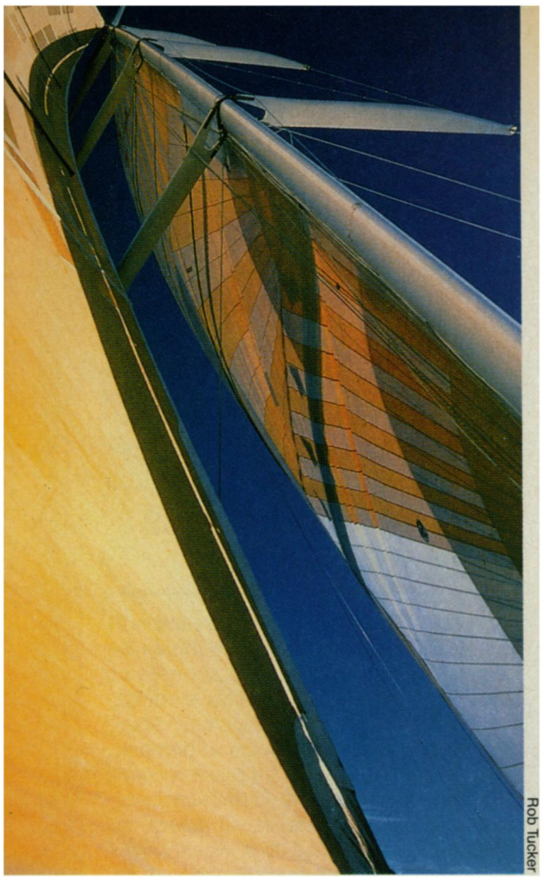


Rob Tucker

The New Zealand's *lightweight, 150-foot mast bends to get maximum speed upwind.*

Engineering a Victory on the Water

The America's Cup runneth over with new designs

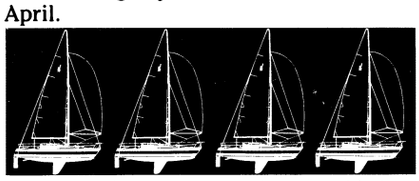
By CHRISTOPHER VAUGHAN

As if to prove that the America's Cup trophy is indeed awarded to the winner of a boat race, and not to a team of lawyers for their prowess in court, contestants in this year's America's Cup race will soon take to the waters off San Diego to sail against each other. But the legal tacks and jibes of the last year have made this a match race unmatched by any in the Cup's 137-year history.

A judge's literal interpretation of the original rules has unbound boat designers from decades of tradition and transformed this year's race into a no-holds-barred contest. As a match of widely disparate boat designs, constrained by little more than a maximum waterline length and the desire for speed, the race may not be an even test of yachting skill, but it will offer a showcase for many of the innovations that are endowing yachts with strange outlines and unprecedented speed.

Like the turbocharger that showed up first in race cars and then on the road, new sailing designs and technologies such as lightweight Mylar sails often show up first in the most expensive racing yachts and later are used by other racers and weekend sailors. Races with few design restrictions often produce such new designs.

The America's Cup hopefuls will show off leading-edge technology and engineering in three kinds of boats: the monohull *New Zealand,* the double-hulled *Stars and Stripes* and an exotic hybrid from England—in a class of its own—called *Blue Arrow.* After a long court battle over the rules, the Mercury Bay Boat Club's *New Zealand* and the San Diego Yacht Club's *Stars and Stripes* will race for possession of the Cup Sept. 7, 9 and 11. England's Royal Burnham Yacht Club is hoping to race its *Blue Arrow* against *New Zealand* before that race, but the New Zealanders now refuse to race the Britons, although they had accepted the challenge by the *Blue Arrow* team in April.



The key to making a fast sailboat is the same as making a fast anything: Maximize thrust and reduce drag. For sailboats, maximizing thrust means increasing the size and efficiency of the sail, which acts like an airplane wing to give the boat "lift." Most of the drag on a boat in light winds, typical off San Diego, comes from the water, so reducing drag requires reducing a boat's weight. This makes the boat sit higher in the water and reduces "wetted surface."

