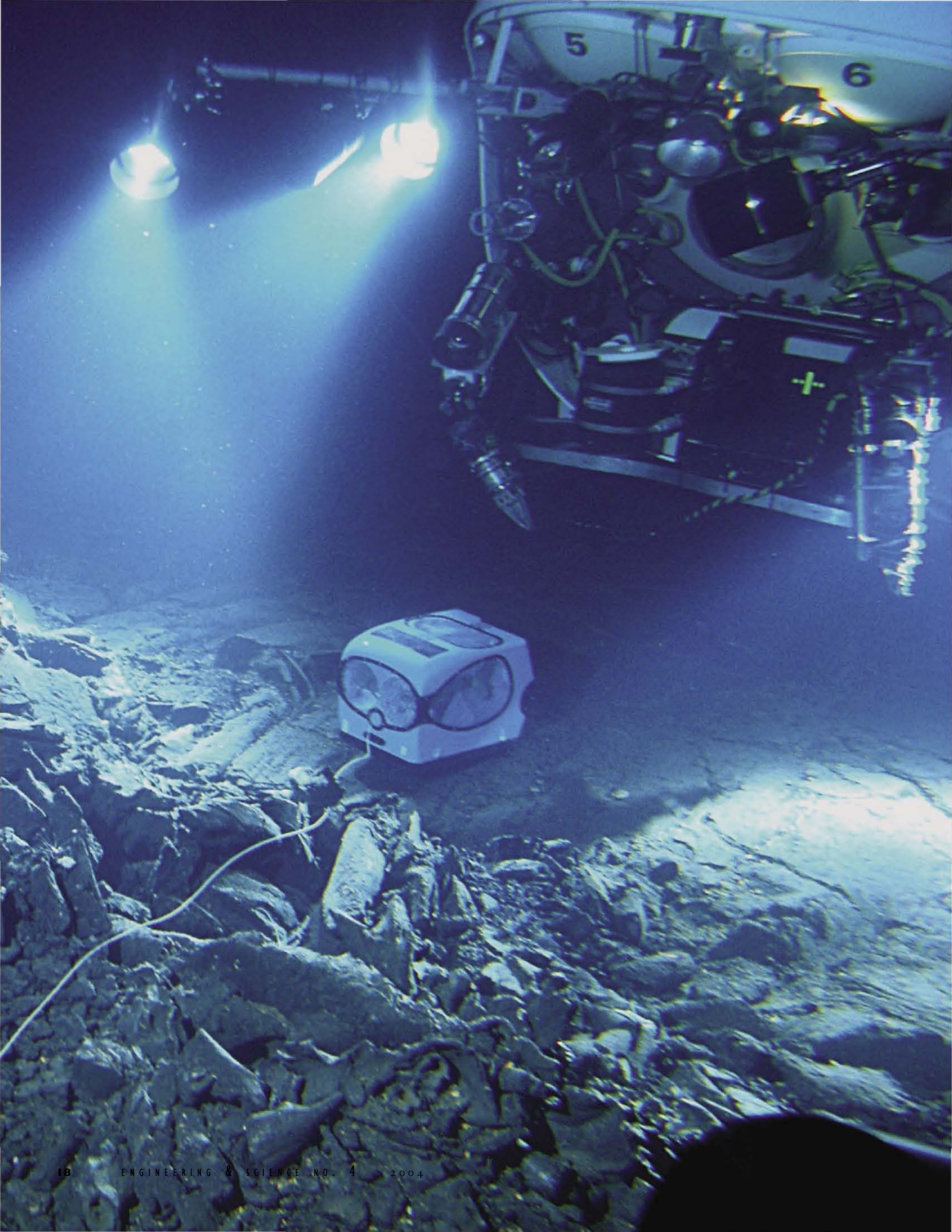


What do you do when filmmaker James Cameron, of *Titanic* fame, invites you to dive to the bottom of the sea with him—as long as you bring along your coolest gadgets? It's like being offered a free rocket launch and a place on the spacecraft. Of course, you accept the invitation!

# Voyage to the *Aliens of the Deep*

by Arthur Lonne Lane

Above: McDUVE, JPL's instrument, is readied to scan a volcanic rock surface for signs of life once Mir's lights are turned off. On the facing page, Mir 2 hovers over Mike Cameron's "fly-by-wire" hydrobot after its control and data optical tether crossed an invisibly small and very hot water vent that burned through the fiber in a second. Without command capability, the hydrobot sank to the ocean floor, a heart-wrenching moment for those watching in the Mirs. How it was retrieved is told on page 23.

What do you do when filmmaker James Cameron, of *Titanic* fame, invites you to dive to the bottom of the sea with him—as long as you bring along your coolest gadgets? It's like being offered a free rocket launch and a place on the spacecraft. Of course, you accept the invitation!

That's how JPL astrobiologist Pan (Pamela) Conrad and I were able to build a point-and-shoot instrument to look for organic biosignatures in extreme environments, and test it out at hydrothermal vents in the Pacific while being filmed for Cameron's latest movie, *Aliens of the Deep*. Part science documentary, part imaginary journey to Jupiter's moon Europa, the film is currently showing at IMAX 3-D theaters around the world. This is part of "The Making of" story you won't find on the extended DVD, taken from the daily e-mail journal I sent back to the team at JPL. But first, some background on how JPL joined forces with Hollywood.

