

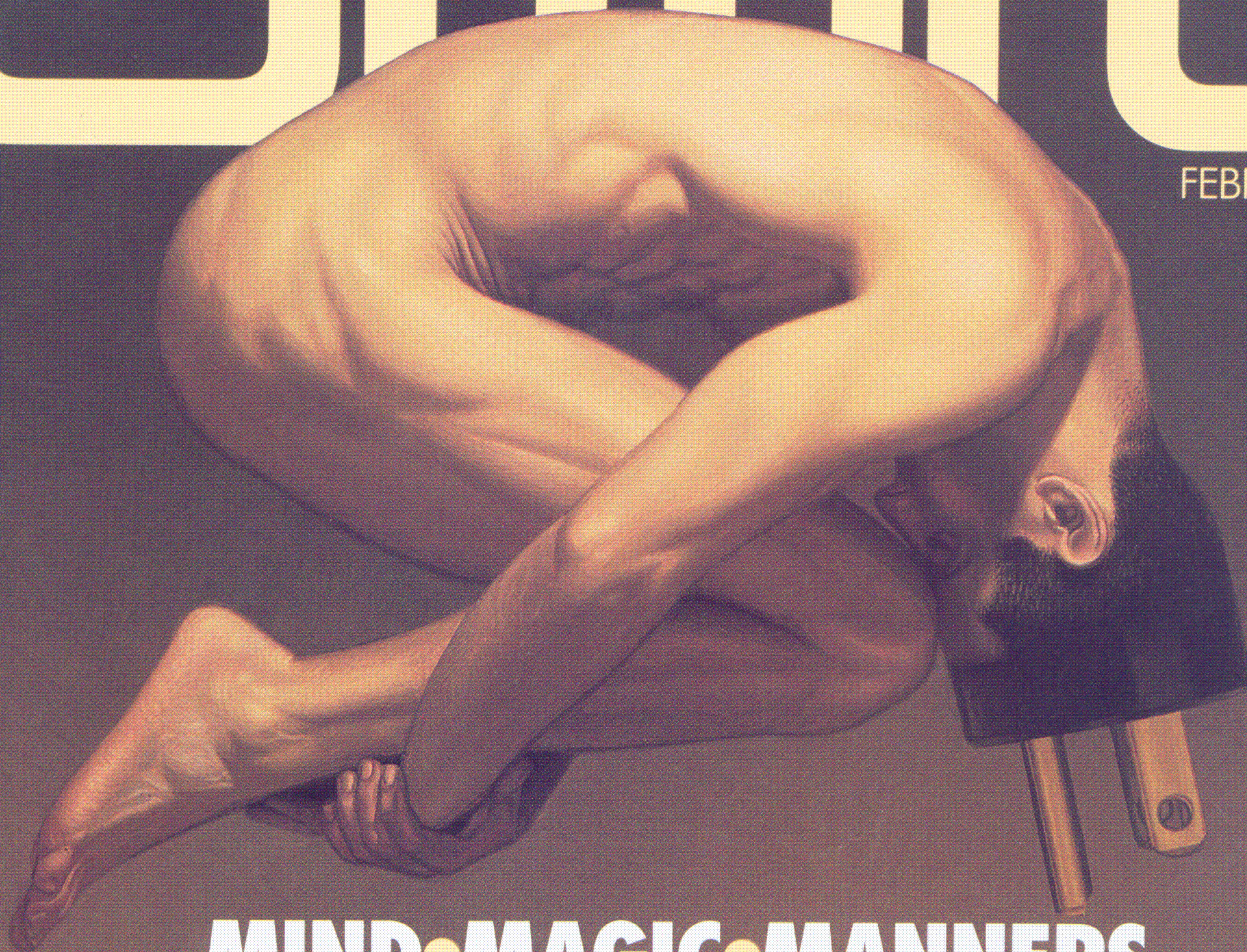
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