WOODS HOLE OCEANOGRAPHIC INSTITUTION 1930

OCEAN explorer

For the Young Associates of Woods Hole Oceanographic Institution VOL. 1, NO. 4 MAY, 1992

You never know what you'll run into on a dive in the deep, dark sea. You just might see two-inch wide "Dumbo" (an octopus whose scientific name is *Opisthoteuthis agassizii*) flutter by.

TRAVELING TO INNER SPACE

Until the mid-1960s, the only way scientists could collect samples from the deep sea was to dangle nets, buckets, and other devices over the sides of research ships. They scooped up whatever was within reach. The scientists learned a lot from what they collected, but they didn't know much about the environment their samples came from. It was as though they were reaching blindfolded into a big bag — they didn't know what they would pull out, or what they might have missed.

With the development of manned deep-sea submarines such as *Alvin*, this unknown world began to be revealed. More recently, oceanographic engineers have developed much smaller vehicles, remotely-controlled from surface ships to which they are connected by a tether (an electronic cable). These smaller subs, which carry no passengers, are called remotely-operated vehicles, or ROVs.

Woods Hole Oceanographic Institution has long been a pioneer in developing deep-sea research equipment. The Institution developed and operates the deep-sea submarine *Alvin*, and the ROV *Jason*. Engineers at WHOI are developing yet another new technology: a very small sub called ABE. ABE, called an AOV (autonomously-operated vehicle), will operate like a robot, untethered and with no passengers. ABE will operate following a computerized set of instructions.

In this issue, *Ocean Explorer* enters the world of deep-sea technology. You'll meet engineers who invent these devices, and scientists who are inspired by the discoveries the equipment makes possible.

SEEING IS BELIEVING: Deep Sea Dives Reveal Underwater Mysteries

Submersibles have introduced hundreds of people to the mysteries of the deep sea. *Ocean Explorer* asked two scientists to describe the impact of submersibles on their work.

THE BIG PICTURE

On her first dive in *Alvin* in 1986, WHOI geochemist Susan Humphris felt like an astronaut travelling to the moon. All the time she had spent beforehand wondering what the deep sea would look like could never have prepared her for what she saw: the utter darkness, except for a few meters that were lit up by *Alvin's* spotlights; the towering underwater rock structures that looked like mere specks on a map; the strange creatures that appeared and disappeared suddenly before the sub's portholes. Susan was also struck by "the excitement of actually seeing something I had tried to understand for so long."

MARGARET SULANOWSKA / WHOI

Susan Humphris begins another dive in *Alvin*.

Though diving in *Alvin* can be uncomfortable, as three people crouch together inside a metal ball with a seven-foot diameter, peering out of tiny windows at the undersea world, awareness of those inconveniences disappears pretty quickly during a dive. "You're so busy," says Susan. "You're so excited and so interested in everything that you see."

Susan had studied the Mid-Ocean Ridge (the underwater mountain chain that cuts through all the world's oceans) for about fifteen years before she actually got down to see it in person. Travelling to the deep sea has changed her perspective on the meaning of the rock samples she works with. "Before I had dived in *Alvin*, I used to work with big bags of rocks that had been dredged from the ocean floor." She could learn a lot by studying the rocks, but something was missing. "I had no idea what the area they came from looked like. I didn't understand where they had been before they were collected." Now that has changed. Diving in *Alvin* has added an important dimension to Susan's scientific work.

MEETINGS WITH REMARKABLE CREATURES

One of the creatures that Larry Madin has observed on his many deep-sea dives is *Periphylla periphylla*, photographed during a dive in *Alvin*.

Voyagers to the deep sea have met up with many species of animals that probably would never have been seen otherwise. Each time WHOI biologist Larry Madin dives in *Alvin* or another deep-sea submarine, he hopes this will happen to him. Sometimes it does.

