You'll also read about a man who was very important to the history of oceanography, the legendary Allyn Vine. He knew the importance of overcoming human limits when confronted with the limitless world of the sea.

MEET "CHARLI

THIS TESTING-TANK TUNA IS MAKING BIG WAVES

by Deborah Kovacs

On the ground floor of a building at the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, a bluefin tuna called "Charlie" is lowered carefully into a 40-metre long water tank. A group of people wait nervously.



An early drawing, by Dave Barrett, of Charlie's skeleton.

Engineer Dave Barrett types into a computer. The tuna springs to life. Gliding gently and easily, it wiggles the length of the tank, completing the journey in less than a minute. Michael Triantafyllou, head of the project, breaks into a big grin. A dream of five years has been realized.

This lifelike movement seems natural...and eerie. Charlie is a robot. In fact, Charlie is the world's first fish robot, with a "virtual" body, connected by cables to an overhead motor and also to a "brain" inside Dave Barrett's computer.

The tuna's first successful swim may be an important milestone on the way to creating a new kind of autonomous (self-propelling) submarine that can travel for a much longer time than today's battery-driven, propeller-powered subs. This new kind of vessel will swim like a fish, by moving a fish-like tail structure called a flapping foil.

THE TAIL WAGGED THE FISH

Charlie's creation began a few years ago with a question asked by Michael Triantafyllou and others. Is it the back-and-forth swishing of a fish's tail that lets it move so efficiently, and for such long periods of time?

A tuna can swim at speeds of 20 knots or more for many hours. That's around the same speed as some fishing boats. Yet the tuna has about the same amount of muscles as a full-grown man in good physical condition. A man could never swim as far and as fast as the tuna. The tuna uses much less energy than the fishing boat. What's the fish's secret?

Mike, his brother George,

E”

a mechanical engineer from New York University, and Mark Grosenbaugh, a physicist from WHOI, designed an experiment to try to answer this question.

DRAG OR THRUST?

The scientists knew that as ships move through the water, they create a wake, also called drag, that slows them down. But other objects can use their shapes and their movements to generate their own energy. This energy is called jet, or thrust. Does a fish's tail produce thrust?

Mike, George, and Mark studied the back-and-forth movement of fishes' tails. That swing, they thought, might let the fish's body produce its own energy in somewhat the same way that a pendulum on a clock does, or in the way that you can help yourself walk faster by swinging your arms.

They built a simulated fish tail, called a flapping foil. They tested the flapping foil by "flying" it in MIT's Testing Tank.

Microscopic glow-in-the-dark objects called kalliroscopic particles were added to the water. As the foil swished through the tank, pulled by an overhead motor, Mark Grosenbaugh shined a thin beam of laser light on the water behind it. He photographed the lit area, in a series of two-millisecond exposures. The glowing particles in the water illuminated the various types of water swirls, called vortices, made by the flapping foil.

The scientists found that if the flapping foil moved at a low frequency, water behind it swirled in a clockwise direction, and produced drag. But if the foil moved at a higher frequency, the water swirled counter-clockwise, producing thrust.

They compared their results with known data on real fish. There was an almost direct match-up between the frequency the simulated tail needed to produce thrust, and that of the living fish. The team was on the right track. They had learned that a fish-tail, flapping at the right frequency, could push the fish through the water.

HOW DO YOU BUILD A SIMULATED FISH?

Next, the they wanted to find out how the rest of a fish's body movements help it swim efficiently. It was time to build an entire fish.

It was very important that the robot have the exact proportions of a real fish. The team decided that a bluefin tuna would be a good type of fish to imitate. Dave Barrett was responsible for the tuna's design. He made many drawings, and then it was time for a team to begin construction.

