Young America is Born

by John Marshall

On a hazy autumn day in 1983, I stood helpless at the mainsheet of *Liberty* as the innovative, wing-keeled *Australia II* sailed away from us to win the America's Cup. Our boat design had lagged in technical innovation, and we lost.

In 1992, after Kevin Mahaney had won his Olympic silver medal, we met to plan a special America's Cup program – a young sailing team with a veteran design team. And we would do something extra by using this event – truly the Olympics of technology – to excite young students about science and design.

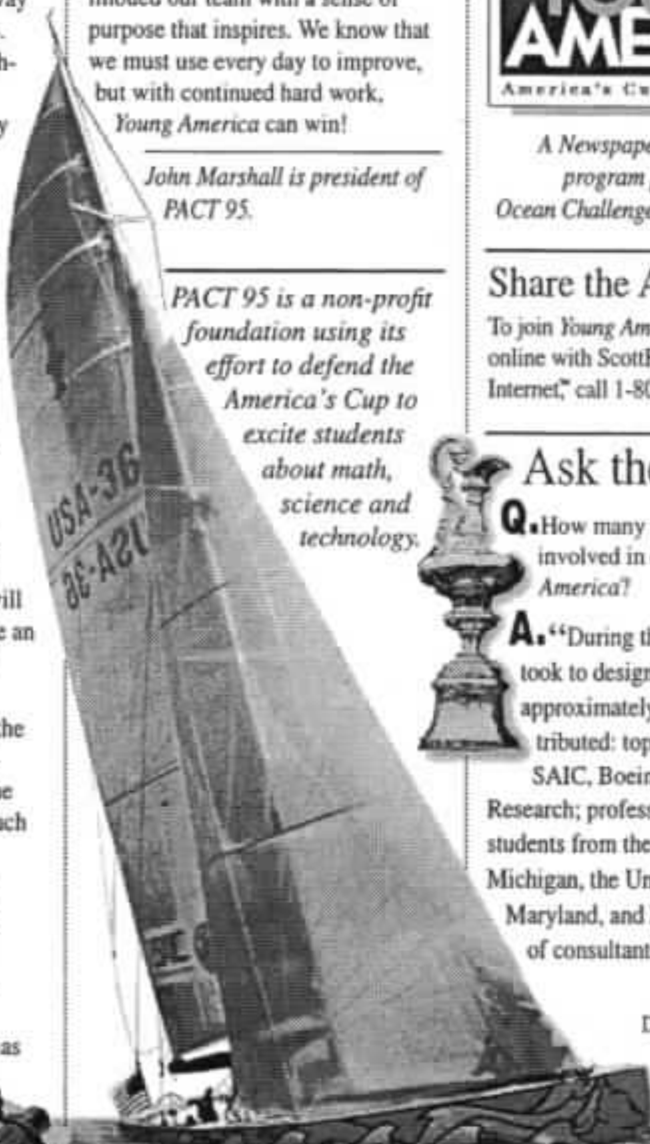
For the America's Cup is not just sailors versus sailors. At its core, the Cup is a competition between our best American scientists and those of the challenging nations. Since the fastest design will probably win, the Cup has become an international symbol of technical excellence.

For our team, just getting to the starting line has been a huge challenge. We started at home in Maine with our dream, no money and much work before us.

Since then, an extraordinary technical team has been recruited: Boeing (aircraft), Cray Research (supercomputers), Ford (automobiles), and Science Applications International (aerospace). Kevin has built a great sailing team, and we've developed this nationwide education program. Private citizens and corporate sponsors have embraced our effort.

On December 21, our *Young America* set sail for the first time. Resplendent in her Roy Lichtenstein mermaid, she came alive and imbued our team with a sense of purpose that inspires. We know that we must use every day to improve, but with continued hard work, *Young America* can win!

John Marshall is president of PACT 95.



PACT 95 is a non-profit foundation using its effort to defend the America's Cup to excite students about math, science and technology.

News Explorer

Look in today's newspaper for as many examples of leaders (company presidents, coaches, directors, etc.) as you can find. What qualities do these leaders share?

1st in a Weekly Series of 11

PACT 95

YOUNG AMERICA

America's Cup Defense Team

A Newspaper in Education program produced by Ocean Challenge, Inc. and PACT 95.

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To join *Young America* and PACT 95 online with ScottForesman and Delphi Internet,™ call 1-800-362-3261.