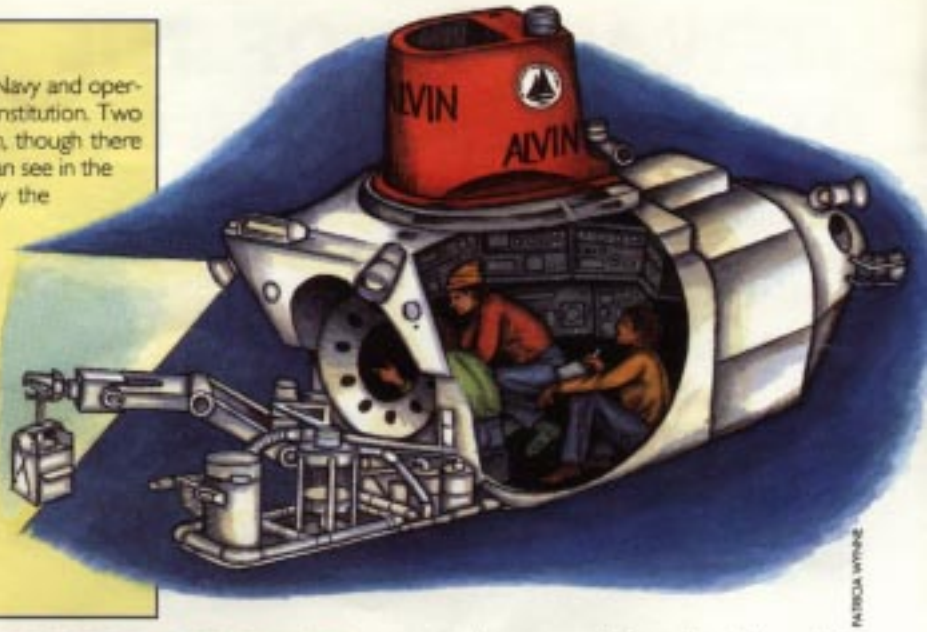
Larry studies jellyfish. Since gooey jellyfish bodies are often too fragile to collect, the best way to study jellyfish first-hand, or even to see them at all, is to travel to their world.

When Larry is on a dive and comes across a jellyfish, especially one that has not been seen before, he photographs it quickly and tries to describe as much about it as he can before it swims away, possibly never to be seen again. He describes what it looks like, how it behaves, what it eats, how it moves, and how its body works.

The weirdest creature Larry ever saw on a dive to the deep sea was a kind of jellyfish nobody had ever seen before. "Unlike most jellyfish, it had no tentacles. It was like a big open sack," says Larry. "If something swam inside, it shut, as though it were pulling a drawstring on a bag. We knew it was something that had never been seen before. It tried to eat our submarine!"

WHAT IS *ALVIN?*

Alvin is a research sub, owned by the U.S. Navy and operated by the Woods Hole Oceanographic Institution. Two scientists and one pilot can travel in *Alvin*, though there isn't much room to move around, as you can see in the drawing, in which the artist has cut away the sub's side. *Alvin* can dive to 4,000 meters (13,000 feet), deep enough to reach many, though not all, of the important features on the ocean floor. Here you see *Alvin*'s robot arm carrying a tube of deep-sea mud to the sampling basket, located directly in front of the porthole. Three video and two 800-frame 35 mm cameras are mounted outside *Alvin*, and can be operated by the scientists inside. Because there is no light in the deep sea, more than twelve lights surround the outside of the sub. An *Alvin* dive usually lasts about eight hours.



PATRICIA WYNNE

CINDY LEE VAN DOVER: Two Hats, One Head

For almost two years, biologist Cindy Lee Van Dover held two very different jobs. She was a deep sea biologist, and she was an *Alvin* pilot — the only scientist and the only woman yet to earn that position.

Biologist Cindy Lee Van Dover studies creatures that live near hydrothermal vents — warm-water oases on the deep sea floor. "I want to be the best deep-sea biologist I can be," she says. "To do that I need to see as much of the ocean floor as possible." Just about the only way to get there is by diving in a sub like *Alvin*. Many scientists want to dive to the deep sea. But very few subs can take them there. Scientists are lucky if they can get to dive even once or twice a year.

The only people who dive more often than scientists are the sub pilots themselves. Cindy realized that if she became a pilot, she would get to see a whole lot more of the sea floor. No scientist had ever become a pilot before. And no woman had, either. That didn't stop Cindy. "I'm a dreamer," she says. At first, "becoming a pilot was a daydream."

Other scientists found Cindy's desire to be a pilot surprising. "They said to me, 'What do you want to do *that* for?'" Fred Grassle, her graduate advisor, understood, though he was afraid becoming a pilot would take too much time away from Cindy's scientific career.