Jim Cameron and Mike, his engineer brother, have a deep interest in space science and exploration. They learned about our work developing detectors for organic material in and around hydrothermal vents during a visit to JPL in 2001. Jim was planning a voyage to the German battleship *Bismarck*, 3,700 meters below the North Atlantic, to film *Expedition: Bismarck* and to examine some hydrothermal vents near the Azores, so he invited us along. But four weeks' notice was not enough to find funding and convert our instrument, tested to a man-rated 2,000 meters depth, into one safe at 4,000-plus meters, so we had to pass up the opportunity.

We were given a second chance in April 2003, when Jim called with an invitation to join a cross-disciplinary, multi-institutional science team for his next movie, *Aliens of the Deep*, but once again the timescale was too short; he was leaving for the Atlantic Ocean in six weeks. But a Pacific Ocean part would be filmed in October. Now *that* was warning time enough. Pan, engineer Lloyd French, and I quickly wrote a proposal, got the go-ahead and some money from chief scientist Tom Prince and director Charles Elachi, and assembled a small team that also included Gindi French (Lloyd's wife), Bob Wilson, Rohit Bhartia, Barbara Kachachian, Everett Salas, Colin Mahoney, members of "Team I," an instrument engineering group, plus Ray Reid and Bill Hug of Photon Systems. Michael Eastwood interfaced with Cameron's organization. We had just four short months.

The development of our instrument, McDUVE (short for multichannel, deep-UV excitation fluorescence detector), proceeded in the normal, chaotic manner of a very rapid, multidimensional implementation task: some component suppliers were on time, some were late, and some never delivered what they promised. Components failed, software broke, and testing systems didn't always perform to spec. But by early August we were on track for an October 8 delivery. Then the inevitable happened. Cameron shortened one segment of the timeline, and we now had to be in Acapulco on September 24 or miss the boat! Just about the time that news arrived, one deep-ocean pressure test produced crazing and microfractures in several of the instrument's quartz windows, so that we also had to design, fabricate, and test an additional pressure dome for the windows.

One week before the shipment date, however, the entire instrument system came together and played as a unit. The control and data acquisition software was a bit incomplete, but a modification could be delivered to us at a port of call during the cruise. We completed the work in 91 days from start to finish, with no weekends and no holidays, so when my journal begins on our last day at JPL, we're all pretty exhausted. But our problems aren't over yet.

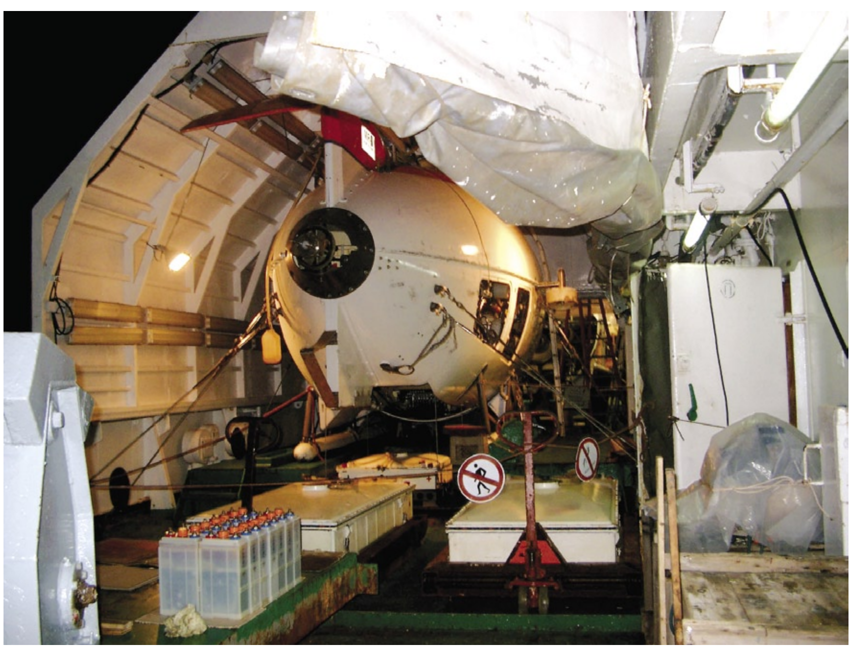
**Wednesday, September 24, 2003.** We're boarding the Russian research vessel *Akademik Mstislav Keldysh* in Acapulco tomorrow. Some

Designing, funding, and building a fluorimeter in just 91 days was a challenge, and Pan Conrad (center), Rohit Bhartia, and Everett Salas (in the patterned shirt) were still fine-tuning the instrument in the corner of an Acapulco hotel room the day (and night) before the voyage.

of our equipment has been trucked there by Jim Cameron's production house, and eight more boxes are supposed to go by FedEx today for overnight shipment. But when we got them to FedEx, we were told they had given us the wrong information, and would not be able to deliver them in time. The only option left to us was to take everything with us as luggage on our flight to Acapulco. We quickly had to commandeer two of the instrument's software developers, Rohit Bhartia and Everett Salas, to fly with us so that we had enough fares to cover the baggage allowance, and then we hurriedly unpacked all our carefully packaged equipment and tossed it into an assortment of suitcases and carry-ons. Once on the plane, all four of us immediately fell asleep, as we had been sleeping only four hours a night for the previous week.