Ask the Team

Q. How many people have been involved in designing *Young America*?

A. "During the 18 months it took to design *Young America*, approximately 50 people contributed: top scientists from SAIC, Boeing, Ford, and Cray Research; professors and graduate students from the University of Michigan, the University of Maryland, and MIT; and a number of consultants and volunteers."

. . . John Kuhn,
Design Team Manager,
Young America

Designing for San Diego

2nd in a Weekly Series of 11

by Jim Teeters

To win the America's Cup, we design for San Diego in May. Buoys record wave size and frequency; vanes and anemometers record wind trends. Like TV, we use probabilities: 30 percent chance of 12-15 knot winds with 4-foot seas, etc. Some designs excel in light winds, others when the wind is "honking"; some get stopped by waves, others slice through them. We designed 500 variants and compared their performance.

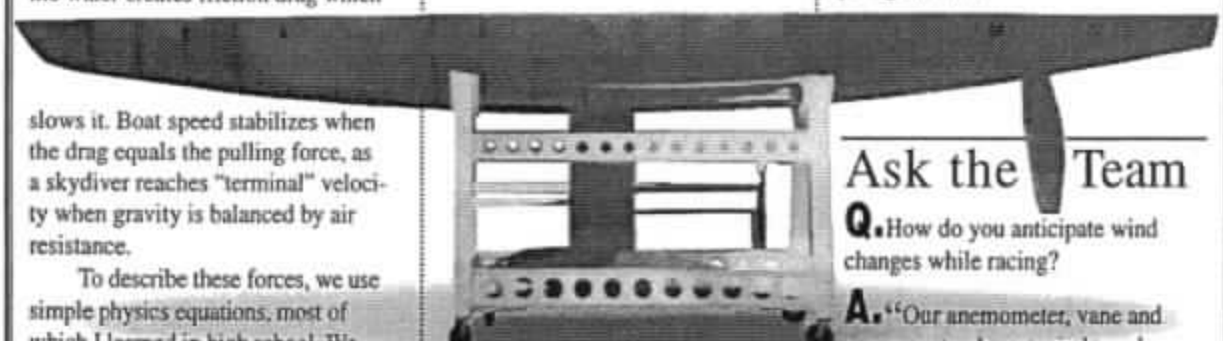
The idea in boat design is to balance forces. For example, when wind blows across sails, it creates lift that pulls the boat, but the hull moving in the water creates friction drag which slows it. Boat speed stabilizes when the drag equals the pulling force, as a skydiver reaches "terminal" velocity when gravity is balanced by air resistance.

To describe these forces, we use simple physics equations, most of which I learned in high school. We then validate our equations by testing them. In a huge tank, we tow models and measure the forces created in different wave conditions. If this test data agrees with our equations, our equations reflect reality. If not, we change the equations.

We can test many more designs in the computer than in the tank, so we write a computer program – our Velocity Prediction Program (VPP). The VPP balances our equations for different hull and sail combinations. It acts like a sailor: it steers closer to the wind in calm waves, reduces sail area in strong winds, and hoists curvy sails when it needs more thrust.

The VPP races various designs against each other in the range of probable San Diego conditions, keeping track of wins and losses. The design that won in this computer racing became our real boat: *Young America.*

Jim Teeters is a naval architect for Sparkman & Stephens in New York and a PACT 95 Design Team member.



▲ *International America's Cup Class test-tank model*

Masthead weather instruments ▼

photo: Bob Grieser

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Ask the Team

Q. How do you anticipate wind changes while racing?

A. "Our anemometer, vane and computer track past wind trends. My job is the inexact science of forecasting the wind ahead.

"A dark patch on the water shows an extra puff; the angle of the ripples tells direction; incoming clouds or a distant smokestack may preview later changes. Data, eyesight, intuition and experience combine in my educated guess. If I'm right, we get a big advantage; if not, well..."

—Ken Read, Strategist, *Young America*

News Explorer

PACT 95 used extensive computer simulations to design *Young America*. Search today's newspaper to find other people using computers to accomplish tasks.

Making Waves

by Paul Sclavounos

Flotation is a gift of nature to us. Ships have sailed the seas for millennia, carrying goods and people efficiently to places not easily reached by land. Since Archimedes first described the physics of flotation over 2,000 years ago, naval architects have claimed many successes: deep-sea submersibles, fast hydrofoil ferries, huge tankers, and luxurious cruise ships! Yet their crown jewel is an International America's Cup Class (IACC) sailboat.

