Back to the Jurassic in Space-Age Subs

Deep-Ocean Exploration for the Next Millennium

By GIGI MARINO

The 19th-century poet Coleridge broke away from the conventions of his day by pushing the limits of form. Instead of adhering to the strict pattern of rhythm and rhyme for a sonnet, he experimented with "organic form," an idea he borrowed from the naturalists. In essence, the shape of a thing rises out of its reason for being. Or, simply put, form follows function.

Today, Graham Hawkes, a marine engineer and cofounder of the Ocean Exploration Group in Point Richmond, Calif., captures that vision in his "organic" designs of submersibles.

Hawkes, the architect of manned submersibles and unmanned, remotely operated vehicles (ROVs), creates underwater craft that have more in common with ocean mammals than with the first generation of submersibles. Those vehicles, designed in the 1960s and 1970s, now seem bulky and slow, weighing as much as 57 tons and traveling at less than 4 knots per hour.

"Animals in the wild don't behave the way submersibles do," Hawkes says. "Submersibles become heavy and sink." With his latest effort, the *Deep Flight* project, Hawkes aims to produce an underwater vessel that weighs less than 1.5 tons and cruises at 10 knots, imitates the dolphin's ability to twirl and turn 360°, performs "barrel rolls with the whales at 4,000 feet," and "flies" to the bottom of the ocean on downward-lifting wings.

His new design borrows from airplanes as well as animals and looks a bit like a shark with wings. At its widest point, the wingspan, the vessel measures 8 feet. Looking out of a clear dome and steering with joysticks, the pilot lies in the body of the 12-foot-long submersible. The "people pod" is narrow, allowing for little payload aside from the pilot, who wears the craft as much as steers it.

Even more daring, Hawkes and his business partner, marine biologist Sylvia Earle, want to return to the deepest place known on Earth – Challenger Deep. This spot lies nearly 11 kilometers below the surface of the Pacific Ocean in the Mariana Trench, located 320 km southeast of the island of Guam.

Photos: Ocean Exploration Group

Deep Flight *prototype takes a dip.*

And they're not alone.

The Japan Marine Science and Technology Center (JAMSTEC) in Yokosuka plans to send the unmanned ROV *Kaiko*—meaning "trench" in Japanese – to the bottom of the Mariana Trench as well.

In 1960, the Mariana Trench saw its first and, to date, last visitors. U.S. Navy Lieutenant Donald Walsh and Swiss oceanographer Jacques Piccard descended into Challenger Deep in the U.S. bathyscaphe *Trieste*. The French bathyscaphe *Archimede* also made the deep-sea dive. Since then, no one has even tried.

During a sea trial in March, before being delivered to JAMSTEC, *Kaiko* nearly broke the *Trieste*'s record. *Kaiko* descended 10,911 meters flawlessly. Then, 1 m short of *Trieste*'s record, the Japanese craft's video screens went blank.

"Some trouble happened in the image transmission system," says Akihiro Fujita, science officer at the Embassy of Japan in Washington, D.C. "The test was interrupted, and the vehicle *Kaiko* was sent to the factory for investigation."

Although the $50 million, 5.4-ton *Kaiko*, built by Mitsui Engineering & Shipbuilding Co. in Tokyo, is temporarily grounded, JAMSTEC is moving ahead in submersible exploration and intends to get back into the trenches soon.

In the meantime, the Japanese are focusing their efforts on a manned submersible, the *Shinkai 6500*, which can descend to 6,500 m. *Shinkai 6500* is currently part of a Japanese-American research effort that includes scientists from JAMSTEC, a number of other Japanese organizations, and Woods Hole (Mass.) Oceanographic Institution.

The deepest-diving submersible in the world, *Shinkai 6500* will explore the Mid-Atlantic Ridge in a series of cruises that began in June and will continue into early 1995. (Only five submersibles can tolerate depths below 6,000 m: the United States' *Sea Cliff*, Japan's *Shinkai 6500*, the former Soviet Union's *Mir I* and *Mir II*, and France's *Nautile*.)

During the expedition, *Shinkai* will investigate one of the largest known hydrothermal vents in the Trans-Atlantic Geotraverse (TAG) hydrothermal field. Underwater volcanism creates hydrothermal vents – large ore mounds populated by communities of shrimp and anemone – and the TAG vents reach temperatures of 665° Farenheit.

The Mariana Trench plummets 11 km (7 miles). That makes it, inversely, higher than Mount Everest.