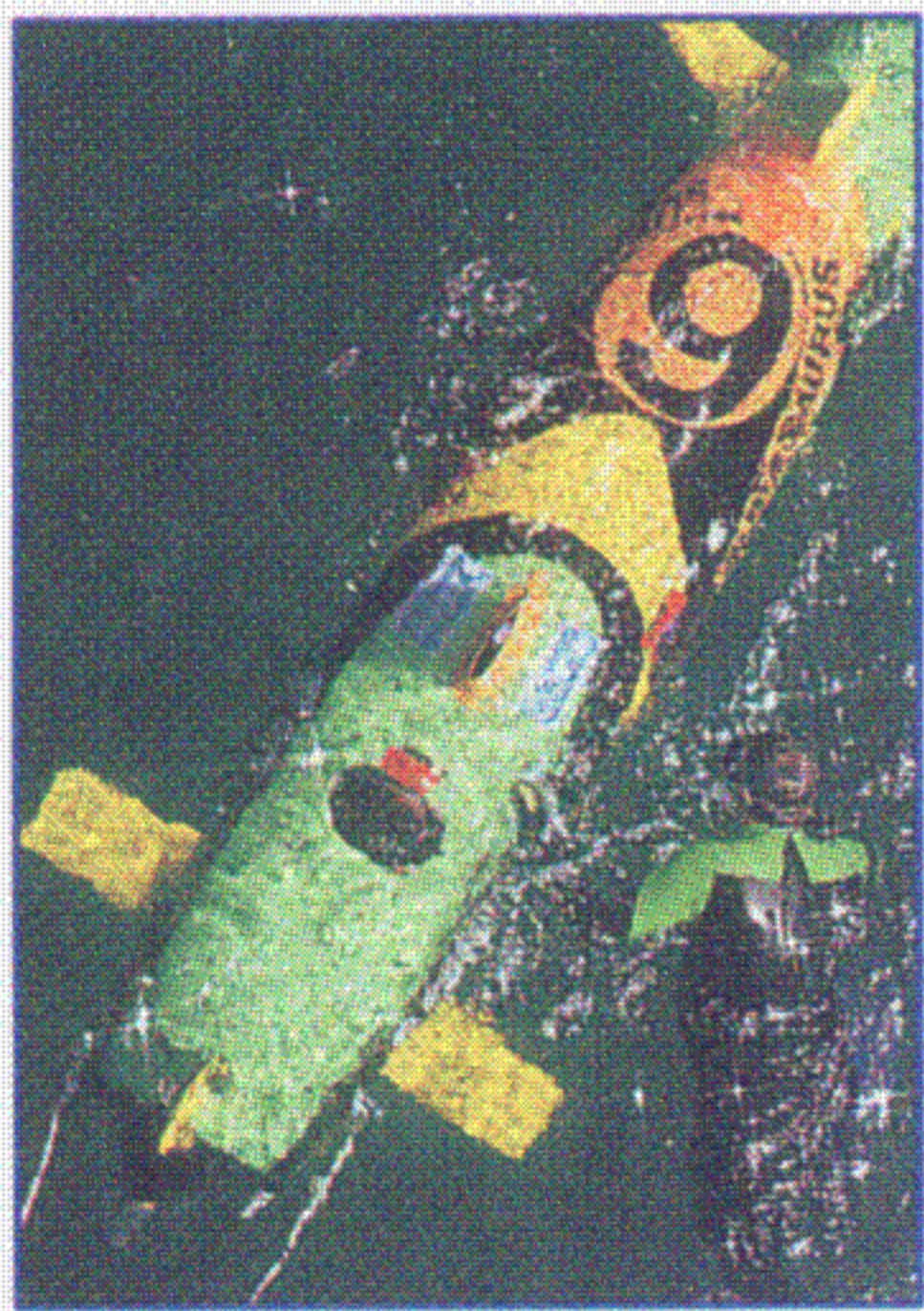