If this were all the designers had to worry about, the answer would be obvious: Make a very small boat with a huge sail. Unfortunately, such a boat tips over easily, so designers must strive to craft a boat that balances an equation involving sail size, weight and stability. Designers of the three America's Cup hopefuls devised very different solutions to this equation.

The New Zealanders picked the traditional answer by making a boat of enormous size. The *New Zealand* has a 150-foot mast and is 90 feet long at waterline, the maximum length allowed by America's Cup rules and longer than any America's Cup boat since the dramatic "J-boats" of the 1930s. But its construction is very untraditional. With new materials and modern design, the builders have strived to get the maximum sail area without adding much weight or losing stability. In fact, although the *New Zealand* is half again as long as the 12-meter boats that usually sail in the America's Cup, it weighs almost the same, about 60,000 pounds, according to *New Zealand*

Rob Tucker

Sail Performance Technician Richard Morris working the computers aboard the New Zealand. *The computers help monitor wind and boat speed, stress in the boat and sail trim.*

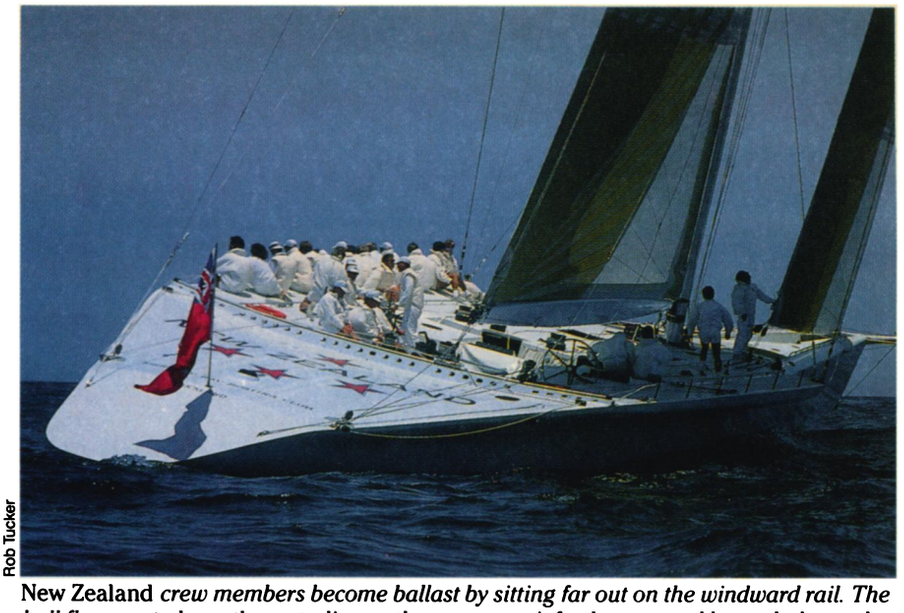
Design Coordinator Peter Walker. (Contrary to popular belief, 12-meter refers to the final product of a design equation and not to the length of the boat.)

The savings in weight come from using new types of carbon fiber composites to build the boat. The mast is all carbon fiber material, and the hull's core is a carbon fiber honeycomb with foam inserts, Walker says. To help bring the weight down to the absolute minimum the designers built strain gauges into the mast, hull and rigging. These gauges let them monitor stress on the boat's components so they know if a section has been made too light or too heavy.

When weight is lost, stability must be acquired in other ways. *New Zealand's* designers did this by making the hull flare out above the waterline, giving the gargantuan boat the look of an aircraft carrier with a mast and bowsprit. These "wings" let the 40 crew members stabilize the boat with their own body weight when they sit, like birds on a rail, far out on the windward side of the boat. The keel, the design of which the New Zealanders are keeping a secret, also contributes to the boat's stability. The keel's ability to hold up 18,000 square feet of sail despite its "small" size is "quite a trick," Walker says.