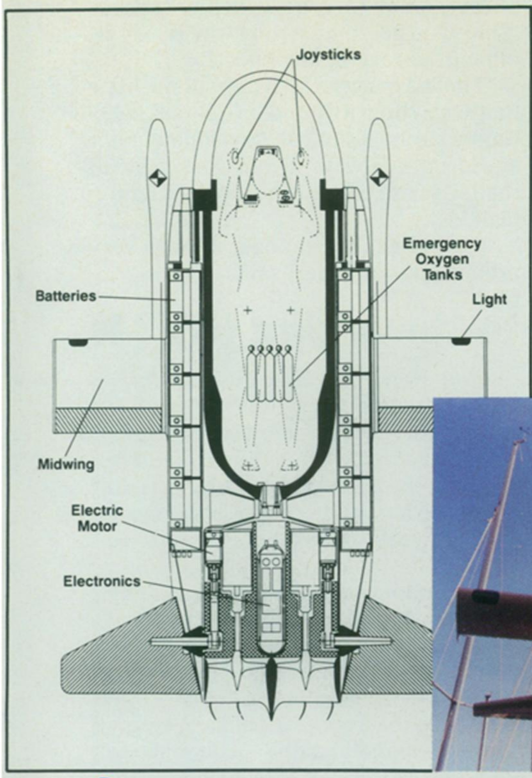

Diagram: Manipulating the wings, the pilot can counteract positive buoyancy and "fly" the submersible into the ocean depths. Photo: Deep Flight *designer Graham Hawkes demonstrates the pilot's prone position.*

(In fact, Earle has dubbed Project Deep Flight "Ocean Everest.") Here, on the muddy bottom of the ocean floor, with some rocks as old as the Jurassic, Earth turns in on itself.

According to the theory of plate tectonics, Earth is on a slow boil. Deep beneath the surface of the planet, rock currents move like water boiling in a pot: The stirring action causes hot matter to rise under plate boundaries. Near the surface, the hot rock liquefies. Fingers of magma then fill the gaps in the lithosphere, Earth's outermost shell, where the plates diverge. Quenched by seawater, this molten material solidifies as rock in the gap. As the plates continue to move apart, more magma fills the gap and the process is repeated, thus creating new seafloor.

Plates elsewhere converge. In a process known as subduction, the edge of one of these colliding plates plunges under the other. Ocean trenches form at these subduction zones.

Deep-sea trenches embody Earth's volatility. Earthquakes, volcanoes, and mountain building all result from these same tremendous forces.

The theory of plate tectonics did not become an accepted chapter in geological science until about a decade after the *Trieste*'s venture to the bottom of the sea. For that reason, many geologists would love to visit a subduction zone, armed with the plate tectonic knowledge of how trenches form. But Robert L. Fisher, a trench geologist retired from the Scripps Institution of Oceanography in La Jolla, Calif., says that trench research can be done without humans making the descent.

"There's a great deal more to be learned about trenches," says Fisher. "And going down with people isn't necessarily the only thing to do. We shouldn't put our eggs in that basket."

Why send manned submersibles to the Mariana Trench now? Hawkes and Earle have fielded that question many times since they conceived the idea for Project Deep Flight in 1988.

Earle cites one argument: the proposed use of subduction zones for nuclear waste disposal. "There are those who want to put the most noxious, toxic materials in the trenches with the thought that this is about as far away on the planet as we're likely to get. But there's no true 'away.'"

Don Walsh of the *Trieste* crew and now owner of International Maritime, a private consulting firm in San Pedro, Calif., says that Project Deep Flight has a lot to offer ocean research and materials science. "The development of new platforms is quite important, and that's what Graham's doing. He's also doing it with a great spirit of adventure, going back to the deepest place in the ocean."

No one doubts that the return trip will be exciting, but critics question its scientific exigence. Marine geologist Robert Ballard, Woods Hole's noted deepwater explorer, is often quoted as calling the venture "a stunt" and "trivial."

Marine biologist Art Yayanos, also of Scripps, says: "I have a gut feeling that says man's presence leads to discoveries that are difficult to make without man's presence.... But the cost is quite substantial, and if a fraction of that cost were put into an unmanned exploration, maybe we'd learn 99 percent of what we'd learn otherwise."

"There is a good reason for having access to the deep trenches," counters Earle, former chief scientist at the National Oceanic and Atmospheric Administration. "The seismic activity associated with the trenches is significant enough to inspire the Japanese to pour many millions of dollars into having access so they might be able to predict when earthquakes will occur....That could translate to some sizable economic benefits."

Besides, notes Earle, Hawkes believes he can keep his costs to a minimum. His Ocean Exploration Group relies completely on funding from the private sector. He hopes to build *Deep Flight II* on a budget of $10 million, one-fifth of *Kaiko*'s cost. Currently, Hawkes' company has built two *Deep Flight* prototypes to reach 1,000 meters; both are expected to undergo sea trials this October. If all goes well, construction of *Deep Flight II* will begin in 1995.