The next frightful point was Mexican customs, which we thought would be a nightmare. I fully expected to have to consider paying bribes to keep them from taking our hardware. Amazingly, the customs agent at Acapulco understood that we were scientists going to work with all the equipment on a ship and had no intention of selling any of it locally. He waved us through.

Rear view of one of the Mirs in its hangar on the deck of the *Keldysh*. The Mirs can descend to 6,000 meters and are fitted with powerful lights, ideal for movie-making. Cameron also used these submersibles in *Titanic*, *Ghosts of the Abyss*, and *Expedition: Bismarck*.



**Thursday September 25.** While we loaded our equipment onto the ship, Rohit and Everett worked in my small, but comfortable, single cabin putting the final touches to the control software (having already worked through the previous night in our Acapulco hotel rooms).

We finally left Acapulco at about 10 p.m., after saying good-bye and many thank-yous to Rohit and Everett. Exhaustion set in by 11 p.m., and I was soundly asleep in seconds, while the ship steamed to area 9N on the East Pacific Rise. This is the famous area where deep-ocean hydrothermal vents were first sighted (by humans) in 1977.

**Friday, September 26.** Today was mostly a day for adjusting to the ship and getting to know the people aboard. Leading the Russian team is Anatoly Sagalevitch, program director of the Shirshov Institute of Oceanology and "father" of the Mir deep-diving submersibles. Piloting the Mirs are Genya and Viktor, and then there's a sizable crew associated with the submersibles, and a few Russian scientists with whom we're sharing lab space. Jim has brought along scientists from Woods Hole Oceanographic Institution; Columbia University; Scripps Institution of Oceanography; UC Santa Barbara; Stanford; NASA Ames; and Johnson Space Center, plus a 20-strong film crew. There's also Jim's brother Mike and his small support team for the two hydrobots carried by the Mirs. Mike designed and built these small, remote-operated vehicles himself. Also tossed into the complement are two paying American guests, who will be diving with the Russians.

**Saturday September 27.** Pan and I spent the day unpacking our 15 boxes and cases, and setting up our lab in the small area we've been allocated. Just before 1 a.m., we quit for the day. This expedition is turning out to be no picnic.

**Sunday, September 28.** We arrived at the dive location in the early morning. Anatoly and Jim have decided that McDUVE will be mounted on the forearm of Mir 1's hydraulic manipulator arm; not the easiest decision to make, because now the arm will not be able to gather samples, pick up dropped items, and guide the hydrobots. But, to our benefit, it means that we can now point the instrument up close and personal at targets of interest. Genya's team fitted mounting brackets and installed the oil-filled pressure-compensated cable that links McDUVE to the laptop computer in Mir's cabin in preparation for the first dive on Tuesday. I'm going down to test the instrument's ability to withstand deep-sea pressures, but not to do any experiments with it yet.

**Tuesday, September 30**. DIVE DAY! I stopped most of my fluid intake at midnight, so no coffee or tea for me this morning. There's a urine

## The Science Mission

We wanted to search for organic chemicals distributed on the vents and rocks, and distinguish whether they were living or nonliving—knowing what constitutes a signature of life is an important objective for astrobiologists.

We also wanted to see if complex organic materials were being synthesized in the plumes of hot water and condensing minerals coming out of the vents. Some people think that these deep-ocean plumes may have been where life originated; newly developing complex organic molecules would have been shielded from the heavy bombardment of particles that occurred during the nascent stage of Earth's formation. (The same process may have occurred elsewhere in the solar system, which is one reason why a mission is being planned to explore the ocean that lies below the frozen surface of Europa.)

And we wanted to study the variation in the distribution of organic chemicals in the water column above the vents to see how far these chemicals might rise and be available to other ocean creatures.

There were many other experiments to try during this unique chance to explore the nearest thing to alien territory available without a long trip through the solar system, but we limited ourselves to these.

We also wanted to advance the type of instruments that might be sent to Europa, Titan, and the deep atmospheres of Jupiter-like planets. If our instrument couldn't withstand the harshest of earthly analogs, it might not be robust enough to withstand a deep-space mission.