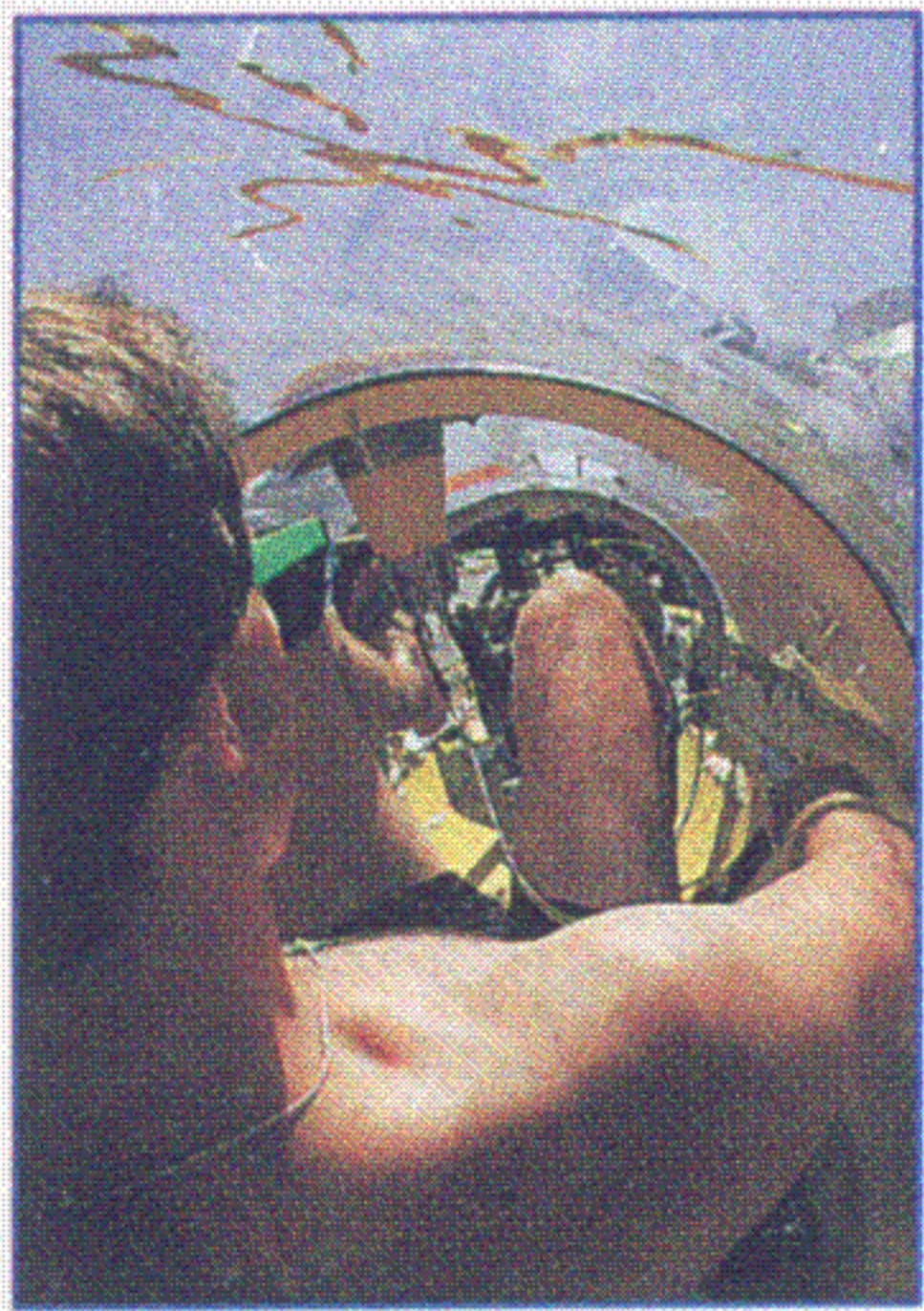
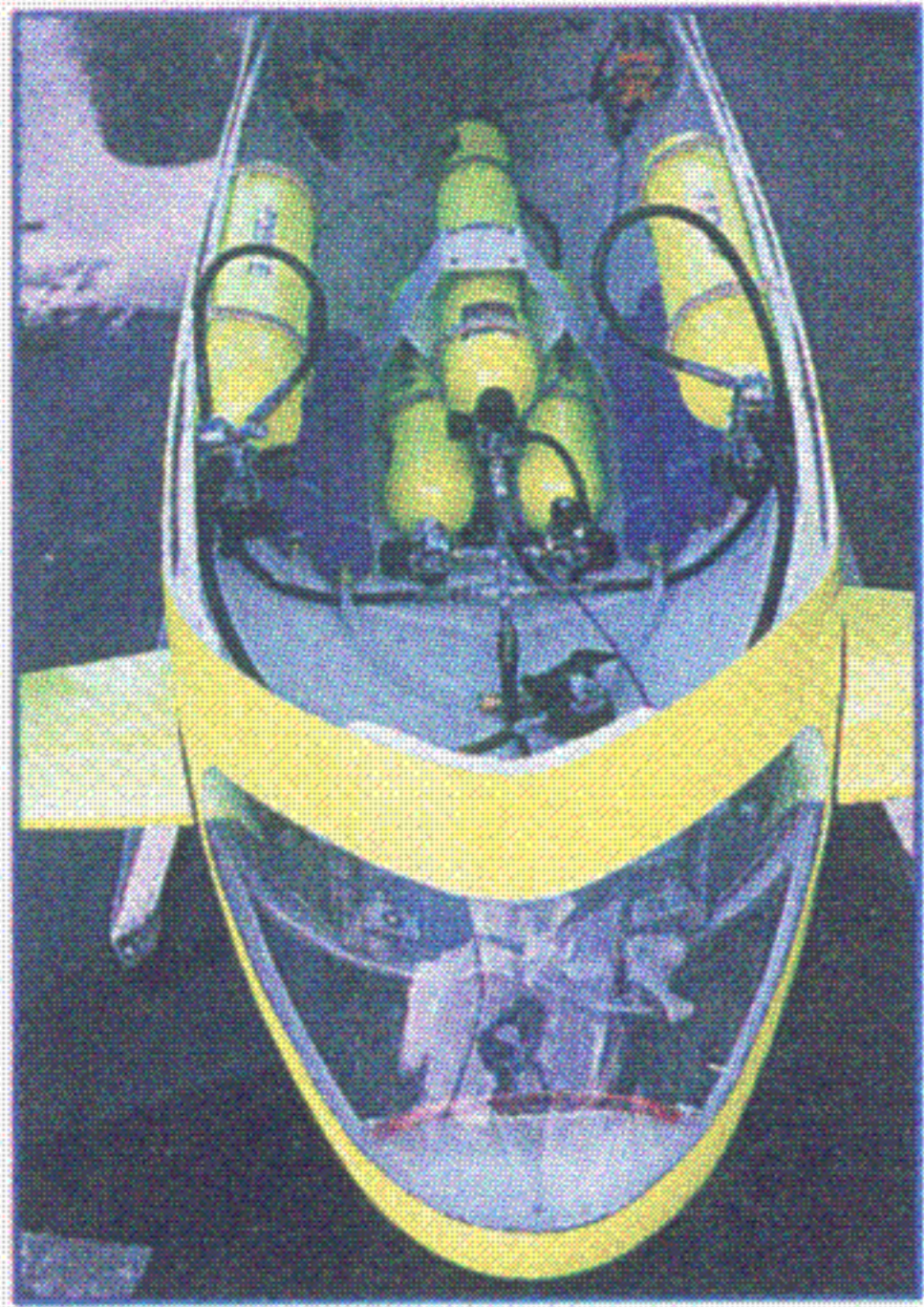