But Cindy was determined, and her determination won out. She was accepted in *Alvin's* Pilot-in-Training program.

As part of her training, Cindy worked as an *Alvin* technician. She had to learn everything about the sub's mechanical and electronic systems from the inside out. The chief pilot, Dudley Foster, constantly told his trainees: "Attention to detail. Attention to detail."

"It was not hard to pay attention to detail," says Cindy. "But sometimes it was hard to keep up the effort, twenty-four hours a day, seven days a week." Though most of the other pilots had some background in mechanics or engineering, Cindy had none. She was starting from scratch. After her long work days ended, she read technical manuals. "I'd study my wits out," she remembers. "I thought I'd burst with details." After a rigorous one-year training period, Cindy was awarded the dolphin pin that all submarine pilots wear.

Cindy worked as an *Alvin* pilot for twenty-one months. She was Pilot-in-Command 48 times. As a scientist or a Pilot-in-Training, she dived 15 times. Her piloting experience allowed her to spend much more time on the seafloor than she might otherwise have done.

Though she loved being a pilot, she was eager to get back to her scientific work. "It was hard to do quality science during those 21 months," she says. "I'd come back from a cruise, spend two weeks here, which was just enough time to get back into the routine of scientific work, then I'd head back to sea again to work as a pilot for several months."

These days, Cindy is focused on her scientific work once again. But she will always be glad she challenged herself to earn the dolphin pin.

ROD CATANACH / WHOI

Scientist and former *Alvin* pilot, Cindy Lee Van Dover, with *Alvin*.

NEW VIEWS OF THE DEEP: *JASON* Struts Its Stuff

JOSEPH H. BAILEY © NATIONAL GEOGRAPHIC SOCIETY

As *Jason* makes its first scientific dives, its design team works to perfect the ROV's systems

Andy Bowen at sea. Andy says a high school teacher who was an avid sailor first gave him the idea of studying the ocean.

"I'd say there is a time lag of about six years from when a new device is conceived until it is a useful scientific tool," says Andy Bowen, who builds remotely-operated vehicles and manages their operation for WHOI's Deep Submergence Laboratory. "These are very complicated systems, loaded with engineering challenges." In Andy's experience, the process of taking an idea from the drawing board to a working device is long and hard. The first prototype (working model) of *Jason* was tested in 1988. Since then, Andy Bowen and others have worked hard to modify *Jason's* design as necessary.

"*Jason* was Robert Ballard's brainchild," says Dana Yoerger, the research scientist who designed *Jason's* control system *(see page 7)*. Says Dana, WHOI geologist Robert Ballard "saw the potential of ROVs early on. He came up with the the basic idea for *Jason*. He raised the money and hired the staff to build it."

LISA GARLAND

Covered with deep sea mud, Rose Petrecca works on the deck of the *Betty Chouest* during the Dump Site 106 cruise.

Last summer, *Jason* took part in its first two fully scientific missions. The first cruise took *Jason* to Dump Site 106, off the coast of New Jersey. The scientists on that mission were trying to understand if sewage sludge, dumped into the ocean from barges, was affecting deep sea marine life.