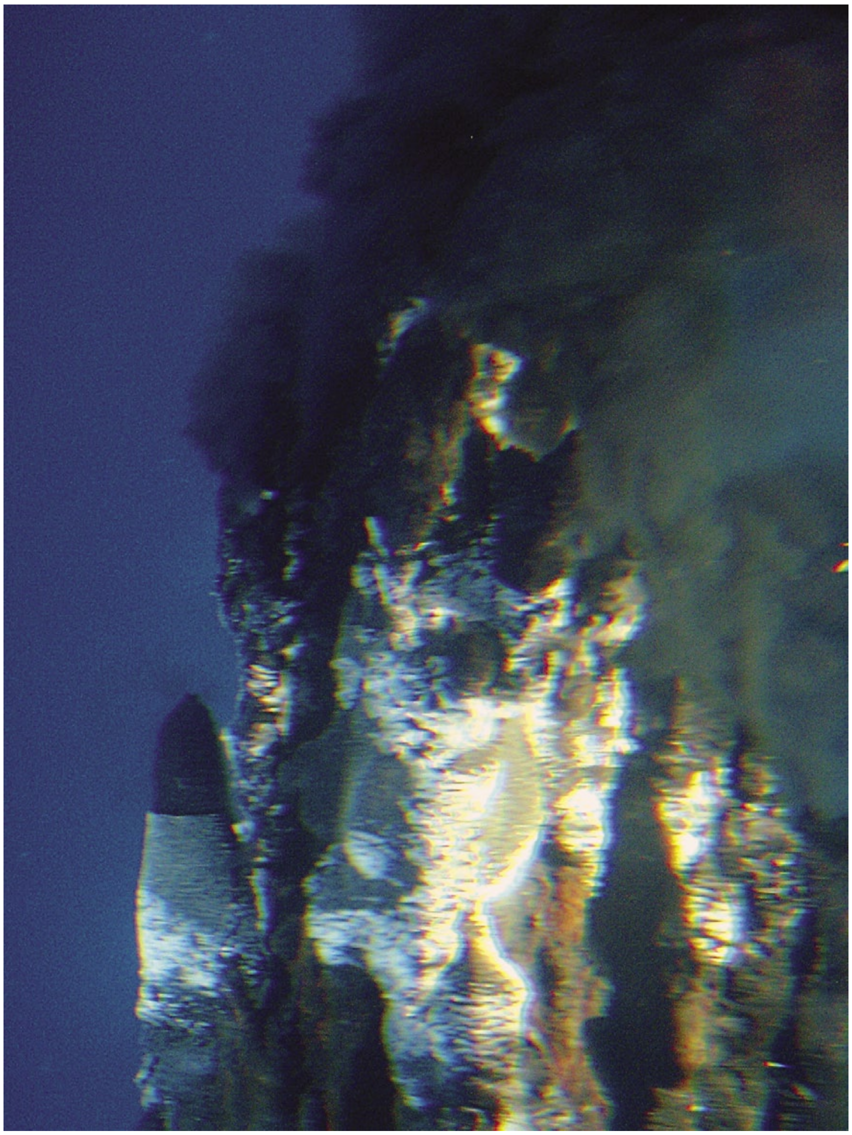
To measure the presence of organic chemicals, we used the fact that many of them "glow" under the stimulation of coherent light, the type that comes out of a laser, producing a phenomenon known as laser-induced native fluorescence: when hit by a wave of light energetic enough to stimulate fluorescence, different types of material fluoresce at different wavelengths, depending on the complexity of the molecule. This method can distinguish between some of the different amino acids and a number of cyclic-ring organic molecules.

About a meter long, 15 centimeters in diameter, and a hefty 40 kilograms in weight, McDUVE was built to withstand the external pressure of more than 400 atmospheres (6,000 pounds per square inch) we would find at the depths we were diving to. A titanium pressure housing protected electronics and optics, and included a demountable front-end dome with UV-transparent quartz windows, and a rear endplate for electrical access by a pressure-compensated cable. We controlled the instrument from inside Mir 1 by using a laptop computer attached to this cable, and powered the system from the submersible's batteries.

A deep-UV hollow cathode laser (224.3 nanometers) stimulated fluorescence in the organic molecules, and five photomultiplier tubes detected wavelength bands in the optical region, defined by 50-nanometer-wide optical filters. Four of these detected the deep-UV and blue end of the spectrum, and one covered the deep red to very-near-infrared (700–850 nm). We used a red channel because little exploration had been done in this wavelength region underwater, so we thought we'd go fishing with this new and very sensitive capability.


**Top: This view of McDUVE taken in Mir 1's hangar shows how it was attached to the manipulator arm. Above the JPL logo is an ingenious fast-response thermal-data logging sensor (aka temperature probe) designed by Mike Cameron. We placed it just above and slightly forward of McDUVE's light shield to give us a history of the water temperature the instrument was looking through. (The black object by the front of the instrument is a lamp on the side of the ship.) Above: The small hole in the center is the UV laser output window, and the four red circles are entrances for the photomultipliers. The fifth circle is a titanium plug installed at the last minute when one window showed microcracks. It blocked the green channel, but saved the instrument from water damage.**

The remainder of the dive was a trip to a magical world. Apart from the weightlessness, the wonderment and sensations must be similar to being in space. I saw huge, broken lava bubbles with collapsed roofs, strange archways, white crabs, giant shrimps, and strange-looking fish.



**The black smoke coming out of this hydrothermal vent chimney on the East Pacific Rise supports a rich ecosystem entirely independent of solar energy. Superheated water welling up from below the ocean floor is rich in dissolved minerals, mainly iron, zinc, copper, and sulfides, which precipitate out as soon they hit the cold ocean water, forming the clouds of black particles. Sulfide- and sulfate-reducing bacteria can live on these minerals, and other animals in turn live on them. The existence of so much life in one of the most hostile environments on Earth raises the hope of finding life below the frozen surface of Europa.**