IACC hulls float effortlessly, but not all sail equally fast. Our challenge is to shape our hull so that it slips through calm water or waves with minimal resistance, thus maximizing its speed for a given sail force. Hull shapes used to come solely from a designer's ingenuity. Then came the test tank, a design aid in which hull models are towed to measure their resistance without full-scale building or cost. Now computers are the newest design tool.

Here at MIT, we have adapted our computer program SWAN (Ship Wave ANalysis), originally written to analyze U.S. Navy and commercial ships, to apply to *Young America*. SWAN predicts how smoothly the water will flow around various designs for *Young America*'s hull, keel, winglets and rudder, and how much extra resistance results when waves are encountered. SWAN can mimic the ocean by simulating waves of different height and speed.

Yet the tow tank can't measure resistance perfectly, nor can my theoretical equations predict water flow perfectly. Thus our Design Team debates about who and what is right. This has taught me a great lesson: that scientists like me, who have developed techniques in a laboratory, must defend their ideas to the practicing engineers. In the end, both viewpoints have been integrated into our design, *Young America*.

Paul Sclavounos is a professor at MIT and a member of the PACT 95 Design Team.

News Explorer

SWAN is an acronym for Ship Wave ANalysis. Search today's newspaper for as many other acronyms as you can find!

Ask the Team

Q. With advanced computer modeling, why test scale models of the boat in a towing tank?

A. "Some of our physics questions are so complex that they're hard to describe with equations. One example is 'form drag' – a component of resistance related to hull shape. Measuring this drag by towing models in the tank gives us real data with which to validate our equations."

Amy Chen, high school student, PACT 95 research assistant and John Kuhn, PACT 95 Design Team manager

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photo: Bob Grieser

Staying Upright

by Tina Guldberg

Have you ever wondered how a sailboat stays upright? It does so by balancing forces.

With *Young America*, the wind blows against the sails (3,000 square feet on a 110'-tall mast) and pushes the boat over. The keel hanging underneath the hull has a bulb attached which contains over 20 tons of lead and acts as a counterweight to keep the boat upright. Imagine the huge loads that are inflicted on the hull!

The challenge is to design a hull and internal support structure strong enough to hold together the keel, heavy bulb, long hull and tall mast, and yet lightweight enough not to load the boat down in the water. This trade-off between strength and weight is critical. If the structure is too light and breaks, the boat stops and you lose the race (as happened to *oneAustralia* when its hull cracked, folded up and sank on March 5). If the structure is too heavy to guarantee against breaking, it makes the boat sluggish and slow.

This trade-off exists in the design of automobiles as well as sailboats. At Ford, we're testing advanced materials to develop stronger, yet lighter and more fuel-efficient automobiles. As engineers, we use our education in mathematics, computer science, physics and statistics to conceive new designs and test new materials.

Ford has helped PACT 95 to optimize its hull structure and to conduct mechanical tests to verify computer modeling results. And PACT 95 has helped Ford to understand about advanced building materials for structures under large loads. It is mutual learning and technology transfer at its best, and the result here is a fast, stable and winning *Young America*.

Tina Guldberg is an engineer for Ford Motor Company and a PACT 95 Design Team member.

photo: Sheila Hill

PACT 95 is a non-profit foundation using its effort to defend the America's Cup to excite students about math, science and technology.

News Explorer

PACT 95 and Ford are working together toward a common goal of developing the best technology possible. Search today's newspaper for other mutually beneficial collaborations.

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Gordy Wagner climbing Young America's mast ►

photo: David J. Shuler

Ask the Team

Q. What's it like to climb *Young America*'s 110' mast while racing?

A. "My mountain climber's harness is hooked to a halyard, and four 220-lb. grinders – football player types – pull me up, launching me like a rocket. The 110' mast sways in all directions and it's hard to hold on. Though safe, I feel very scared, as when riding a roller coaster."