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Motorless subs sprout an array of appendages: striped fins, porpoise tails, propellers that sweep back and forth.

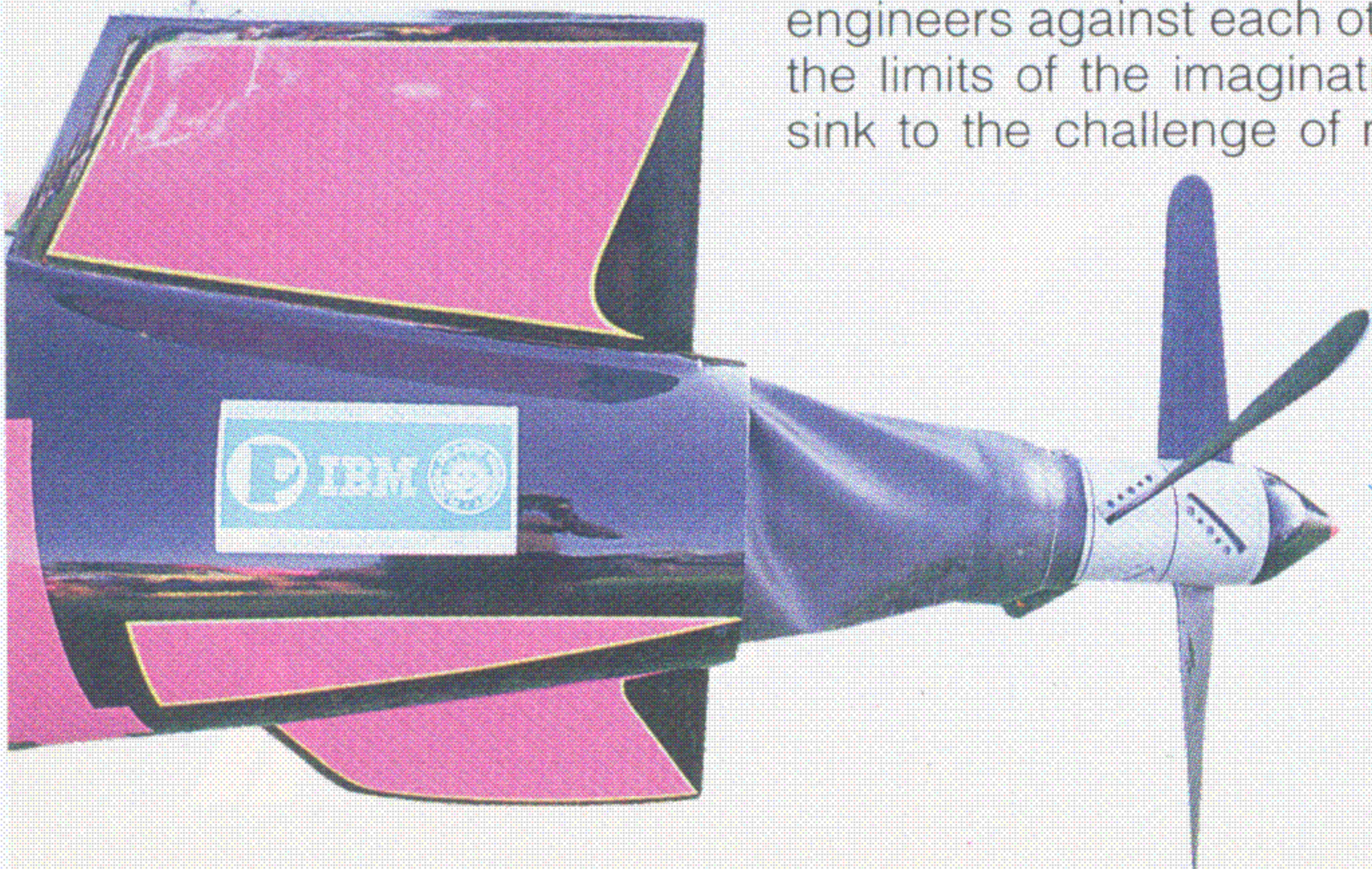
What are these things?

