Flying Boat

An Innovative Sailboat Design Did Not Just Set a New Record--It Skimmed Over the Water at Highway Speed. Will the Sailrocket Usher in a New Age of Sail?

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Abstract

A child can draw a sailboat.

This article is a study of engineering concepts behind design and functioning of SailRocket, an innovative sailboat, and other ongoing experiments on different sailboats. Researchers believe that to push sail technology to the extremes of performance requires disregarding the child's eye view of a sailboat. Conceptually, the SailRocket owes more to aircraft and wind turbines than it does to traditional yachts. The engineering concepts behind the sailboat design are: the hydrofoils lifting up as the wind tries to push the mast over; the sails on one side of the center of mass and the sailor on the other; the force of the water on the keel resisting the windward drift of the boat. According to the calculations, the only leftover force would push the boat forward at high speeds. After a series of incremental improvements followed by incremental larger crashes, Vestas, the Danish wind turbine manufacturer, stepped in with enough sponsorship money to allow for a more thorough analysis. Even without the SailRocket's success, the shape of wind-powered vehicles is moving away from the classic billowing sails.

A child can draw a sailboat.

It's pointy in front and rounded along the sides, with a mast that holds tight to a billowing sail. An adult might point out some other features: additional sails, say, or lines that allow for hoisting and adjusting of the sheets but the gist of the technology can be sketched out in crayon.

To push sail technology to the extremes of performance requires disregarding the child's eye view of a sailboat.

The largest sailing ship ever built, the Preussen, was a steel-hulled windjammer that carried six square sails on each of its five, 190-foot masts. Likewise, the yachts scheduled to compete in the America's Cup in September are catamarans, which have two slender hulls connected by lateral struts, and tip to one side in a strong wind. Compared to the Vestas SailRocket 2, however, those ships are plain vanilla. But the SailRocket recently made the case that its odd-looking design could be the future of sail-powered transportation. The craft as needle-thin and sleek as a javelin, with a solid wing for a sail mounted on a boom sticking to the side set the all-time speed record for a wind-powered vehicle in November 2012, averaging 65 knots (75 miles per hour) over a 500-meter course in Walvis Bay, Namibia.

Racing shell

The SailRocket 2 is designed for speed. The main fuselage is made from carbon fiber and the entire boat, including its rigging, has an aerodynamic drag equivalent to a 29-inch sphere.
Skimming the surface

During this November 2012 run in Namibia, the SailRocket 2 reached a peak speed of 68 knots. The boat is designed to make minimal contact with the water, with its three floats often skimming inches above the surface.

Conceptually, the SailRocket owes more to aircraft and wind turbines than it does to traditional yachts. Instead of something from the water reaching up to touch the air, said skipper Paul Larsen, the SailRocket is more like something from the air reaching down and touching the water.

His record run was the culmination of 12 years of effort on the part of the Larsen and the lead designer, Malcolm Barnsley. But even more, it was a vindication of a largely forgotten 50-year-old concept developed by a U.S. Navy weapons designer.

The earliest sailing likely involved hoisting a sheet on a mast mounted on a raft and allowing the force of wind to push the raft forward. Sailing this way is easy to understand—the raft goes where the wind blows—but limiting both in direction and in speed. The faster you go when running with the wind, the less force pushes on the sail.

In time, however, sailors figured out how to use weight and leverage to get more from the wind than simple pushing. Sailing across the wind, for instance, in a boat with a keel allowed for a more or less constant force on the sail even at higher speeds. And with the sail angled with respect to the wind, lift developed across the leeward side of the sheet so that drag isn’t the only force propelling the craft.

Wing sail

Air rushing over the solid aerofoil powers the SailRocket. The outboard wing extension (top) provides upward lift to pull the leeward pod out of the water at about 50 knots. The upright portion of the wing is made of independently moveable sections that can be controlled via rigging from the cockpit (left).
Sailing across the wind isn’t without its drawbacks. In addition to the component that creates lift, another component of the wind acts on the mast and works to tip it to the side. To keep a lightweight boat from heeling too much and capsizing, sailors lade the hull with ballast. Sometimes, instead of ballast, sailors on speedy boats will hang from the upwind side of the hull to counteract the force trying to tip the boat over.

Daredevils

Until recently, sail speed records had been held by kitesurfers (like the one in the foreground at left) who operate in inches of water.

That sort of leverage must have been on the mind of Bernard Smith when he began noodling with experimental sailboat designs in the late 1950s. Smith wanted to find a design that would be close to impossible to heel, and looked at configurations where the various forces acting on the boat—the wind pushing to heel the boat, the keel opposing any sliding forces, gravity pulling various segments to the water—all work to cancel each other out.