bottle on board the Mirs, but to avoid using one is better. Once McDUVE was mounted, I donned a fire-retardant coverall and got the rest of the hardware together along with log books, a few sweets, a soft hat, and extra socks for keeping warm after the shell has chilled down to below 10 °C (the water at the bottom is close to 2 °C). I climbed into Mir 1 with Genya and Jim, and stowed my little bag of clothes and goodies, and then the top hatch was locked in place. Three adults inside a two-meter-diameter ball with a lot of electronics and energy converters generate a lot of heat, and I was sweating quite a bit. Out the small viewport on my side of the sphere, and through the larger viewport Genya uses for driving, I watched the deck crew loosening the tie-down cables. Then the crane lifted us up and over the side of the *Keldysh* to the dark-blue water below. Pan waved me off—she was just itching to go also—and within a minute we were in the water. One of the support team jumped on top of Mir to undo the cable tie to the crane and affix a rope attached to the support motor launch, which maneuvered us away from the ship. We bobbed about in the waves for 10 minutes (the surface zone is the problem area for seasickness) but then we were on our way down, and the sea darkened rapidly as we descended. Suddenly, at 200 meters depth, there was a loud pop. My mind quickly assumed that McDUVE had had a window failure and the instrument was flooded with seawater. An instant wave of dismay flashed over me. Everything ruined! A second later there was another pop, and a fraction of a second after that a third, all coming from the front of the Mir. I knew that if there was a water flood into McDUVE, only one implosion was possible, so something else was happening. Jim and Genya were visibly concerned; these are not the kinds of noises one wants to hear deep in the ocean. Then we realized that the Plexiglas sample-collection carousel had not been loaded with seawater before the dive, and the build-up of pressure on the top surface plate over the empty sample cups had imploded the structure. Genya turned on the front lights, looked down, and saw the broken parts floating upward as we descended. The fluorimeter was OK.

An hour later we were at 2,500 meters and near the bottom. The remainder of the dive was a trip to a magical world. Apart from the weightlessness, the wonderment and sensations must be similar to being in space. I saw huge, broken lava bubbles with collapsed roofs, strange archways, white crabs, giant shrimps, and strange-looking fish. These fish had what looked like eye structures, but to what purpose? At this depth of the ocean there is no surface light. There might be some bioluminescence, but could a fish see that?

Jim shot a number of scenes, changing the lighting and view angles, and working the 3-D imaging system. He filmed a scene where Mike, who was nearby in Mir 2, piloted his hydrobot over to a

**Pan talks on camera about her research, with UC Santa Barbara marine biology graduate student Dijanna Figueroa, foreground, Loretta Hidalgo, MS '02, and Mike Cameron.**

small, white octopus resting on a ledge. Mike extended the bot's gripper arm toward the octopus and it gingerly extended two tentacles toward the arm and tried to grab it. For about five seconds there was a short tug-of-war, and Jim caught it all in 3-D.

As the bot was heading back to Mir 2, its optical fiber command and data cable (which connects it to Mike's control station in Mir 2) crossed a small surface vent spewing out clear, hot water. The cable burnt and ruptured, and the lifeless bot slowly sank to the ocean floor. Thus began the great bot recovery operation. With us in Mir 1 trying to be a second set of eyes at a different angle, Mir 2 left its high perch on a ledge and descended to the floor where the bot lay. After several unsuccessful attempts to use the manipulator arms to pull the disabled vehicle into the garage slot on Mir 2, Viktor tried using one arm like a bat to lift it off the floor, and the other to swat it into the garage opening. Ever tried playing volleyball on the ocean floor? After several tries, it finally worked, and we began our leisurely 90-minute float back up to the surface. At about 100 meters depth, Genya turned on the high-intensity lights so the recovery team could find us (to the folks on the *Keldysh*, we looked like a phosphorescent whale), and that's when I saw the most amazing collection of strange, gelatinous creatures. They were translucent white with an orange disk, and each was about the size of a thick cigar. I saw a hundred or more between 100 and 70 meters depth, and then they were gone. At the surface we bobbed about for 15 minutes before we were caught and towed to the lifting crane. It had been an amazing 12-hour ride. Back on deck, we were greeted by the film crew and the Russians, something that is done for each crew that goes down. Later, Pan and I checked the fluorimeter: no damage, no water inside, no window problems. It was ready to do great new science measurements.

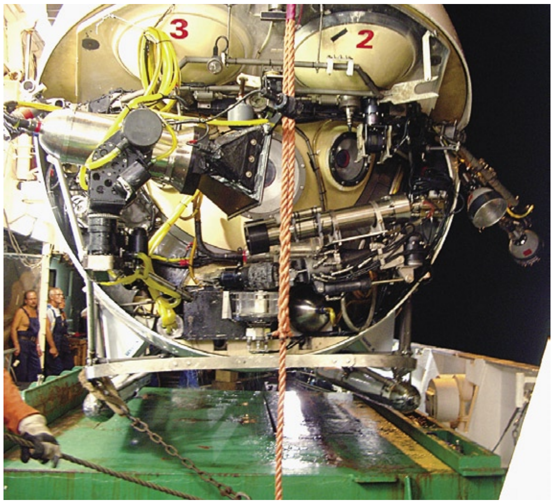
**Wednesday, October 1**. The third dive is planned for tomorrow, but Jim Cameron decided not to have JPL present on this one, so Pan will have to wait until we get to the 21N site.

**Thursday, October 2.** We spent most of today working on McDUVE in the lab, studying the anatomy of the software that controlled the electronic state of the instrument. We had very little in the way of precision optical components with us, so it took a number of trial-and-error optical setups to get conditions properly adjusted to enable us to measure gains that differed by factors of 10. By dinnertime we had puzzled our way through several configurations but were not able to explain some observations with respect to the control settings, so after dinner we put in a call to Rohit. With the assistance of Ray Reid, Bill Hug, and their electronics fabricator in Fallbrook, Rohit answered several of the questions, and we used that information to push a little further that evening.