The fish's skeleton is built of anodized aluminum. It is covered with styrofoam, which is in turn covered with a skin of lycra, the same material used to make many types of bathing suits. A post in the middle of Charlie's back connects the robot to motors that move back and forth on a track in the ceiling. The post also connects Charlie to a computer program that helps it learn how to move. Pressure sensors along the sides of Charlie's body help it know where it is. These sensors are like the nerves that run in stripes down the sides of most fishes' bodies. Called lateral lines, the sensors help fish orient their bodies and let them sense the presence of of other creatures.

Charlie is simpler than a real fish. For example, the robot has about 100 sensors, while a real fish has about 20,000. "You have to make choices," says Mike Triantafyllou. "You have to make sure you don't leave out those things you really need."

Like a real tuna, Charlie's body moves in an s-shaped wave that starts at the nose and ends at the tail. When Mark begins to photograph Charlie, he will be looking to see if the water swirls that help power the fish's movements form at its head, roll down its body and are then put in the right position by a well-timed flick of the tail.

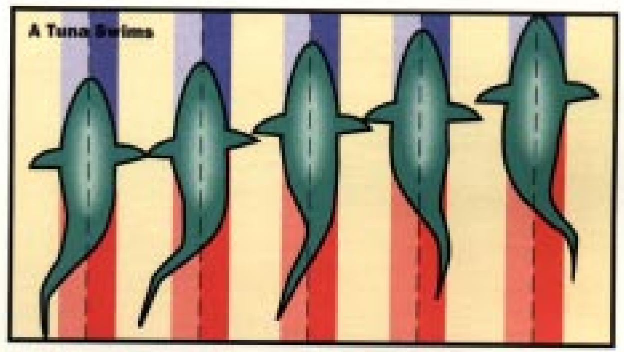
"We think the fish is able to organize the mini-vortices that move down its body," says Mark.

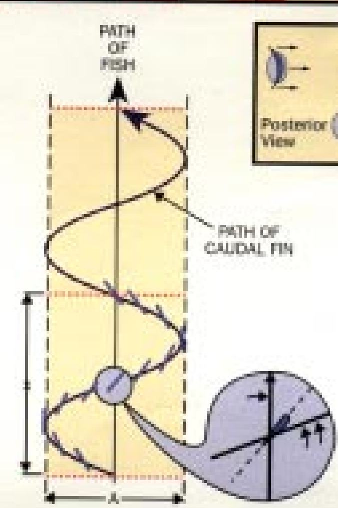
DOWN THE ROAD

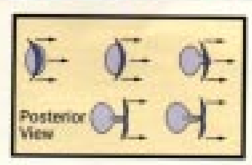
A descendent of Charlie that can do oceanographic research is still years away. It may not even look like a fish. Still, Charlie's moves today are giving researchers a lot of information.

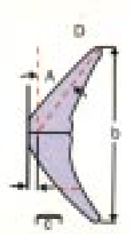
But no robot tuna will ever be as complex or powerful as a living creature. "The better we get at what we do, the more we realize how far behind we are," says Mike.

OTHERS WHO HELPED CREATE CHARLIE INCLUDE PEHR ANDERSON, JOHN KUMPH, GILLIAN LEE, ELISE MARTIN, AND OWEN WESSLING. FUNDING FOR THE PROJECT IS PROVIDED BY ARPA, ONR, THE MIT SEA GRANT PROGRAM, AND WHOI.









Problems... and

by Deborah Kovacs

The biggest obstacle to a better understanding of the ocean is the ocean itself. Vast, forbidding, ever-changing, it is a very difficult environment to work in. Over the years, hundreds of ocean scientists and engineers have developed tools and techniques to overcome the difficulties of ocean research. Here are just a few examples of ingenious solutions to ocean-research problems.

PROBLEM:
EQUIPMENT SCOOPED UP BY FISHING BOATS

Expensive, sometimes irreplaceable oceanographic research equipment is occasionally lost at sea. Many engineers have thought about this problem, often coming up with great solutions.