...Gordy Wagner, *Young America* bowman

Steering *Young America*

by Winfried Feifel

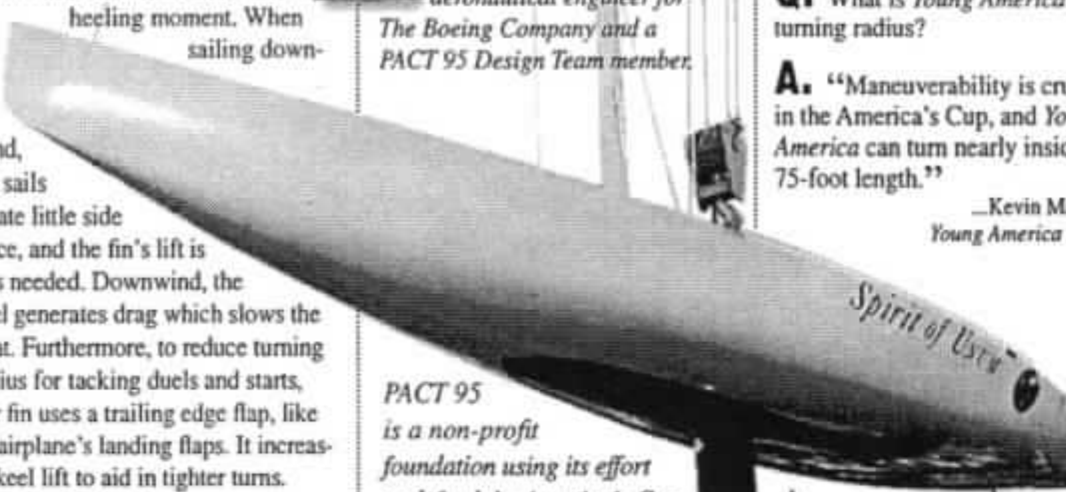
A boat's underwater control surfaces are called appendages. *Young America* has two: a rudder at the stern and a keel amidships. The rudder steers and gives directional stability, like an airplane's vertical tail. The keel has more complex purposes.

When sailing upwind, the sails produce a small, desirable forward force, and a large, unwanted side force. The side force tries both to slip the boat sideways and to heel it over. The keel fin counteracts the sideslip force by creating an opposing lift force as it slices through the water, as an aircraft wing does in air. The fin also must support a 20-ton streamlined lead bulb which counteracts the sails' heeling moment. When sailing downwind, the sails create little side force, and the fin's lift is less needed. Downwind, the keel generates drag which slows the boat. Furthermore, to reduce turning radius for tacking duels and starts, our fin uses a trailing edge flap, like an airplane's landing flaps. It increases keel lift to aid in tighter turns.

The Design Team optimizes our appendages for good upwind lift, low downwind drag and tight turning ability. Fortunately, the same equations describe water flowing past our appendages and air flowing past airplane wings. We start with a "seed" configuration, analyze it on Cray supercomputers using programs written by Boeing, NASA and university scientists, refine it, and analyze again. A good keel evolves from many design iterations.

As computer solutions are not fully reliable, we verify the goodness of our designs by measuring keel drag and lift in model testing at the University of Maryland wind tunnel. The proof of our design method will be the final record of *Young America*.

Winfried Feifel is an aeronautical engineer for The Boeing Company and a PACT 95 Design Team member.



▲ *PACT 95's practice boat, Spirit of Unum, lifted by a crane*

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News Explorer

As a teenager, Winfried Feifel knew he wanted to become an engineer. Search today's newspaper for all the information you can find about a career that interests you.

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Ask the Team

Q. What is *Young America*'s turning radius?

A. "Maneuverability is crucial in the America's Cup, and *Young America* can turn nearly inside her 75-foot length."

—Kevin Mahaney, *Young America* skipper

Sail Design

by Karl Kirkman

Sails are as important to *Young America* as an engine is to an Indy Car. In our sails, we need horsepower, fuel (wind) efficiency and durability.

Sails are similar to aircraft wings which have two operating modes: a high-lift, curvy shape for low-speed takeoff and landing, achieved by lowering the leading edge slats and trailing edge flaps; and a low-drag, knife-like shape for efficient high-speed cruising, achieved by retracting these slats and flaps. The first mode resembles our downwind, curvy spinnakers; the second mode resembles our upwind, flat jib and mainsail. Also, the 2-D outline of our mainsail is as important as its 3-D shape. A bird's wingtip is not sharp, but curved, and so we use battens at the top of our sail to project a curved outline.

In designing our ideal 3-D shape, we first assume a material that won't stretch under load – our imaginary "tin sail." We analyze proposed shapes in the computer, but don't usually test them in the wind tunnel: first, it's hard to trim the tiny sails exactly; second, at sea the wind velocity increases with altitude, so the tunnel's consistent wind is unrealistic.