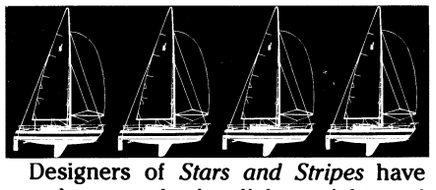
The combination of the boat's size, light weight and stability makes *New Zealand* the longest and fastest monohull racer in the world, according to designers from both the *New Zealand* and *Stars and Stripes* teams. The boat is further distinguished by being the first monohull to sail faster than the wind on both upwind and downwind legs of a race, Walker says.

One major innovation that keeps the boat sailing fast is the use of computers to monitor sail shape. A "Sailvision" program written especially for *New Zealand* takes video images of the sails from different angles and compares those images to recorded images of optimal sail shapes used in similar conditions in the past. The computer then tells the sail trimmers how to correct the sail trim. The America's Cup race will mark the first use of such a system in a race, Walker says.



Rob Tucker

New Zealand *crew members become ballast by sitting far out on the windward rail. The hull flares out above the waterline so the crew can sit farther out and better balance the relatively lightweight boat.*



Designers of *Stars and Stripes* have opted to emphasize light weight and stability rather than size. *Star and Stripes* is a catamaran, whose two widely separated hulls allow boat builders to erect a large sail without a heavy lead keel slung under the boat to counterbalance the force of the wind. Consequently, the 59-foot boat weighs one-tenth as much as the *New Zealand* but can unfurl 4,500 square feet of sail—about one-fourth as much as its much larger competitor.

Stars and Stripes' most striking feature is that its mainsail doesn't look like a sail at all, but rather a solid, vertical wing like those used by the much smaller class-C racing catamarans. Instead of a fabric sail and a mast, the "wing sail" is a two-piece Kevlar- and Mylar-covered foil that gives the boat more lift and less wind resistance than a conventional sail, says wingsail co-designer David Hubbard of Pitney Bowes in Norwalk, Conn.

"The wing shape is aerodynamically cleaner and gives more lift per square foot of sail," Hubbard says. One reason the wing sail provides more lift is that it is tall and narrow from front to back. Since most lift occurs near the leading edge of a wing, this maximizes lift for a given sail size.

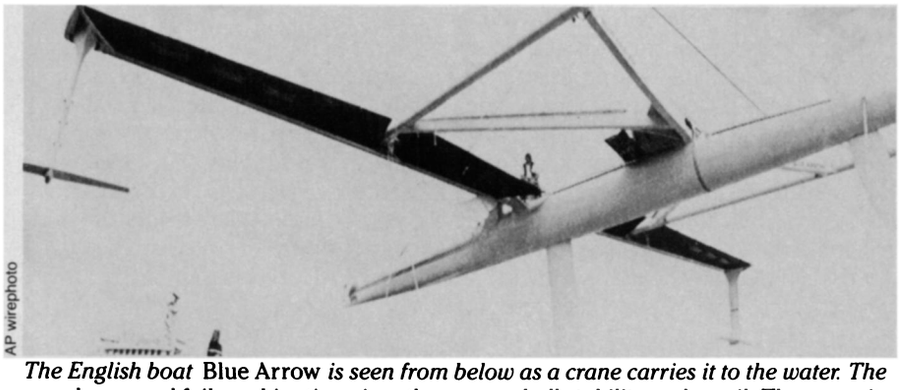
Another method of increasing lift is to keep the flow smooth across the whole sail. Almost all wings have disrupted airflow near the trailing edge of the wing, which reduces overall lift, Hubbard says.

To ensure maximum lift by keeping the airflow smooth over most of the wing sail, it is actually constructed out of two foils, one in back of the other. The flow of air through a slot between the foils keeps the wind pinned to the surface of the rear foil when it might otherwise break away and eddy on a single foil, Hubbard says. "This is much like the slats on airplane wings that keep them from stalling" on takeoff, he explains.

Like *New Zealand, Stars and Stripes* has a network of sensors to monitor stress. The designers use these monitors to tune up the boat, but sailors on the more fragile, tightly rigged catamaran also need stress information to know when they can "put the pedal to the metal" and when to "throttle back" in a race, says *Stars and Stripes* Information Officer Lesleigh Green.