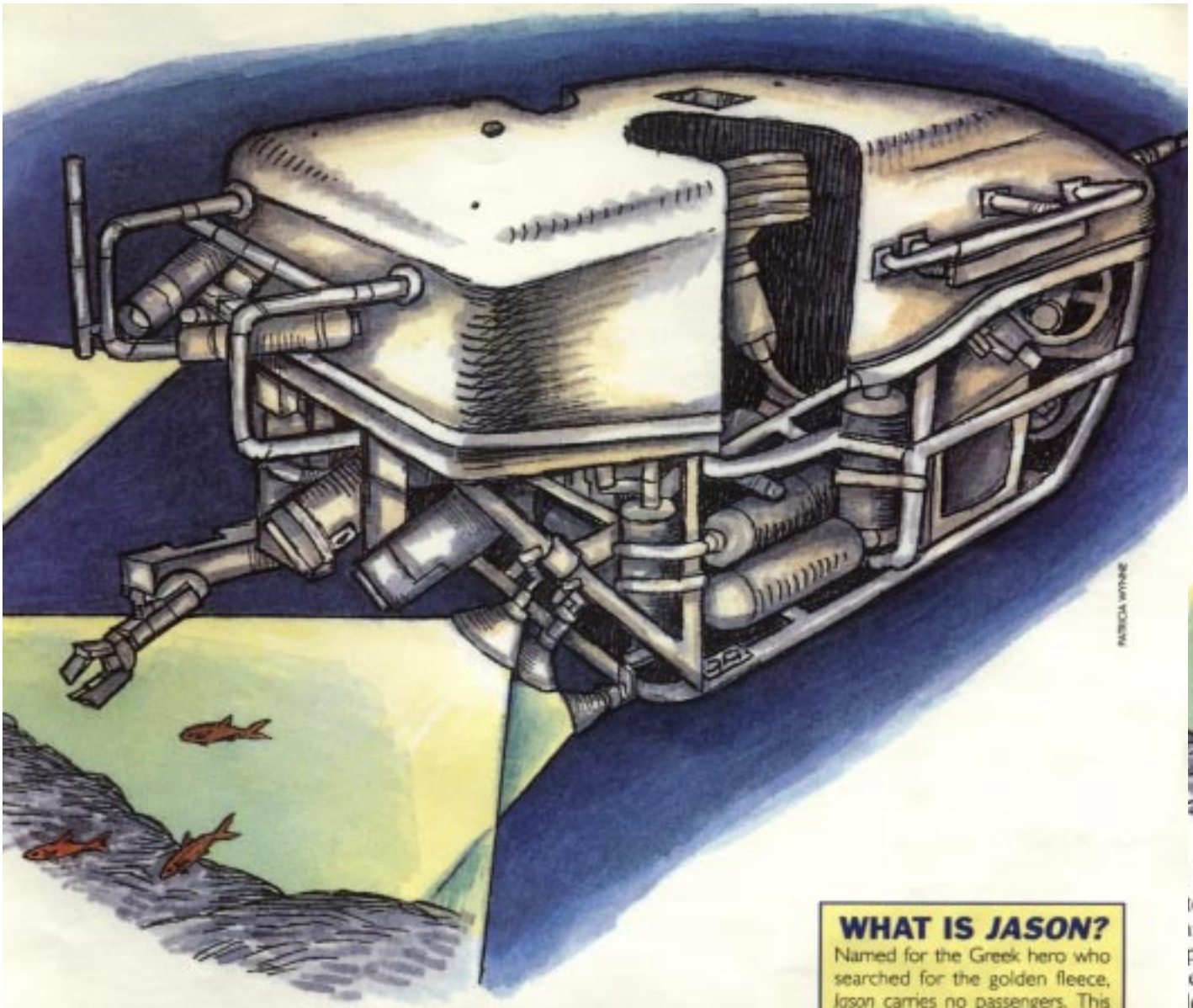
Scientists used *Jason* as their underwater eyes as they sat on the deck of a ship and watched video images made by the ROV. "It is much more comfortable to work with *Jason* than with *Alvin*," says Rose Petrecca of the Institute of Marine and Coastal Sciences at Rutgers University, a biologist who was on the Dump Site 106 cruise and who has dived many times in *Alvin* and other submersibles. "Working with *Jason*, we could sit in the big control van and watch the deep sea through ten different television monitors. In *Alvin*, you're just looking out a very small porthole."

On that voyage, *Jason* ran into technical problems, which is typical of a new piece of equipment. For example, some fiber optic cables in *Jason's* tether broke. These very thin glass fibers are used to transmit information between the sub and the control van on the surface. Luckily, the cables were fixed.

More frustrating, the scientists were counting on *Jason* to bring up cores of mud from the ocean floor. These cores contain microscopic animals that deep-sea biologists want to study. But *Jason's* arm and claw could not easily grasp the t-bar shaped handle of the mud sampler. The t-bar sampler, a simple plastic tube, is successfully used by *Alvin's* hands. Scientists and engineers thought *Jason* could use it just as well. It couldn't. Over and over again, *Jason's* pilot patiently approached the t-bar, trying not to stir up mud on the bottom, trying to maneuver the ROV's delicate pincers into place.

After several hours, *Jason* had managed to collect six samples, when disaster struck. The pilot had directed *Jason* to plunge yet another sampling tube into the seafloor. But the amount of torque (force of rotation) necessary to collect the sample at this spot was more than anybody expected. The sub's hand was ripped off. *Jason* was quickly recalled to the surface. The engineers reattached the hand with longer screws.