A few years ago, Sean Kery, an engineer at WHOI, was approached by the Navy with this problem: the large trawl nets operated by fishing boats often scoop up oceanographic research equipment by mistake. The Navy wanted to start using an expensive new piece of equipment called an acoustic current meter. They did not want these current meters to be destroyed by fishing boats. Could Sean come up with some sort of housing for the equipment that could outfox the scooping nets?

After studying the problem for some time, Sean has built a prototype housing that he thinks will solve the problem.

This stop-sign shaped device weighs as much as a car when it is out of the water. It is almost four meters across at its widest points. The key to its design is its sides, which slope upwards at about 30°. "Think of it like a blister sitting on the bottom of the ocean," says Sean. "Whatever comes along rolls over the top. Or think of it as a giant scallop shell with its flat side down on the bottom."

The device will be lowered over the side of a ship by a giant crane. Then it will fall straight down, to a depth of up to 600 meters. It will land on its flat side, and can then remain in place for up to two years, collecting data. When scientists want to recover the device, they will send down an acoustic signal that will free a center "pod" from the larger anchor that surrounds it. The pod will float back up to the surface, and the housing will remain on the ocean floor.

SHELLEY LAUZON/WHOI

SOLUTION:
A TRAWL-PROOF ACOUSTIC CURRENT METER

The trawl-proof acoustic current meter is still in the testing phase. But the first trials have been very encouraging. "We tested it to see if we can freefall it and get it to land the right way," says Sean. "It's performed quite well." Someday, Sean hopes that many of these eight-sided devices will be at work, avoiding the scoops of deep-sea trawls.

PROBLEM:
SAFER, LIGHTER-FLOTATION DEVICES WERE NEEDED FOR DEEP-SEA RESEARCH

Benthos, Inc. is an oceanographic manufacturing company located near Woods Hole. Since its founding in 1962, the company has worked very closely with scientists and engineers at WHOI to design and build oceanographic equipment.

Though the company has developed many complex devices over the years, it is one of their simplest products that has proved to be the most universally useful. This is a glass sphere, sometimes encased in a yellow plastic covering called a "hard-hat" and sometimes simply in a net bag. Any trip to the WHOI dock reveals large cages of these floats, ready to be loaded onto a research ship.

How did these devices come to be made? Says Benthos founder and president Sam Raymond, "I was called down to WHOI to talk to scientists who wanted us to build some free-falling coring devices to go down to the ocean floor and retrieve sediment samples."

The coring devices at the time were huge and very heavy. They used a concrete weight to drive the corer into the ocean floor, and a plastic bottle filled with gasoline as a float to bring the corer back to the surface after it had collected a seafloor sample. "They wanted us to build some of these," says Sam. "We did. We built six. They were monstrous, great heavy things, hundreds of pounds each." Sam didn't like the design of the corers at all. He thought the concrete weight was impractical. And he was especially concerned about the safety of the gasoline-filled bottles. If a bottle spilled on the deck of a ship, there was a great risk of fire.

Sam returned to shore, thinking about this problem. And on his desk he found a brochure from the Corning Glass Company, advertising a hollow glass sphere. Sam ordered a few of the spheres, and tried using them as floats, to see if they could substitute for the gas-filled bottles. They worked very well. At the same time, Sam decided to change the weight on each corer from concrete to steel.

With these improvements, Sam and WHOI engineer Peter Sachs developed a product called a boomerang corer, which proved very successful. But an even bigger success than the corer were the glass floats that

Solutions

PROBLEM:
NEED MORE EFFECTIVE PUMP FOR COLLECTING MICROSCOPIC MARINE ANIMALS

In the late 1970s, biologist Cheryl Ann Butman was studying microscopic larvae of marine animals off the coast of California. She wanted to understand how the rise and fall of animal populations related to the larvae supplied to the bottom by flowing sea water. But she couldn't interpret the data she was collecting with traps. "We got phenomenally different numbers each time we made collections," she says. "We found large numbers of animals in our traps that didn't occur on the bottom, and large numbers of animals on the bottom that didn't occur in our traps."