To the uninitiated, it looks like spacecraft from a fifties science fiction flick have invaded the Howard Johnson's parking lot in Riviera Beach, Florida. There, only a stone's throw from the ocean, stands a cluster of bubble-domed vehicles resembling rocket ships. These alien craft, whose fluorescent colors can only be safely viewed with sunglasses, sprout a bizarre range of appendages: striped fins, wings that flap, porpoise tails, propellers that sweep back and forth, even mechanical frog legs.

Welcome to the second international submarine races, a competition that pits intrepid ocean engineers against each other, a hostile sea, and the limits of the imagination. Contestants must sink to the challenge of maneuvering a motor-

less submarine of their own design twice around a 400-meter oval course 20 feet under the ocean. The rules require that the craft be operated by a pilot and propulsor—usually an endurance athlete who pedals or turns a crank. To add to the challenge, the subs are “wet”—that is, the hulls flood with water—so the crew must wage their battle under the waves wearing bulky scuba gear in quarters often snugger than a coffin. Beyond those requirements, almost anything else goes—at least in theory.

In practice, the vehicles glided, kicked, flapped, paddled, wiggled, and, on more than one unplanned occasion, barrel-rolled through the water. The Indianapolis 500 this is not. Subs that achieve speeds greater than four knots, or five miles per hour, are hailed as record-break-



WHAT ARE THESE ALIEN, YET INGENUOUS CONTRAPTIONS THAT



ing fast. Small wonder that this spectator sport has inspired comparisons to snail racing. But that didn't stop enthusiasts from cramming into a sweltering beach tent last June to watch live footage of the underwater spectacle on TV.

While the event may not have attracted speed freaks, it was first-rate entertainment for techno-fans, inventors of every ilk, ocean lovers, and anyone else with an appreciation for the adventurous, the original, and the offbeat. This is not so much a race as a testing ground for new concepts in underwater-vehicle designs.