We then test them full size. Unlike an airplane or bird wing, our real sails must flop back and forth and set the same shape on either port or starboard tack. For that, we need flexible fabrics with high strength and low stretch and weight. We test the sails in races to learn which are fastest in which conditions. Sometimes a sail might be fast not because it has the ideal shape, but because it can maintain its shape more consistently when the boat bounces.

As with the keel or hull, sail design involves leading-edge science, and also knowing when to believe, and when to doubt.

Karl Kirkman is an experimentalist at Science Applications International and a PACT 95 Design Team member.

News Explorer

Carbon fiber, Kevlar and Mylar are new materials being used to make modern sails. Search the newspaper for other objects made of these or other advanced materials.

Ask the Team

Q. What materials are in the sails, and how often do you reshape them?

A. "The upwind, highly loaded sails are carbon fiber (very strong) and Kevlar (very durable) sandwiched between layers of Mylar. Comparing daily sail photographs warns of shape changes due to stretch. This might dictate re-cutting to the target shape. Like a car, we tune up our sails regularly – about every 10 sailing hours."

...Steve Calder, PACT 95 sail designer

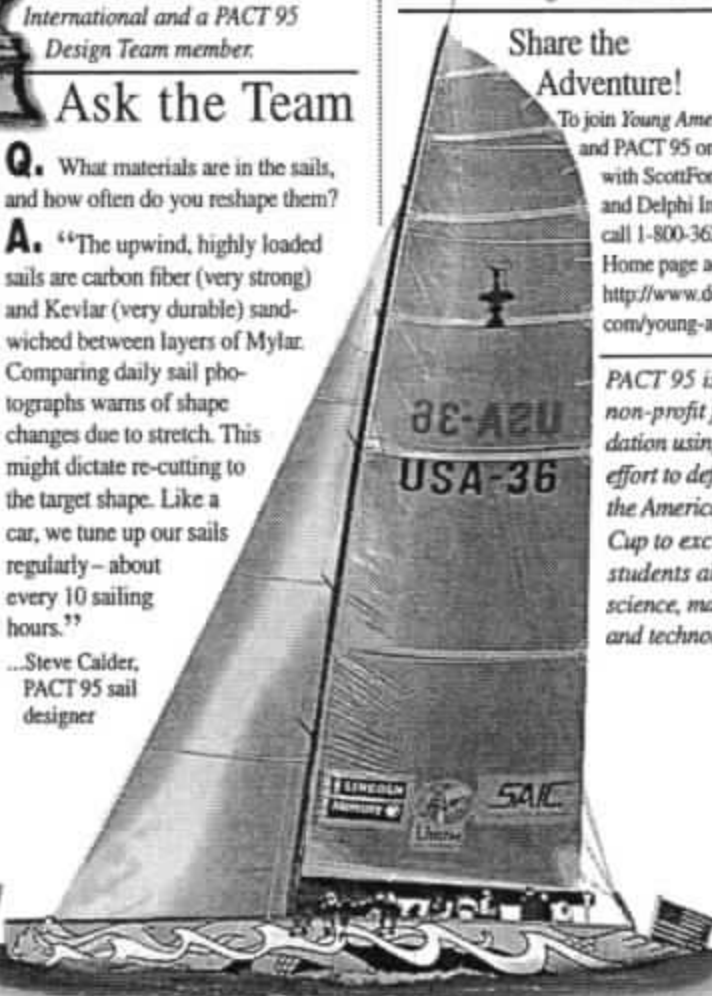

photo: Bob Grieser

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Design Trade-offs

by Bruce Nelson

As principal designer, I help to organize our research, design test models, analyze the results, and draw the final design and requisite construction plans. After launch, I work with the sailmakers and sailors to optimize performance.

We develop a "test fleet" of thousands of design concepts. Our Velocity Prediction Program (VPP) evaluates design trade-offs by quantifying a design's speed potential at each wind speed. For example, the IACC rating rule,

$$\frac{L+1.25\sqrt{S}-9.8\sqrt[3]{DSP}}{0.679} \leq 24.0,$$

balances length (L), sail area (S) and displacement (DSP) under a limit. Increasing length or sail area improves performance, so we reduce one to increase the other, or make the boat heavier in displacement to offset both.