Was there an ecological cause for these results? Was there something wrong with the data collection devices? Cheryl Ann spent several years exploring these questions and found that the fault lay with the traps.

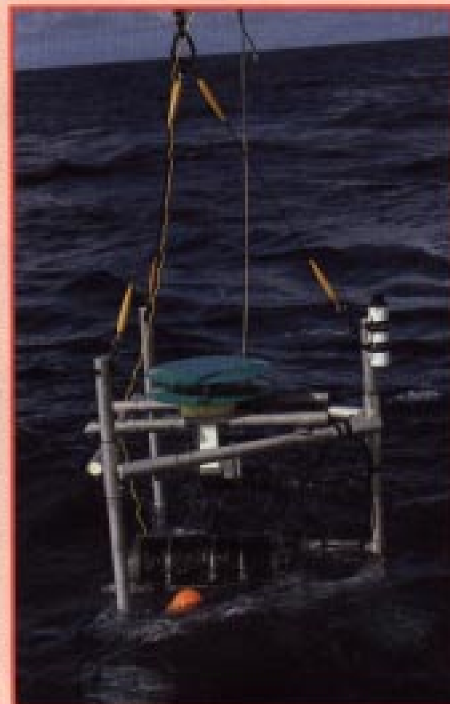
Most biologists would look to an engineer to solve a problem like this one. But Cheryl Ann was intrigued enough to try to solve the problem herself. She decided to build an instrument that could answer her questions. She had some training in physics in graduate school, and applied that training to study how larvae and other microscopic marine creatures behave in currents.

Many marine animals are able to sense changes in water pressure, and swim out of the way, often very quickly. Cheryl Ann knew that her pump collector would need to suck in water a little faster than the animals can swim. She also wanted an instrument able to collect data over several months. Existing pumps could only be operated by researchers who were right at the site, because of the high power requirements associated with very fast pumping rates. Her pump needed to use just a little bit of power when it operated, so it could stay in place for a long time.

The physics of water movement became part of the investigation, as well. "To do this engineering," says Cheryl Ann, "I had to understand how the instruments interacted with the ocean."

Cheryl Ann has spent the last four years working with WHOI engineer Ken Doherty building a device they call the Moored Automated Serial Zooplankton Pump (MASZP for short). This instrument pumps at a very slow rate, and so it needs very little power. It only slightly disturbs the flow of water, so the animals are not alerted to swim out of the way. Ten MASZP pumps have now been built, and are at work collecting animals in the waters off Duck, North Carolina.

Because Cheryl Ann is interested in research that combines both biology and physics, she is part of the Institution's Applied Ocean Physics and Engineering Department. She is the only faculty member in her department with a specialty in biology. She loves working with people who have different expertise than her own. "I think it's great for oceanography," she says. "The best way to have a dialogue is to be in the thick of things."



CHERYL ANN BUTMAN/WHOI

SOLUTION:
MOORED AUTOMATED SERIAL ZOOPLANKTON PUMP

made it work better.

The glass floats have been improved over the years. The spheres are really two hemispheres fused together. But the seams on the original floats did not match perfectly. They would sometimes break when deep under water. Also, because they were made of clear glass, they were hard to see on the surface when the time came to recover equipment.

To solve both of these problems, Sam started ordering hemispheres, rather than full glass balls, a practice which his company still follows today. At Benthos, the hemispheres are sanded with diamonds, so that their edges match perfectly. An electronic flash device is placed inside some of the floats and the two halves are carefully sealed together. These glass spheres light up and are easily spotted from research ships. Some floats are encased in two yellow plastic hemispheres called "hardhats" *(see photo).*