From as far away as Germany and British Columbia, some 36 teams flocked to the Florida competition. They included engineering students from such big-name schools as M.I.T., the U.S. Naval Academy, and Texas A & M as well as the

employees of government shipyards and underwater technology firms. But not everyone fit that profile. Stephen Barton, a freckle-faced high-school student from Spring Hill, Florida, built his sub in the family's garage after developing the idea as a science fair project. And Gary Masouredis, a dentist undaunted by lack of engineering experience, made his machine in the waiting room of his Manhattan office. (Astonished patients are purported to have stammered, "What the hell is this?")

The smallest subs managed to compress two adult men, air canisters, and control equipment into narrow torpedoes just over ten feet long. The largest subs were boxy fish shapes and whale forms nearly twice that size. The remarkable diversity of inventions also reflected the back-

Bizarre underwater vehicles (above) designed by engineering students, ocean lovers, a high-school kid, and one dentist

By Kathleen McAuliffe

GLIDE AND KICK, FLAP, PADDLE OR JUST BARREL-ROLL THROUGH THE WATER? WE CALL 'EM **SUBCYCLES**

grounds—and budgets—of their creators. The most high-tech teams sunk upwards of \$20,000 into the campaign: They used computers and wave tanks to test their designs and harnessed exotic space-age materials for the construction of hulls. On the other end of the scale were funky, Rube Goldberg contraptions put together on shoestring budgets out of junkyard supplies and other odds and ends. Dentist Gary Masouredis, for example, built his hull out of a plywood frame across which he stretched Day-Glow orange T-shirt fabric coated in fiberglass resin. The Florida Institute of Technology's black-and-white striped *Sea Panther* on the other hand, is a dressed-up sewage pipe. And when the team from U.C. Santa Barbara ran out of wood for the hull of their multifinned *Love Missile*, they substituted with cardboard from boxes confiscated during a midnight raid of the college coffee shop. "It worked great," said team leader Jack Bish, "and the price was right."

This lack of conformity among entries was exactly what the judges sought to encourage. The competition, organized by the H.A. Perry Foundation and Florida Atlantic University, offers separate \$1,000 prizes for speed, cost-effectiveness, and innovation. But a submarine must score high in all three categories to win the grand prize—a \$5,000 check for best overall performance. (There are 14 other prizes including best safety design, \$200, and best use of composite materials, \$2,000.) This nurturing of creative and practical objectives reflects the foresight of 43-year-old Henry "Hap" Perry, the marine enthusiast whose capital and vision launched the first human-powered submarine race three years ago. "The triumvirate scoring system ensures that there's no restraint on the ideas that come down here," says Perry. "It's not enough to be the fastest guy around the course; ingenuity and an eye for the bottom line count just as much toward the end score."

Perry's insistence that the subs be human-powered is also intended to spur technological progress. Since even the strongest Ironman is no match for a motor, this handicap forces teams to develop sleeker hulls, control planes with reduced drag, and use other innovations to enable the sub to push through the water with less power. The best solutions, Perry says, may ultimately find a broad range of applications in remote-operated vehicles for use in ocean exploration and in the maintenance of oil platforms. "A few innovations—namely, techniques for bonding new composite materials to metals—

might even be used by the shipping and aeronautics industries," he says.

Perry is not the first person to see exciting potential in this enterprise. The development of human-powered submersibles has a long, intriguing history which began in ancient Egypt. The first modern prototype, however, was born of Yankee ingenuity during the American Revolution. In 1775, a Connecticut inventor named David Bushnell built a one-man, pear-shaped sub for the purpose of launching sneak attacks against British warships patrolling New York Harbor. Called *The Turtle*, it was made of 6-inch-thick oak strips held together with iron bands, with the entire vessel coated in tar pitch. A pilot perched on a high seat held a rudder in one hand while cranking a 12-inch screw with the other to propel the vessel through the water. There was enough air in the sub for the operator

● A few innovations may find a broad range of applications in remote-operating vehicles for use in ocean exploration, and in the aeronautics industry. ●

to remain submerged for half an hour. And to regulate its buoyancy, Bushnell designed an ingenious ballast system of pumps that blew water out of the hull for surfacing. In an emergency, a 200-pound lead weight could also be released from the bottom of the sub to increase its buoyancy.

This improbable underwater sub was equipped with 150 pounds of gunpowder, which the operator had the unenviable job of fixing with a time fuse to the underside of enemy ships. To Bushnell's credit, his ambitious plan nearly succeeded, being foiled at the last moment by one small obstacle: A wooden screw for attaching the mine could not pierce the reinforced iron hull of a British gunship.