Resistance and stability also trade off. More stability (wider hull, heavier keel) means more sail power can be applied, but a wider hull or bigger bulb increases wetted surface area, thus slowing the boat with more friction. In San Diego's light winds, stability is less needed than at a windy site like Fremantle ('87 Cup). We have tended, as others have, toward sleek, narrow (low stability, low resistance) hull forms.

Our Race Modeling Program then determines which trade-offs average out the best by simulating a nine-race series off San Diego given probable wind and wave conditions in May. This simulation's winning design is designated "the fastest," and is fine-tuned further by the VPP.

The final variable is our competitor's performance. If fast in light wind but slow in heavy wind, then tuning our boat toward light wind speed improves our probability of winning. Knowing and preparing for our competition – like a pitcher knowing a batter – is critical to winning the Cup. Time is limited, so we study hard every day!

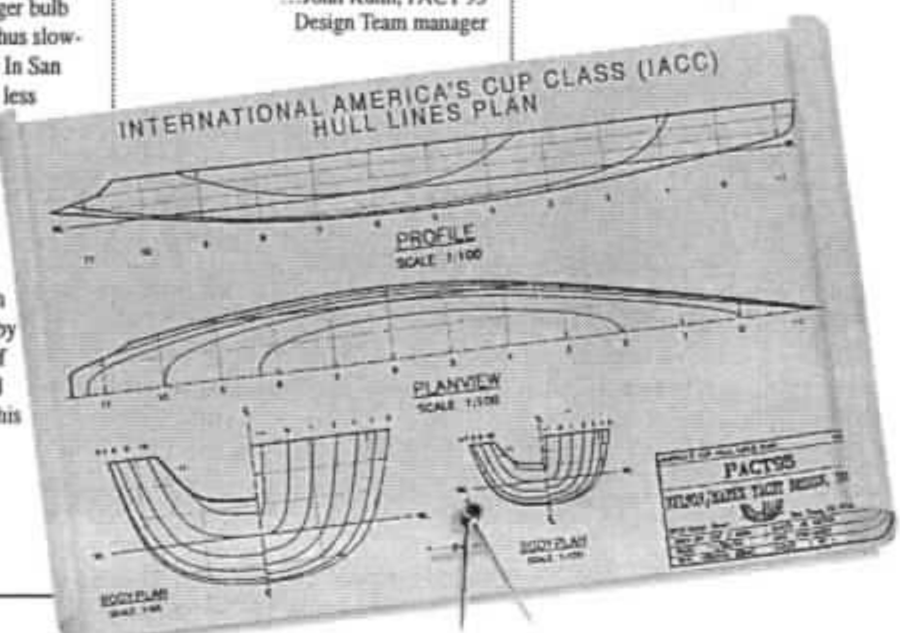
Bruce Nelson is president of Nelson/Marek Yacht Design and principal designer for the PACT 95 Design Team.

Ask the Team

Q. What was the hardest part of *Young America* to design?

A. "Most parts of the design are very challenging. Some are time pressured by the construction schedule; some cannot be changed once finalized. Together with its overall impact on performance, these issues make the hull shape the hardest part to design."

...John Kuhn, PACT 95 Design Team manager



News Explorer

The PACT 95 Design Team predicted probable May wind and wave conditions to design *Young America*. Use today's paper to predict your weather for the next seven days.

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Building *Young America*

8th in a Weekly Series of 11

photo: Billy Black

by Eric Goetz

After the designers finish, we turn their drawings into an IACC boat. Since weight vs. strength is a critical trade-off, we use carbon fiber – as strong as steel, but 1/5th the weight. We must build accurately, with no more or less material than specified. Without a prototype, we must complete the boat (one of the biggest carbon fiber "parts" in the world) in 22 weeks, and get it right the first time!

We built a sacrificial hull mold from wood, fiberglass and epoxy resin. After painting and sanding until smooth, a non-stick film was applied. The real hull structure was then layered over this mold. Thin sheets of carbon fiber fabric, pre-impregnated with epoxy resin, were laid on the mold in a prescribed pattern. A thicker core material was laid on top. Finally, 10 to 30 more carbon fiber layers completed the "sandwich."

The entire structure was wrapped in a giant plastic bag, sealed, and excess air was pumped out. This "vacuum bagging" compressed the mold-film-carbon-core-carbon layers together. The structure was then baked, curing the resin, in an 80' oven at 105° C for three hours. The mold was pried out and presto – a boat!