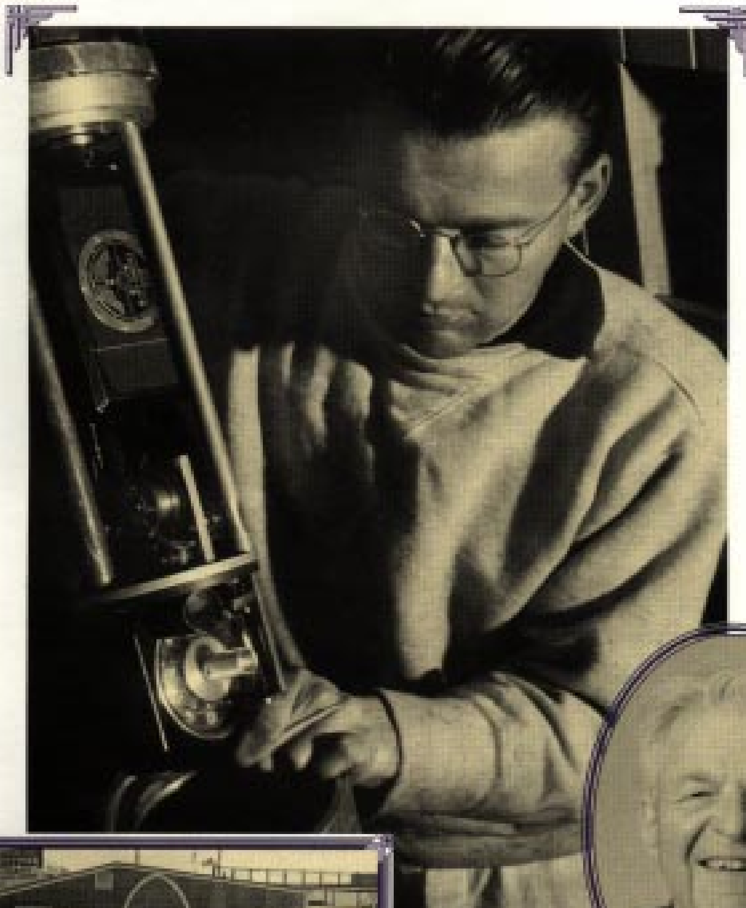
Thirty years later, these simple spheres are still standard oceanographic research tools.

SOLUTION:
GLASS FLOTATION SPHERES

A HEAD FULL OF IDEAS

ALLYN VINE—OCEANOGRAPHIC INNOVATOR

by Tom Gidwitz



Allyn Vine, 1914-1994

Allyn Vine in 1940 with the first free-floating , bottom-release underwater camera *(top)*.

When the Woods Hole drawbridge got stuck in the raised position, Allyn invented a solution—a rubber-tire ferry boat *(bottom)*.

In the late 1930s, a young graduate student at WHOI named Allyn Vine had an innovative idea. He wanted to use a glass sphere, five feet in diameter, to send a researcher to the bottom of the ocean.

The glass sphere was never built, but Allyn Vine did not give up his mission to send scientists deep beneath the sea. For the next thirty years, he kept coming up with new ideas for ways to take oceanographic researchers deep beneath the sea.

Finally, Allyn's vision and determination paid off. In 1962, work on a research sub began. When it was launched in 1964, it was named in his honor — *Alvin* is a contraction of Allyn Vine. And *Alvin's* first mother ship, designed with Allyn's help, was named Lulu, after Allyn's mother.

AN INNOVATIVE LIFE

Allyn, who died earlier this year at age 79, was a fountain of innovation and ideas.

For more than 50 years, he was involved with advances in deep sea geology, underwater acoustics, and deep-sea photography. He invented or perfected devices that measure the tide, buoyancy, subsurface pressure and temperature of the ocean. "Al Vine had a really fertile, imaginative mind," recalls Dave Ross, a WHOI geologist and friend of Allyn Vine for 30 years. "He probably *forgot* more great ideas than most scientists *have* in their lifetime."

He also made innovation part of his everyday life. Once, when he needed an alarm clock, he plugged his vacuum cleaner into the electric outlet on his stove, set the timer, and, in the morning, awoke to the vacuum's roar.

"He just bubbled over with ideas all the time," recalls Dr. J. Lamar Worzel, a geophysicist who first met Allyn in the 1930s. "He had very unconventional ways of thinking about things."