Many observers expect the catamaran to sail away with the race, but a few caution that the outcome is not foreordained. In light wind and choppy seas the catamaran's two hulls will bounce the boat around, slowing it considerably, notes *Stars and Stripes* Design Program Manager John Marshall.

New Zealand's large size could also offer an advantage. A common sailing tactic is to "cover" the competition by



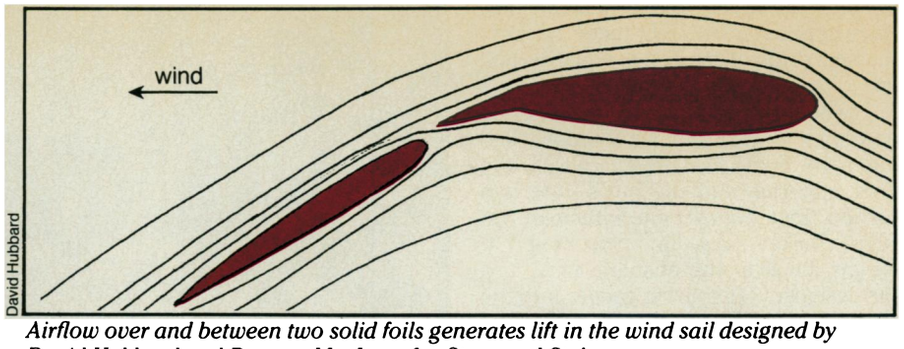
AP wirephoto

The English boat Blue Arrow *is seen from below as a crane carries it to the water. The crossbeam and foil combination gives the narrow hull stability under sail. The crew sits in the net aft of the crossbeam.*

putting your boat upwind of them to block the "air," or wind. If *Stars and Stripes* is unlucky enough to be covered by the nearly half-acre of sail on *New Zealand,* "we'll have to reach for our oxygen masks," Marshall says.

New Zealand's sponsors have already legally "covered" the Royal Burnham Yacht Club's *Blue Arrow* and left it dead in the water by refusing to race an elimination race against it, which, as the official challengers, they have the right to do. The New Zealanders contend *Blue Arrow* is a trimaran and not an equal match against *New Zealand.* The English insist their boat is a monohull, but unlike any monohull before built.

Blue Arrow combines the stability of a catamaran with increased weight savings by using one instead of two narrow hulls. The 2-foot, 7-inch-wide hull does not tip over, though, because a 26-foot crossbeam carries underwater foils at either end to stabilize the boat. In the cockpit, a crew member called the "pilot" controls the angle of the winglike foils to counterbalance the force of the wind on the sails.



David Hubbard

Airflow over and between two solid foils generates lift in the wind sail designed by David Hubbard and Duncan MacLane for Stars and Stripes.

The result is a 65-foot boat that is light and has little wetted surface to cause drag, while it carries as much sail on its 80-foot mast as the crossbeam and foils can handle. *Blue Arrow* is, therefore, very fast, says *Blue Arrow* spokesman David Redfern.

How fast remains unknown. The boat was designed and built only in the last few months, so the *Blue Arrow* crew has yet to master sailing it. One crew member likens it to "learning to ride a bicycle with eight guys on your back," Redfern says.

Blue Arrow will race for the America's Cup only if its owners can persuade the New Zealanders or a court of law that the underwater foils and crossbeam, which can move forward or backward 1 foot, constitute the movable keel that is explicitly allowed in the deed-of-gift setting forth the original America's Cup rules. This seems unlikely, but the English boat will go to San Diego anyway and will "sail against anybody," says Royal Burnham Yacht Club Commodore Anthony Clare.

Clare argues the case for letting *Blue Arrow* race for the Cup by citing the sparseness of design restrictions in the deed-of-gift. "The deed-of-gift was drafted by people interested in yacht design," Clare says. "It deliberately contained little restriction so that the Cup would encourage and demonstrate the advantages of new design concepts."

If that is so, their intentions have been well satisfied this year. □