Float

At low speeds, the SailRocket is supported in the water by two flotation pods under the fuselage and one under the wing. The front pod (above) is designed to be pounded by waves.

Design evolution: Rethinking sailing to get more speed and better stability


Forces of wind and water propel traditional sailboats, too. But since the force of the wind (CE) and the resistance of the keel (CLR) are not properly aligned, wind works to tip boats over.
Smith experimented with various designs. Many of these were skeletal, little more than a few floats held together by bracing. In time, however, aerodynamic analysis combined with trial and error to produce something that could be sailed. Smith laid out his concept in patent filings and obscure books.

"Stated in the simplest possible terms," Smith wrote, "the machine for deriving the ultimate in sailing speed consists of two vertical wings, an inverted one in the water joined to an erect one in the air. When coupled in this way the assembly may be likened to a sailboat that has a sail and a centerboard, but no hull; except that the sail is no longer a sail but an airfoil, and the centerboard no longer a centerboard but a hydrofoil."

The experimental boats Smith built, some scale models of which he tested in the reflecting pool of the Lincoln Memorial, looked like nothing else in the water. Unlike the sailboat of children’s drawings, the sail is mounted on a spar supported in the water by a pair of hydrofoils. And the mast also differs from the platonic sailboat: it leans toward the sailor (as do the hydrofoils), who would be sitting windward on a float above the keel when the boat achieved its fastest speeds.

The result is a balance of forces: The hydrofoils lifting up as the wind tries to push the mast over; the sails on one side of the center of mass and the sailor on the other; the force of the water on the keel resisting the windward drift of the boat. According to Smith’s calculations, the only leftover force would push the boat forward and at high speeds.

Smith laid out his ambition in the title of a 1963 monograph, *The 40-Knot Sailboat*. The fastest wind-driven speed in 1972, when world sailing records were codified, was only 26 knots. One illustration in the book described a plan for a boat he called the Memmac: an idealization of his concepts featuring three hydrofoils, a wing-like airfoil instead of a sail, and a cockpit hoisted clear out of the water. The resemblance to the SailRocket is startling.
Extreme sailor Paul Larsen had set several records before signing on with the SailRocket team.

For most of the past 25 years, sailing speed records have been held not by boats, but by boards. Windsurfers and, later, kitesurfers have achieved ever faster speeds due to the daredevil ethos of extreme-sports athletics. Recordsetting kitesurfing runs, for instance, have been conducted in 50-mile-per-hour winds on boards skimming through a few inches of water.

At about the time that those minimalist watercraft started outracing yachts, Malcolm Barnsley began taking an interest in experimental sailboats. In the early 1980s, he began designing boats for competitions in the United Kingdom. “I realized that I could build a small boat and have a chance,” Barnsley said. His early designs were relatively conventional—monohulls with some hydrofoil stabilization—that topped out at nearly 20 knots.

Through the 1990s Barnsley, who by day is a blade test engineer for Vestas, the Danish wind turbine manufacturer, created successively faster and more ambitious sailboats. Then he discovered the work of Smith and was swayed by the logic behind his designs. The two even began talking on the phone. “Smith, who had retired as director of the Naval Weapons Laboratory in Dahlgren, Va., regretted that his radical ideas had never caught on. He told me that my taking his ideas seriously had kept him alive,” Barnsley said.
Closing in on the record took time and constant tinkering with the hydrofoil including taking a handsaw
to it at one point.

Around 2000, Barnsley began roughing out the designs for the SailRocket. In naval architecture terms, it
was an asymmetrical hydrofoil proa with an inclined wing. (By this point aircraft-style wings, rather than
cloth sails, had become a standard feature of experimental sailboats, just as Smith had predicted.) As the
design developed into its final form, there were departures from Smith’s sketch of the Merrimac. Instead of
a rounded nacelle for the crew, the SailRocket’s cockpit became as long and narrow as a rowing shell, and
was supported by fore and aft hydrofoils in the water.

Early in the design process, Barnsley joined up with Paul Larsen, a sailor who had also run across Smith’s
books. With Barnsley aiming to have his SailRocket go faster than 50 knots—a speed some have called
the sound barrier for sail—he needed Larsen to not only help design and build the boat, but also to be his
Chuck Yeager.

Larsen had experience in extreme sailing—not only global circumnavigations but also as part of a crew
that set a 24-hour distance record of nearly 700 miles. To Larsen, it was a natural progression to aim for
the sail speed record.It wasn’t easy, however, to get support for the project; while Smith’s concepts
made intuitive sense to Barnsley and Larsen, they ran counter to centuries of marine design. “And even
if core concept is right, your interpretation of how to apply it may be wrong,” Larsen said. That led to some
small disasters.