SOLVING MYSTERIES

Allyn thought, talked and even walked a half-speed faster than most people. And he followed his thoughts wherever they might lead. In *Water Baby: The Story of Alvin*, author Victoria Kaharl tells how Allyn, while waiting in a Midwest airport for a plane to Boston, fell into conversation with a stranger. The talk was so interesting, Allyn climbed on the stranger's plane to continue it. Unfortunately, the plane was headed to California. Allyn got home to Massachusetts twenty hours late.

He compared scientific research and problem solving to a mystery story. "How do you get from here to there? How do you get out?" he asked during an interview late last year. "Some people think you have to have everything all worked out ahead of time and know your plan down to the last eyebrow. Others feel you want to be sure you're headed in about the right direction, and then take your pair of pliers or your various ideas, and as you meet situations, you figure out a way to get around them."

Above all, failure was not something to be feared, but to be learned from. "Experiment, make your mistakes," he would say, and then add with a twinkle in his eye, "There's an enormous number of them still out there to be made, you see."

Although Allyn valued improvisation and often worked quickly, there was a guiding principle behind his work -- the advancement of knowledge about the sea.

A LIFE OF CURIOSITY

Allyn's curiosity showed itself at an early age. Born in Garrettsville, Ohio in 1914, he loved school and his teachers, and he quickly showed an aptitude for science. As a teenager, he combed through the junk pile of the local telephone company, collecting discarded parts and wires that he made into burglar alarms and other electronic gadgets.

In college, he majored in physics. After graduation, he entered the Master's Program at Lehigh University, where his adviser was Maurice "Doc" Ewing, one of the fathers of modern oceanography.

During the summers of the late 1930s, Ewing brought Allyn and other graduate students to WHOI. The group went to sea on the research vessel *Atlantis*. They did experiments with sound to learn about the sea floor. In 1940, the group moved to Woods Hole full-time to study sound transmission in the sea.

Modest Allyn Vine always insisted that WHOI's deep-diving submersible *Alvin* was named after Alvin, the cartoon chipmunk, and not after himself.

WORLD WAR II YEARS

When World War II broke out, Allyn's knowledge of sound, echoes and ocean physics helped the Allied cause by improving a device, the bathythermograph (BT) that helped Allied surface ships detect enemy submarines, and that also helped Allied submarines evade enemy surface ships.

Allyn and his former professor, Doc Ewing, improved the BT's accuracy and speed, and redesigned it so that it could be used on subs. Throughout World War II, Allyn and his colleagues rode on over 100 submarines, teaching the crews how to use the BT. Years later, the Navy gave Allyn a commendation that said his work had saved "untold numbers of lives and millions of dollars in ships and equipment."

A PROBLEM-SOLVER

Throughout his life, Allyn made enormous contributions to oceanography. He worked to enlarge the world's fleet of surface research ships. He liked to work with scientists from different countries, because he believed that the ocean is a common bond that links the nations of the world.

But his ideas were not limited to the sea. He felt scientific research of almost any sort was important, because no one could predict when or how it might pay off. "You cannot tell when it will be useful or where it will be useful," Allyn said. "It might not be useful today or tomorrow, but it's like having a flashlight in your car to use if you happen to get a flat tire in the dark."

Allyn gave free rein to his ingenuity, letting it roam around the world wherever there might be a fun problem to solve.

When the drawbridge over the inlet to the pond in the center of Woods Hole became stuck in the raised position for several weeks, Allyn converted a huge tire into a floating platform to ferry passengers back and forth across the water.

SCHOLAR, TEACHER, FRIEND

After his retirement from WHOI in 1979, Allyn continued to press for innovations. He worked to improve the design of future research vessels and spent time with students, discussing issues such as waste disposal at sea.