Of course, submersible designs have come a long way since Bushnell's pioneering effort. But testing newfangled ideas in as unforgiving an environment as the sea is still far from a precise science. For that reason, the Florida competition made safety a top priority. The subs had to pull two buoys

on the surface, carry spare air bottles and regulators, and have quick-release hatches for fast escapes. As a further precaution, crew members clutch "dead-man switches," which automatically release safety beacons should they fall unconscious.

The task of racing a wet sub in scuba gear also raised a host of unprecedented design challenges. For example, what is the best position of the pilot and propulsor for maximum output of power? The optimal shape of the hull? The fastest propulsion method? And is it wiser to stay with tried and proven technologies or risk everything on a wholly new, untested scheme?

There were almost as many answers to these questions as contestants. In the most common design, the pilot lay belly down in the front while a propulsor in the rear, facing either the seafloor or the surface, pedaled a bicycle drive train that spun a two-bladed prop. Others veered from this convention, placing pilot and propulsor in seated upright positions or lying side by side. One propulsor had the exhausting job of simultaneously cranking both hands and feet.

Even greater permutations were evident in propeller designs. Instead of the standard fixed prop, MIT's *Sea Beaver* had one that served as a rudder by rotating horizontally and vertically. Other teams had two props, which counter-rotated to prevent the sub from rolling. Inspired by a jet engine, West Virginia University put its prop *inside* the hull and cut off the nose cone so a stream of water would rush through. (The pilot gets hit by the inflow jet, though team leader Scott Wenger says, it feels "tame compared to being in the back seat of a convertible.")

The most adventurous subs abandoned props altogether. Alternative propulsion methods ranged from a paddle wheel to a flapping contraption that worked like penguin wings. *The Spirit of Columbus*, from Battelle Memorial Institute in Columbus, Ohio, even attempted to mimic the swimming motion of frogs and other web-footed sea creatures. As team leader Brad DeRoos explains, "These animals drag a large surface area through the water to propel themselves forward but then retract the limb with as little drag as possible." The machine thus inspired uses a push-pull linear pedal motion to drive a set of flippers about four and a half feet through the water. Once fully extended, the flippers then snap shut, barely rippling the water as they return to the starting position. In this way, the whimsical vehicle lurched forward at a ponderous 1.5 knots.

And then there was the *Coelacanth*, the brainchild of dentist Masouredis. In a class of its own, this flamboyant creation virtually defies categorization. It is named after a prehistoric fish, but the hull of the *Coelacanth* looks more like a funky two-car train minus the wheels. The pilot sits in the front compartment behind a Plexiglas windshield. The propulsor lies on his stomach in the back compartment, engaging in a strange form of "aquabatics" that resembles cross-country skiing. The two compartments are separated by an articulated passage, and when the propulsor begins "skiing," the machine is supposed to flex in the middle. In response, the "tail"—a 10-foot pole tipped with a triangular fin—should sweep back and forth, whipping the vehicle forward like a fish. At least, that is what is suppose to happen. After wiggling—and jiggling—at the starting gate, the *Coelacanth* sunk to the bottom. "It's a deep-sea fish," Masouredis says. Last seen, it was dangling at the end of what looked like a giant fish hook from a crane in Howard Johnson's parking lot with a beaming Masouredis and his crew standing before their trophy.

The *Coelacanth* may not have been fast, but it waged a noble fight under

the circumstances. A British entry, *Submission Impossible*, never did make it to the competition. And a compact, 110-pound German sub (*Berti I*) survived a rough transatlantic flight in the baggage compartment of a plane only to break up on a reef its first day in Florida. Other subs snagged buoys, lost propellers, blew hatches, and skyrocketed to the surface like sea-to-air missiles.

Ironically, the most expensive, state-of-the-art designs often fared no better than thrifty, homespun inventions. High hopes and big bucks were riding on the Rolls Royce of subs, *Team Effort*, manufactured by Bennett Industries of Cookeville, Tennessee. It had a unique hydrodynamic shape—bullet-like—that permitted the sub to slip through the waves with almost no friction. Still more revolutionary was its propeller—a stainless-steel jewel with 12 individually pitch-controlled blades. Functioning like a helicopter rotor, the propeller provided three-dimensional control in all directions. Its designer, 68-year-old Ted Haselton, a retired navy submariner, initially conceived of the propulsion system in the early sixties as a technique for stabilizing fleet ballistic-missile submarines during launch. "If the propeller works," he boasted before the race, "we'll blow everyone else

away." Indeed, with the aid of a slick new polymer that interacts with water to reduce drag, Haselton calculated that *Team Effort* might reach a remarkable 7.4 knots.