Hydrofoil

Acting to counter the lateral drift of the wing, the hydrofoil was a critical part of the boat. But some changes
were made on the fly: team members installed a new foil (top) and Nick Hewlin manually shortened one
before a run.

“We were forced to realize that our first boat’s first interpretation was flawed,” Larsen said.
“We had a lot of crashes working that out.”

After a series of incremental improvements followed by incrementally larger crashes, Vestas stepped in
with enough sponsorship money to allow for a more thorough analysis. In 2007, the Larsen reached 40
knots in the SailRocket; the team called the 97-year-old Bernard Smith at his Florida home to tell him that
his outrageous ambition had become a reality. By then, however, daredevils skimming the waves in gale-
force winds on kite-boards had already surpassed that mark. Larsen and Barnsley were going to have to
push harder to set the record.

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.crashes working that out.”

Eventually, Larsen pushed the SailRocket to break the 50-knot mark hard enough that a run ended in a
spectacular end-over-end crash and another landed Larsen in the hospital.

FAST FORWARD

Though the record runs were solo, the SailRocket is a two seater. Adding a passenger cuts about 3 mph off
the peak speed.
More money from Vestas helped build a second boat in 2011. It was a major redesign. The *SailRocket* 2 featured three pods that helped lift the craft out of the water at speed and a fuselage that pointed not in the direction of travel but into the apparent wind to cut down wind resistance. Instead of the multiple hydrofoils of the classic Bernard Smith design, there was just one, mounted on its own outrigger and jutting into the water like a long knife, positioned and angled to directly oppose the lateral and vertical loads generated by the wing some 40 feet away.

67.74

Larsen (at right) revealed that he had set a new record by writing the peak speed, in knots, in the sand. Lead designer Malcolm Barnsley looks on at the far left.

In the redesigned boat, the pod below the wing would rise out of the water at high speed. Indeed, as the boat reached maximum velocity, it would scarcely contact the water at all, skimming along often with only the single hydrofoil preventing the boat from launching into the air.

The *SailRocket* team delivered the new boat to Namibia and quickly reached the 40-knot mark. (The celebration was bittersweet; Bernard Smith had died the year before.) But closing in on the record took time and constant tinkering with the hydrofoil—including taking a handsaw to it at one point.

The sequence of trial-and-error runs stretched into 2012 until, suddenly in November, while trying add-ons to a new foil developed by the design team, everything seemed to align. The boat started making runs with averages over 50 knots and peak speeds in excess of 60, or 69 miles per hour. Over the course of two weeks, the speeds kept jumping higher until finally Larsen and the *SailRocket* 2 surpassed every expectation. Larsen’s fastest run clocked a 500-meter average of 65.37 knots and a one-second peak of 67.74 knots, the equivalent of almost 78 miles per hour.

What’s more, those speeds were set in 30-knot winds. Unlike the kiteboards, the *SailRocket* developed its speed through engineering.

At last

Larsen and Barnsley congratulate each other after the recordsetting run, the culmination of 12 years of perfecting their radical boat design.
“This is the classic example of why you have to push these things,” Larsen said weeks later. “We’ve been able to demonstrate that, by looking at things differently and being more efficient, there’s a lot of power that can be ripped out of a small amount of wind energy.”

Larsen added, “Maybe the most important legacy of this project is to get people to rethink about the serious power that can be gotten from the wind.”

Even without the SailRocket’s success, the shape of wind-powered vehicles is moving away from the classic billowing sails. The land speed record for a wind-powered vehicle—an astonishing 126 miles per hour—is held by the Greenbird, a low-slung needle-shaped car with an outrigger and a vertical wing. And the AC72 yachts set to compete for the America’s Cup in September are all catamarans, each sporting an airfoil larger than the wing of a 747.

Those are extreme vehicles, and about as practical as a Formula One racer or a jet car on the Bonneville Flats. Are there useful applications for this new concept in very fast sailing?

Bernard Smith, who worked as a weapons designer during the Cold War, had one practical answer: Navies could use his sailboats to outrace and silently evade submarines. Indeed, one of Smith’s aerofoils at cruising speed would have very little waterline for a torpedo to hit.

Malcolm Barnsley, looking at today’s challenges, sees a commercial potential for these kinds of ships. A passenger ship or freighter that employed some of the concepts of the SailRocket could become an attractive and potentially less expensive alternative to air travel.

Victory. SailRocket team members (from left) Hiskia Sindimba, Paul Larsen, Adam Fisher, Nick Hewlin, Alex Adams, and Walter Hansen (in water) celebrate breaking the speed record.

“There’s the possibility of high-speed transport,” Barnsley said. “Imagine the sailing equivalent of a jumbo jet—300 feet long and 30 to 40 tons: you could cross the Atlantic in two days and save the aircraft fuel. And it could be a lot of fun.”

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