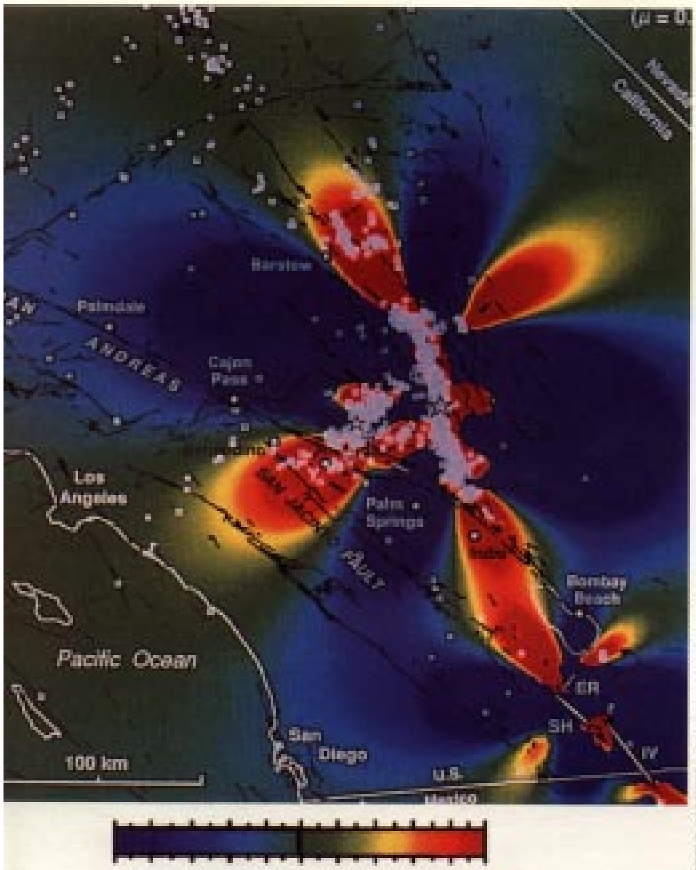
"He loved working with people all the time, anybody and everybody," says his old friend Dr. Worzel. "He thrived on it."

For Allyn, the sea was a place of fulfillment and promise. The joy of discovery was matched by the fun he had and the friendships he made.

"You dive in," he said. "You've got your buddies and your friends, and it's amazing what you can do."

BE AN INVENTOR!

If you'd like to try your hand at inventing a tabletop submarine, write to SUBMARINE, c/o *Ocean Explorer*, Fenno House, Woods Hole Oceanographic Institution, Woods Hole MA 02543. Enclose a self-addressed, stamped envelope, and we'll send you instructions for a mini-submarine activity by our advisor, Jack Crowley.



CREDIT: ROSS STEIN, GEOFFREY KING AND JIAN LIN

WHOSE FAULT IS THIS?

Pictured here is a portion of the San Andreas Fault, the huge crack in the earth's crust responsible for earthquakes in California. The image illustrates the stress changes near the fault following the 1994 Landers, California earthquake that reached a magnitude of 7.4 on the Richter scale. What does a crack on dry land have to do with oceanography? Everything on earth is interconnected, as you will see in the December issue of *Ocean Explorer.*

You'll also dive to the deep sea floor with the *Shinkai 6500.* This Japanese submersible is the deepest-diving people-holding craft ever built. Hold on! It's going to be a wild ride!

OCEAN EXPLORER

Deborah Kovacs
Editor

Angela Tannehill
Designer

Advisors from Woods Hole Oceanographic Institution

John W. Farrington
Dean of Graduate Studies

Charles D. Hollister
Senior Scientist
Vice President of the Corporation

A. Lawrence Peirson III
Associate Dean and Registrar

Shelley Lauzon
Senior News Officer

Educational Advisors

Charles F. Baker III
Administrator, Chapter I Program
New Bedford Public Schools

Jack Crowley
Hingham High School
Hingham, MA

Claudia Gifford
Friends Academy
Dartmouth , MA

Alan Harris
King Philip Regional School-North
Norfolk, MA