Later, Jim Cameron decided to show a few blocks of the imaging product he was developing, and sent a message to all of us to join him in the viewing room around 9 p.m. The 3-D images were again very spectacular, but the highlight of this showing was Dumbo, a meter-sized white octopus (below) that seemed quite unafraid of the noisy and very much larger Mir.

**Friday, October 3.** Seismologists Maya Tolstoy and Dave DuBois from the Lamont-Doherty Earth Observatory in New York had their one and only dive from 6:30 p.m. Thursday night until 7 a.m. this morning (remember, below about 900 feet there is almost no sunlight, so day/night distinctions are meaningless), and once the dive

**Propelled with the help of two flapping "fins," this friendly octopus filmed in the Atlantic part of the movie just had to be Dumbo.**



This view of Mir I being craned back on deck after Pan's dive shows the large 3-D camera on the left-hand side, with McDUVE below and to the right of the camera's front end.

was finished, we began to steam back to Cabo to drop them off. Jim and some of the film crew also left the boat; they were going to film elsewhere for a few days, while we were going to 21N without them.

It was now 10 days since we'd left Pasadena, and I was running out of socks and underwear, so washday was at hand. We'd been given some advice about the laundry service when we came on board: If you really like what you have and want it to remain like that, don't submit it to laundering by the ship's staff. Rust stains would always appear like magic on the garment, underwear would be starched and ironed, and a simple collection of items could run up a $40 bill. Seems the Russian ladies who handle the laundry are making four times the captain's salary. So I decided it would be best if I washed my own socks and underwear. There was no place to hang wet items in my little room, so I strung up a plastic-coated line (taken from our lab) in the bathroom after the room was cleaned in the morning, making sure to remove it early next morning before anyone showed up. After 15 hours of hanging, the clothing was still damp, so I spread it out over hangers and rotated them through the "dryer," the shelf just above the in-wall refrigerator, which had warm air escaping from around it. The socks and underwear are now washed and reasonably clean, but not fluffed and tumble-dried. T-shirts will be the victims next week.

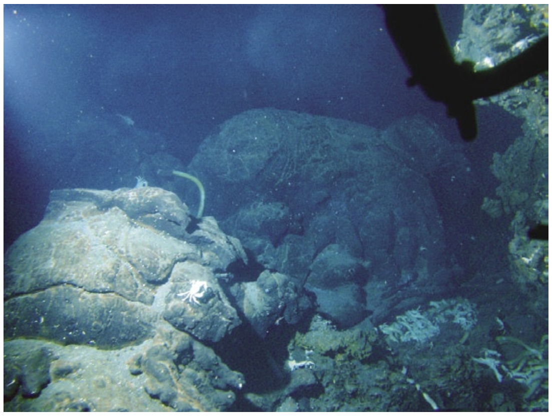
**Monday October 6.** When the *Keldysh* docked in Cabo today, we received a care package from Rohit that included a software upgrade for McDUVE. We tried this out just before supper and were blown away! The high-end sensitivity had increased by more than a thousandfold, and the gain controls were much more responsive. Pan is going to have a great time with this instrument on her dive.

**Tuesday, October 7**. At 4 a.m. we reached our new dive location, a 2,600-meter-deep site at 21N. Tomorrow is to be Pan's first dive, and the first working test of McDUVE.

**Wednesday, October 8**. Pan, Genya, and Ron Allum (on camera in Jim's absence) climbed into Mir 1 at 11 a.m. and were lowered into the water, followed shortly after by Stanford graduate student Kevin Hand, Mike Cameron, and Viktor in Mir 2. On the seafloor, they found some interesting biology and geology, but no hydrothermal activity. This was a disaster for the Russians, who were taking their guests down the next day—guests who had paid to see *active* vents. The Mirs drove round and round looking for active vents, and Pan's science-measurement agenda fell to pieces. After she had been in Mir 1 for almost 12 hours, unable to do very much except look out the small viewport now and then, she was finally allowed to turn McDUVE on and target it at a few rock surfaces and one rather nonplussed sea anemone. She also performed some water-column measurements before Mir's battery energy reserve became too low. Resurfacing around 1 a.m., Pan was rather tired and exasperated, but very pleased that the instrument had successfully detected both organic and mineralogical materials at 2,600 meters depth.

Right: Pan took this photo in Mir I as pilot Genya, on the right, and cameraman Ron Allum despaired of finding any active vents.

**Saturday, October 11**. After much poring over maps, and late-night phone calls with other oceanographers around the world, the Russians had managed to find an active vent site for their paying guests, which Pan and I visited today. We'd hoped to be together in one submersible, but in the end I was in Mir 1 with McDUVE, Ron, and Genya, and Pan was in Mir 2 with Mike Cameron and Viktor. As we headed down to 2,605 meters, I got the instrument up and running and measured the water-column characteristics at different depths. The water cooled from 23 to 1.8 ° C, and the inside of the passenger sphere felt like a pleasant winter's day. One significant problem of measuring water-column properties on the way down is that the Mir is still quite a bit warmer than the adjacent water, so that a thermal wave is generated that peels off the sides as the vehicle descends. Coming up, when the sphere is in good equilibrium with



At vent site 21N, pillow lava covered much of the seafloor.

To produce 15 seconds of the film took two and a half hours. Sure makes you wonder about the movie industry.

the water temperature, measurements can be made up to about 400 meters without affecting the water column. It helps that McDUVE extends away from Mir's body and measures water just outside the edge of this comet-tail-like thermal wave.