Alas, this bold initiative proved a case study in the pitfalls of translating visionary ideas into workable inventions. After bolting out of the starting gate, *Team Effort's* safety buoy accidentally deployed. And that was not the least of its problems: In subsequent tests, the sub's hydraulic control system developed a slow leak, bringing the gleaming \$20,000 machine croaking to a halt on the seabed.

Still, the judges helped to soften the blow. Even though *Team Effort* didn't live up to its tantalizing promise, they awarded its cutting-edge design the top prize for the most innovative sub.

And the other victors?

Economy was the winning ticket for UCSB's *Love Missile*. It's cardboard-fortified hull painted in "cool stripes" did indeed work great and at the right price. For the unbeatable value of \$700, it walked away with the top award for cost-effectiveness. Marvels team leader Bish, "The \$1,000 prize was bigger than our budget."

When it came to swiftness of design, simplicity and reliability reigned su-

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SUBCYCLES

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preme. The last two finalists in the race—Florida Atlantic University's *FAU-Boat* and *Subasaurus*, sponsored by Benthos, Inc. in North Falmouth, Massachusetts—both opted for elegant, streamlined hulls driven by powerful, two-bladed propellers. What's more, both teams prided themselves on their practical, no-frills designs. "We didn't try to do anything fancy," says F.A.U. team leader Rob Coulson. "Take our ballast system. We just stuck in some foam and lead, and that's it."

Echoing that philosophy, Benthos' Mike Bassett reports that the team had initially "toyed with doing all sorts of things. But why mess with success? Now we're afraid that if we chip the paint off, it won't work."

As submarine races go, this one had a climactic finale. Sporting a menacing shark face on its yellow bow, *FAU-Boat* tore away from the starting gate amid a flurry of bubbles, leaving a slow-to-start *Subasaurus* a full sub-length behind. Then it was touch and go, but the hometown darling refused to give up its lead. The underwater camera showed

F.A.U.'s silhouette streaming to victory a full 16 seconds ahead of *Subasaurus*.

Okay, so it wasn't exactly a photo finish. Still, history was made in the annals of human-powered submersibles with the F.A.U. team setting a new world record of 4.7 knots.

As for *Subasaurus*, a dramatic turn of fate moved it from second place to first. Although it lost the speed trophy to F.A.U., it walked away with the much-coveted \$5,000 grand prize for best overall performance.

Submarine racing may not yet have the following of the America's Cup, but for a sport dreamed up over a mug of beer five years ago, it's evolving quickly. "The designs have improved immeasurably since the inaugural race," says sponsor Perry. "Back then, we had to hand some people cement blocks just to get their subs under the water."

Another sign that the sport may have a rosy future: The number of entries is growing steadily. There were 18 subs in the first race; by 1993, when the next race is scheduled, Perry anticipates close to 70. And judging from the big plans now being hatched for the upcoming event including a separate competition for robotic subs, the wackiest inventions are yet to come.

"It would be neat to make a completely transparent sub out of Lucite," suggests F.A.U. oceanographer Ray McAllister "Think of the fish you'd see." Another scheme that inspires him is to "wrap a gigantic screw around a long, tube-shaped hull." As he envisions it, the outer grooved skin would rotate around the passenger compartment, spinning the sub forward through the water like an Archimedes' screw.

This kind of talk sets imaginations whirling. Charles Pell, an artist who creates mechanical sculptures of animals for the zoology department at Duke, speaks of entering a sub modeled after a Kronosaur: "One of those big slippery aquatic reptiles that hung out with the dinosaurs." Not to be upstaged, Masouredis plans to build a "recyclable" sub out of beer cans that will roll along the seabed like a dune buggy.

An excited young man with a business bent gets another brainstorm: "Why not set up submarine tournaments across the country? We'd build the stadiums around gigantic aquarium tanks and get the networks interested."

With enough imagination, one can almost hear tomorrow's techno-fans and spectators crowing:

"What are these things?" 

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