Scientists like Rose Petrecca welcome the chance to work with new vehicles like *Jason*, in spite of occasional technical difficulties. "It's very exciting and beneficial for scientists and engineers to take their new instruments and inventions into the field," she says. "It gives us all practical experience. What might look good on the drawing board might not work. The only way to find out is to try it."



PATRICIA WYNNE

Jason's second scientific expedition, to the Juan da Fuca Ridge off the coast of Washington State, revealed the vehicle's great strengths at taking photographs and making measurements of an extremely large area of the seafloor.

"We figured out a way to program *Jason* to move in an 'etch-a-sketch' pattern (forward, left, back, right) over a 70 meter (230 ft.) cube-shaped path," remembers Dana Yoerger. "This allowed the scientists on the cruise to analyze the water in a specific area very precisely."

Jason's next mission will be early in 1993, when the ROV will visit the Sea of Cortez off the coast of California. In the meantime, engineers and scientists will work together to continue to enhance and improve its systems.

Inside the control van on the Dump Site 106 cruise, Dana Yoerger and others watch video images make by *Jason*.

JOSEPH H. BAILEY © NATIONAL GEOGRAPHIC SOCIETY

WHAT IS *JASON?*

Named for the Greek hero who searched for the golden fleece, *Jason* carries no passengers. This remotely-operated vehicle is attached to a surface ship, or mother ship, by a tether made of fiber optic cable.

An ROV is not a robot, because it depends on people to control it. On the mother ship's deck is a van filled with television monitors, scientists, engineers, and a pilot, who uses a joystick to maneuver the ROV. Those in the van watch the monitors to see what *Jason* "sees" with its three video cameras, located on the front of the sub. *Jason* also carries a 35 mm camera and other equipment. Scientists can tell the sub to take photographs which they later put together like a mosaic to show extremely large areas of the sea floor. Jason can dive to 6,000 meters (18,000 feet). Do you see *Jason's* robot arm? It can lift, pull, push and grasp.

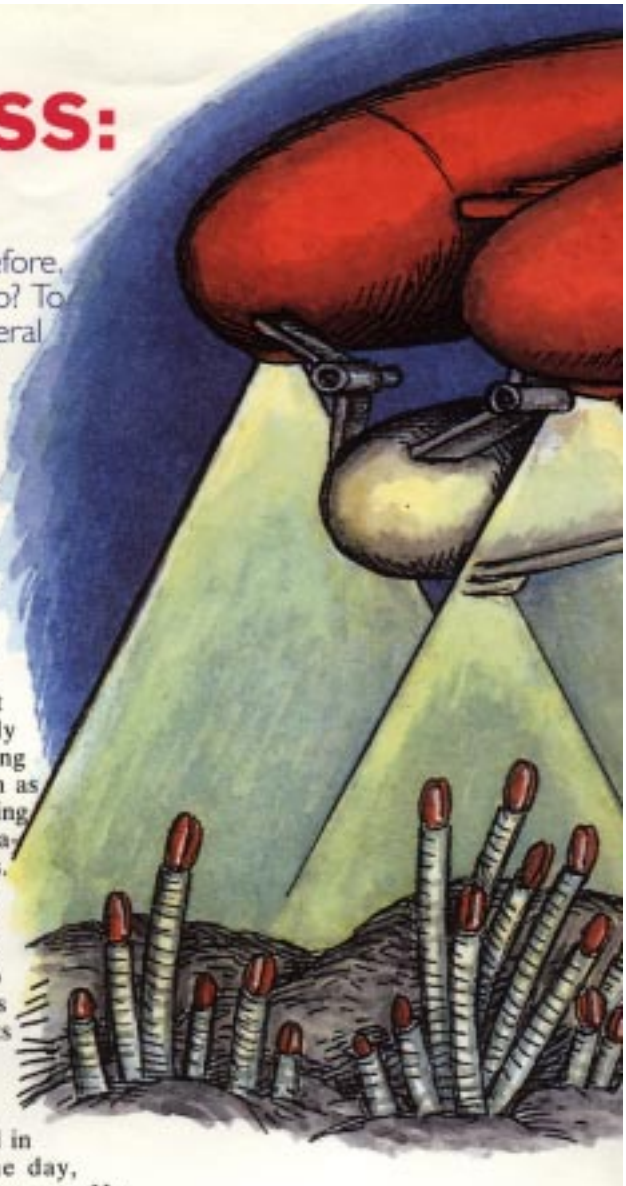
Last summer, *Jason* took part in its first two fully scientific missions. The

control van on the surface. Luckily, the cables were fixed.