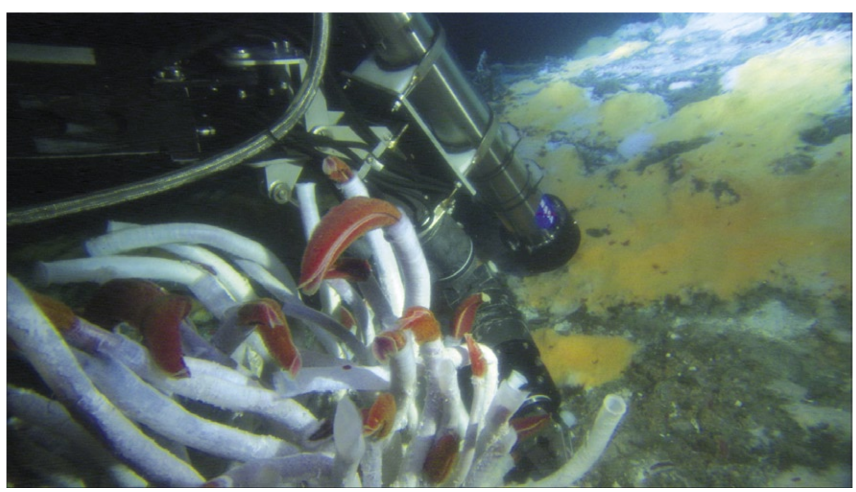
The scenery down here was very different from that at 9N, with a tumult of basalt-pillow lavas (that really do look like giant pillows) tossed about on the seafloor. We parked near a good chimney vent that had a large number of tubeworms (*Riftia* species), and I slowly scanned McDUVE across the chimney and onto the white exterior tubes and some of the live, bright-red worms sticking out of them. Do not fear, we are not hurting them. The laser pulse-intensity is reduced by 70 percent by the time the UV light crosses the 20 centimeters of seawater to the target, and the wavelength we use can only penetrate about 0.005 inches into the animal. It is safe even for humans, in spite of our aversion to anything to do with lasers, as our outer layer of dead skin cells stops the radiation.) As I scanned, I could see the intensities of the different fluorescence color bands going up and down on the screen of the control computer. I think we have some results!

**Wednesday, October15**. After returning to Cabo to pick up Jim and the rest of the film crew, the *Keldysh* set course for the overnight journey around the tip of Baja California into the Sea of Cortez to set up diving at the last location. This was some 50 miles off the coast of mainland Mexico, between Guaymas and the Baja peninsula, where the hydrothermal vents are found at about 2,000 meters depth.

**Thursday, October 16**. After lunch we got word that Jim wanted to film Pan and me showing the inside of McDUVE. We were to pull the instrument out of its titanium shell, inspect a connector or two, and then slide the shell back. We carried the heavy fluorimeter down three flights of stairs to the film studio in the lower bowels of the ship, and set it up with the ancillary props to make things look like our lab. After four rehearsals where we pulled McDUVE in and out of the shell, I said, "*Stop*—the action is putting too much strain on the internal structure." After that we did it in fake motions—again and again. To produce 15 seconds of the film took two and a half hours. Sure makes you wonder about the movie industry.

**Saturday, October 18.** Today, Pan (with McDUVE) and Jim Cameron are diving in Mir 1, this time piloted by Anatoly, and I'm in Mir 2 with Genya and astrobiologist Tori Hoehler from NASA Ames. I had not been in Mir 2 before; without the camera system it was going to be noticeably more spacious (if you can call three people and electron-

At dive site 21N, just southwest of Cabo San Lucas, we pointed McDUVE at tube worms and an orange-white biomat coating the rocks. Biomats are dense communities of bacterial species feeding off the vent-water minerals and each other.



Some vent chimneys at the Guaymas dive site were made of an unusually black, nonreflective material, right. Other rocks oozed a strange orange fluid, below.

ics racks in a six-foot sphere spacious). Because I was diving today, I had stopped most of my fluid intake at midnight (sounds like getting ready for a hospital operation) and breakfast at 7 a.m. was very light; some oatmeal, one grilled sausage link, and a tablespoon of scrambled eggs, no coffee or tea.

There was a briefing to review the dive activities, and then Mir 1 began its final prelaunch preparations. Anatoly, Jim, and Pan had their picture taken in front of Mir 1, and were airborne over the side at noon. Tori, Genya, and I had our picture taken in front of Mir 2, climbed inside, and were in the water just 24 minutes later.

On the bottom of the sea, the two Mirs worked together in an area about 300 meters in diameter, examining a number of structures and sediment and biomat beds. We saw no horrendous sea creatures, such as a giant squid, but we did see a spider crab that had a legspan of over 18 inches, although it is very hard to judge size and distance because of the mild distortion from the view ports and the refractive index change. A jellyfish floated in front of us for a minute or two, doing a sensuous breathing dance that results in propulsion through the water, but this was not a translucent white jellyfish, it was an umber orange, and very different from anything I had ever seen before.

There were also strange, mushroom-like structures, 5–8 meters high, emitting shimmering hot water in excess of 170 °C. On one of the flanges we found vents with small, pinnacled spires that were very black and nonreflective, even when illuminated by 3,000-plus watts of intense movie lights. We collected a small piece and took it back to the ship's lab; it was bone-charcoal black and ultra-finegrained, and had an albedo (reflectivity) as dark as the surface of Halley's comet, but probably a quite different composition.