In order to meet the engineering challenge of designing a craft that will withstand up to 16,000 pounds per square inch of pressure, Hawkes has enlisted the help of the Naval Command, Control, and Ocean Surveillance Center in San Diego.

Richard P. Johnson, an ocean engineer there who's worked on this problem for the last few years, says that in the past, deep-diving hulls were made of high-strength metal alloys. The Russian *Mir* submersibles, capable of taking three people to a depth of 20,000 feet (6,096 m), have a nickel-steel hull. And *Shinkai 6500*'s hull is made of a titanium alloy.

"Ceramics are better," says Johnson. "I can design a chamber that's actually positively buoyant, so I don't need to supply additional materials to keep the whole system neutrally buoyant.... Ceramics have outstanding compressive strength."

Positive buoyancy — the ability to float — provides a safeguard for *Deep Flight* vehicles. The submersible, designed to fly to the bottom of the ocean in an hour or so, will float to the surface if power fails.

The earlier *Trieste* employed negative buoyancy. The steel-hulled float that loomed above the much smaller sphere housing the two crew members was filled with lighter-than-water gasoline. On the descent, the gasoline was vented and replaced with seawater, providing the negative buoyancy to sink. On the ascent, the pilot dumped iron pellets from the *Trieste*'s ballast tanks.

To date, ocean scientists haven't used high-pressure-resistant ceramics in anything larger than housings for underwater cameras. Johnson says Hawkes' application of the material will be its largest use, though ceramics have certainly been well tested. "He's pushing the limits of state-of-the-art pressure-housing design and the use of advanced materials. But it's doable," Johnson says.

Whether by intent or accident, Hawkes seems to be riding on the cutting edge. In fact, the power source he plans to use isn't available yet. The prototypes use a lead-

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acid battery, but Hawkes hopes that the fast-paced electric-car research will yield a suitable fuel cell by the time he has *Deep Flight II* ready to fly. If it hasn't, he will probably use a more expensive silver-zinc battery.

In addition to its new ceramic hull, *Deep Flight II* will employ another technology new to submersibles – fiberoptic microcable (FOMC) developed at the same Navy facility in San Diego. To communicate with the surface, the microcable transmits video and voice and is "about the size of 60-pound-test fishing line," according to coinventor Jim Dombrowski.

The cable's small size – it only needs a spool smaller than a loaf of bread – will reduce *Deep Flight II*'s need for a huge mother ship. The submersible will still rely on a support ship to receive transmissions, but not one of nearly the same proportions as those required by other submersibles and ROVs.

Hawkes wants to build submersibles that are inexpensive, easy to use, and fairly independent. In fact, he calls his designs "microsubmersibles." "We want to make these useful for future generations of scientists.... And we're trying to break away from a dedicated mother ship," he says.

When asked about the safety of sending people into the hadal zone – the Hades zone, or depths greater than 6,000 m – Hawkes replies, "The only sure way to be safe is to be dead.... A full-ocean-depth submersible has no greater risk than a 100-foot[-depth] submersible. The only change includes pressure. People have a big psychological barrier, but really it's a materials problem."

Besides, Hawkes himself will be the first to fly his new machine into the depths.

Science is rife with tales of serendipitous discoveries – and undersea exploration is no exception. Robert Fisher notes that scientists found minerals covering the ocean's abyssal plain during the early days of deep-ocean research. "There are great riches in manganese nodules, cobalt, and nickel. You don't have to get them from the seafloor yet. But knowing where they are, that's important. We discovered those things in the late 1950s when we were taking pictures and going out on these reconnaissance explorations."

And in the late 1970s, the U.S. Navy submersible *Alvin* – operated by the Woods Hole Oceanographic Institution – discovered entire communities of fauna living around hydrothermal vents. In fact, vent fauna have even been named for the submersible: the genus *Alvinocaris* and the family *Alvinellidae*.

"We may not discover anything as fundamentally different as the hydrothermal vent communities," says Charles R. Fisher, a marine biologist at the Pennsylvania State University in University Park. "However, we certainly didn't expect to discover those. Whether it's the Mariana Trench or other areas below 6,500 meters . . . they'll certainly discover new species."

In addition, Fisher argues, there's no substitute for being there. "The human eyes are phenomenal, and you don't realize how much better they are than really good cameras until you try to work using the really good cameras."

The U.S. government will soon have something to say about submersibles. Donald W. Perkins of the National Research Council's marine board in Washington, D.C., says that the Committee on Undersea Vehicles and National Needs which includes scientists, military personnel, and marine consultants, is nearly finished with a 2-year assessment and will publish its findings early in 1995.

"Earth is a marine habitat," says Earle. "The ocean is home to the greatest diversity of the planet.... It's still ironic that there are more footprints on the moon than there are on the bottom of the sea, and we're only 7 miles away.... One of the best things we can do as humans is embrace wild places." □