ments and inventions into the field, she says. "It gives us all practical expe

WORK IN PROGRESS: Making ABE

It's not easy developing a device that never existed before. What should it look like? What should it be able to do? To learn about this process, *Ocean Explorer* talked to several people who are creating a deep-sea discovery device called ABE, short for Autonomous Benthic Explorer.



PART ONE: DESIGNING ABE

At first, ABE's designers thought the new sub should be shaped like a flying saucer. A blob. A lima bean. They built a model of this lima bean and tested it underwater in a laboratory. It swooped and twisted as it dived. That was no good. ABE has to be very stable. It has to be able to travel in a straight line for about the length of a city block, without wobbling.

The team went back to the drawing board, and finally came up with a design that looked so much like *Star Trek's Starship Enterprise* that the model of ABE actually has the numbers from that more well-known craft painted on its bow (front end).

Developing a new piece of equipment is complicated, expensive, and very slow. "By the time we began designing ABE, we were already behind schedule," says Al Bradley, as he conducts a tour of his cheerful, cluttered workshop, where every surface is covered with electronic devices in various stages of construction or deconstruction. Spools of wire of ten different bright colors hang from one wall. Each wire stands for one of the numbers in the decimal system, Al explains. A soldering iron, useful for making circuit boards or, occasionally, making earrings out of cast-off electronic products, is plugged in at a workbench. Computers and other electronic devices are everywhere.

Al is an ocean engineer, though he refers to himself as a "toymaker." He invents equipment that helps scientists study the ocean. These days, Al is busy creating the electronics for a new device called ABE, short for Autonomous Benthic Explorer.

First of Its Kind

Nothing like ABE has ever been built before. When ABE is up and running, it will be able to stay underwater for months at a time, swimming on a pre-programmed track. Unlike *Alvin*, it will have no onboard pilots. Unlike *Jason*, it will not be tethered to a mother ship. It will operate completely independently, performing tasks assigned to it, such as taking pictures and making measurements of temperature and ocean currents. Between tasks, ABE will go to "sleep," returning to an underwater mooring and powering down to conserve energy until it is time for it to perform its tasks again.

The Design Team

How did Al get involved in developing ABE? "One day, Barrie Walden came to see me. He had an idea." Barrie is the manager of Operational Scientific Services at WHOI. His group is responsible for operating and maintaining vehicles, such as *Alvin*, as well as other technical devices used in oceanographic research. "Barrie knew that I had made a piece of equipment that could hit a target at the water's surface. He said, 'How about making something that can hit a target at the bottom?'"

Barrie's idea was to have the deep-diving submarine *Alvin* place a beacon on the ocean floor. The device he wanted Al to help him make would be able to find the beacon, latch on to it, and then go off on research missions in certain pre-programmed directions for specified amounts of time, returning to the beacon at the end of each foray. Ideally, it could perform this same task every day for many days—up to a year.

Al Bradley in his "toyshop," with a model of ABE.

TOM KLEINSCHMIDT / WHOI

"A lot of the work that *Alvin* does is repeat business on continuing experiments," says Barrie. "Every year, we re-visit the same area." If a device could be created that could stay in one place for a long period of time, much more information could be gathered about one spot, without the cost and complications of returning frequently in *Alvin* or another sub.

Al liked Barrie's idea. He knew that scientists were often frustrated with the limited dive capability of the deep-submergence vehicles currently available. The deep-diving submarine *Alvin*, for example, can stay underwater for only six to twelve hours before

PATRICIA WYNNE

WHAT IS ABE?