In the last hour of the dive, our Mir left the area so that Pan could get dark measurements of the plume water without being bothered by our bright lights. We picked up some rock samples, took a water sample from a hot vent, and returned to the surface after six hours of bottom time. Pan came up about 75 minutes later. It had been a great dive set. After photographing, cataloguing, and storing our samples for the next two to three hours, we finally stumbled into our beds around 1:30 a.m. Tomorrow would be a dive day for the Russian scientists, and then we would head back to Guaymas and the end of our trip.

**Monday, October 20.** With *Keldysh* now docked in Guaymas, Pan and I started work on


Pan (left) and Lonne (right), in fire-retardant flight suits, pose with McDUVE before a dive to the Sea of Cortez vent sites near Guaymas.

packing our equipment. We had packed about 75 percent of it when word came from Jim that he wanted to film McDUVE mounted on the manipulator arm. We unpacked the instrument and cable and waited.

**Tuesday, October 21.** After lunch we were told they would be ready for us around 2 p.m. That became 4 p.m., then 9 p.m. At 11 p.m., I left instructions to come wake me when they were ready, and dozed lightly in my room with my clothes on. I awakened at 1:30 a.m., realized that this business was somewhat crazy, and went to bed for the night.

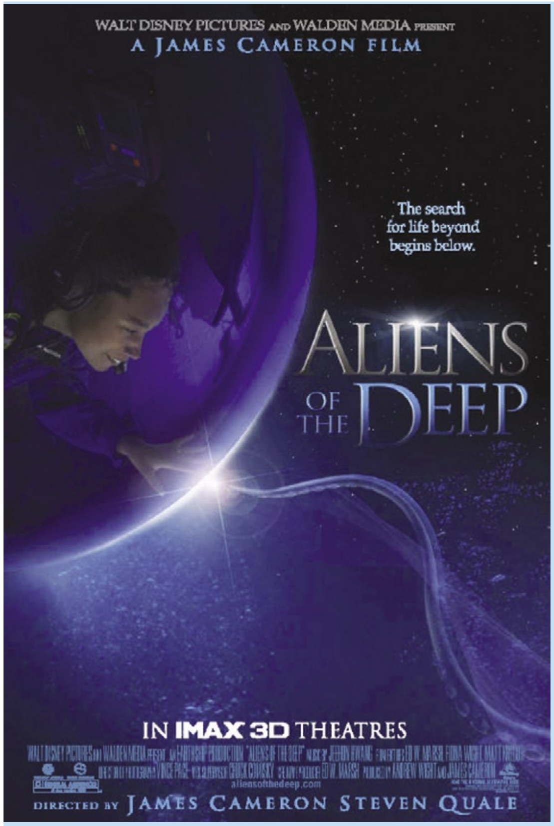
**Wednesday, October 22.** It is 1 p.m. They still have not shot the scene with our instrument. I quit.

**Epilogue.**

We were thrilled when we successfully used McDUVE at 21°N on the East Pacific Rise and in the Guaymas Basin. It operated beautifully. We acquired induced fluorescence data from the orange microbial mats blanketing the rocks near the vents, and saw optical signatures from the vents themselves that we are working to understand right now. Moreover, we believe we've contributed to a new paradigm in deep-ocean research—experiments controlled in real time in a manner that allows a quick response to changing conditions. This maximizes the scientific return from very expensive operations. A single Mir dive, for example, including the support ship, can cost as much as $30,000 for a single day. We'd like to continue this work in the deep ocean, and also plan to transform McDUVE into an instrument that can go down a deep, hot-water-drilled hole in Antarctica to a subglacial lake 3,500 meters below the ice, so we can explore the water and the sediment bed. We hope to find the remnants of organic molecules that will tell us more about what happens to living entities when subjected to long-duration dark, and very cold and icy environments. □

*During his almost 39 years at JPL, planetary scientist Arthur Lonne Lane has "been" to seven of the nine planets, and has also worked on several earth-orbital missions. For the last eight years, he has been developing instruments to detect biosignatures, and tested predecessors of McDUVE at two other vent sites, Lo'ihi off Hawaii and a South Pacific seamount. He holds a BS in chemistry from Harvard and an MS and PhD in physical chemistry from the University of Illinois, though he did his research at Caltech when his supervisor moved here. After that, it was just a short hop across the Arroyo to start his career at JPL. He is currently project manager and investigator for the Deep Ocean Hydrothermal Vent Astrobiology Project and science investigator for the Astrobiology Research Group.*

PICTURE CREDITS: 18-27–Buena Vista Pictures Distribution, Inc.




If you're just itching to be down among the hydrothermal vents yourself, and don't have a spare $30,000 or so to go with the Russians, you can get pretty close to the real thing by donning 3-D glasses at an IMAX cinema screening *Aliens of the Deep*. Pan is a leading member of the cast, and Lonne makes a cameo appearance, though you may see more of him in a longer, non-IMAX version being prepared.

A major aim of the movie is to inspire youngsters to become scientific explorers; for further encouragement, there's an Educator's Guide to download from the movie website, www.aliensofthedeep.com. There's also a National Geographic book, *"James Cameron's Aliens of the Deep: Voyages to the Strange World of the Deep Ocean"* by Joe MacInnis.