An autonomous vehicle like ABE can move on its own, just like a robot: no on-board pilot, no tether to a ship floating overhead. ABE's tasks will be pre-determined by the scientists and technicians using it. They will be able to direct ABE to move around and collect data within an area about the size of a city block. For up to a year at a time, ABE will wake up, day after day, run around a track, making videos, taking photos, taking measurements, and then return to its "garage," an underwater mooring, where it will turn itself off for a certain amount of time to save power.

its bank of batteries must be recharged. Remotely-operated *Jason* is capable of staying down for many days at a time, but usually the mother ship from which it is commanded can spend but a limited amount of time in one place. An autonomous (self-sufficient) vehicle could be useful for many tasks—even if it did not have as many capabilities as a manned or remotely-operated tethered vehicle.

The Team's Task

Al and Barrie divided their tasks. Barrie, whose background is in mechanical engineering, would build ABE's body and "muscles" — its moving parts. Al, who specializes in electronics, would build its "nerves" — the systems that operate the sub's motor, its cameras, its temperature sensors. But they needed somebody to build ABE's "brain" — a control system that could teach the device to power itself up and down on command, that could tell it where to go and when, and that could instruct it to make measurements and record observations.

The right person for the job, they knew, was Dana Yoerger, a Research Scientist in WHOI's Deep Submergence Laboratory who had created the brains of *Jason*. Intrigued by the potential of ABE, Dana joined the team.

PART II: PUTTING ABE TOGETHER

These days, ABE is all over the place. Its fiberglass body lies in pieces in a shed on a WHOI dock.

In his toyshop, Al is working on ABE's "nerves," its electronic system, including a battery pack, temperature sensors, and a television camera. ABE will store up to four thousand black-and-white video images on a videodisk with a very high memory capacity.

Meanwhile a couple of miles away, Dana is creating ABE's "brain" by writing computer programs for ABE's control system that will command ABE to move up, down, sideways, forward and backward. They will tell ABE where to go, and when, and what to do when it gets where it is going.

"ABE only knows how to do a few things: wake up once a day, run around a racetrack, collect data and go back to sleep," says Dana. Still, it is the vast number of consecutive days that ABE will be able to perform its simple tasks that make it a very useful tool.

Hylas Tests ABE's Brain

To test ABE's control system, Dana uses a remotely-operated vehicle that never goes to sea. Called *Hylas*, it is named for Hercules' pageboy, who accompanied him on the quest for the Golden Fleece. The mythical Hylas was sent to shore to search for water. There he discovered a fountain. He also discovered water nymphs that were so charmed by his beauty that they convinced him to stay behind with them and live in their pool. Likewise, *Hylas* never leaves the two-story tank in which it performs its programmed tasks — except when it's hauled out at night to keep it from corroding.

When Dana uses *Hylas* to test programs for a remotely-operated vehicle such as *Jason*, he instructs it to obey commands from a joystick operated by a pilot standing on a deck above the tank. If *Hylas* is testing software for an autonomous vehicle like ABE, Dana sets some switches in a control panel that direct the sub to follow a pre-set list of instructions. As Dana says, "I let the computer fly the vehicle."

Using *Hylas* in the lab to develop software for ocean-going vehicles allows Dana to test new programs for up to a year before they become operational, making changes as necessary. "I learn lessons on *Hylas*," says Dana. "By the time I put the control system in ABE or in any vehicle I'm developing, I want to know that my programs are going to work."

ABE's Future

In its first years of use, ABE will only be able to follow the set of instructions already in its memory when it is placed underwater. But it may get smarter in time. ABE's developers look forward to the day when an antenna attached to a mooring on the sea surface will link ABE with a satellite. The mooring-to-satellite connection is now possible. What is yet to be developed is a way for ABE to send information to the antenna attached to the mooring. When that can be done, it will be possible to change ABE's instructions while it is in the middle of a mission.

And someday, ABE's developers hope, television images will be beamed directly from ABE up to a satellite, and down to a computer on a scientist's desk anywhere in the world.

Come On Down and See Me Next Time

DAVORY KRISTOF © NATIONAL GEOGRAPHIC SOCIETY

Next September, *Ocean Explorer* will visit hydrothermal vents, oases of hot water on the deep sea floor. Vents are home to all kinds of grotesque creatures, such as the *Alvinella pompejana,* or Pompeii worm, shown here. The worm is named after *Alvin,* in which the scientists who discovered it were travelling. Covered with hairlike appendages, Pompeii worms live in tubes that they build directly on black smokers, underwater chimneys that send up chemicals and very hot water — as hot as 350°C (662°F). What else is down there? Dive in with us. You'll be amazed!