The deck, built on its own mold, was glued on top like a lid. Carbon fiber bracing, to support the mast and 20-ton keel, was built inside. The 75' hull measured within 1/10" of specifications and weighed little more than a Lincoln Continental!

Winches and deck fittings were bolted on. Roy Lichtenstein's seven-color mermaid was painted on the outside (no paint inside to save weight) and buffed to a high gloss. Then, *Young America* was padded, wrapped and trucked from Rhode Island to San Diego.

Eric Goetz is president of Goetz Custom Sailboats, Inc., YOUNG AMERICA's builder.

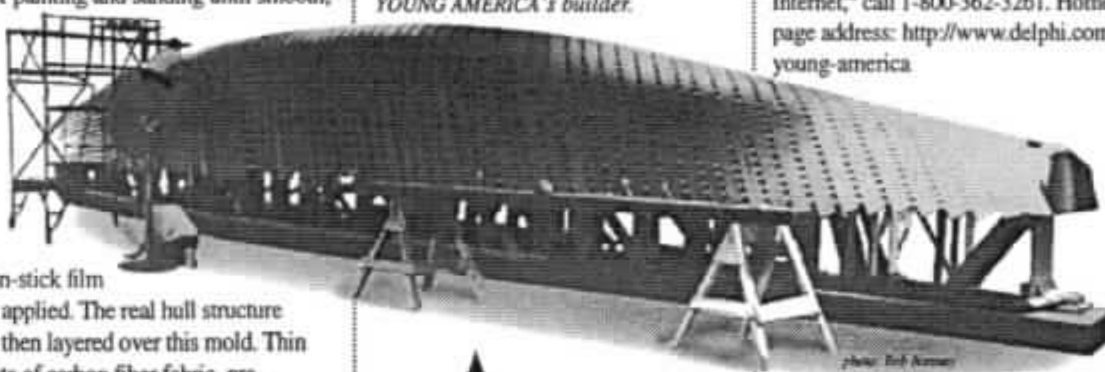

photo: Bob Barrows

▲ *Wooden frame of YOUNG AMERICA's hull mold*

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News Explorer

Search today's paper for news about manufacturing or repairing a product. What materials and technologies are being used?

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Ask the Team

Q. How do you maintain *Young America*?

A. "Starting at 5 a.m., and ending late at night after each race, specialized teams of technicians and sailors (over 40 people) inspect, overhaul, repair or replace each of *Young America*'s components: mast, rigging, hydraulics, composite structures, hull, winches, deck hardware and appendage controls."

... Kerry Geraghty, PACT 95 compound manager

photo: David J. Shuler

Maintenance at the PACT 95 compound ►

The Team

by Kevin Mahaney

Our crew's job is to sail our boat to the speed potential created by our design team. Each of 16 crew positions requires a different physique, skill and mentality. Besides world-champion sailors, we have Olympians in wrestling and rowing, and All-Americans in football and lacrosse, all fused together by intense concentration and teamwork.

The grinders control sails as big as circus tents and ropes so strained that they can rip off a hand. The bowman balances on the dancing bow and goes 100 feet aloft to clear halyards. Like a car driver, I weigh the intuitive feel of the helm against digital readouts of wind speed, direction, boat speed and heel: it's like playing a 75-foot, 55,000-pound, live video game for hours on end!

As the team works 100 hours weekly, a proper diet is essential to success. What we eat directly affects how fast *Young America* sails. If we do not fuel our bodies correctly, our physical conditioning will deteriorate and our mental acuity will become erratic. A diet and training regimen is prescribed for each crew member's physique and job.

We begin at the gym at 6 a.m. Aerobics (running, cycling, or in-line skating) are followed by training specific to our jobs. The big, powerful grinders work on strength and endurance; the small bowman works on agility and quickness; as helmsman, I have few physical demands but need stamina in concentration (I'm chided as "a brain on a stick"). With a limit on total crew weight, I do little weight training, to keep my weight low and let the grinders be bigger.

Our diverse *Young America* crew has molded itself into a potent team in the hope of challenging the world's best in defense of the America's Cup.

Kevin Mahaney is skipper aboard YOUNG AMERICA and a founder of PACT 95.

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Ask the Team

Q. How does a grinder's daily regimen compare to that of the skipper or tactician?

A. "They have very different jobs and energy requirements; a 220-lb. grinder needs more fuel (protein) for his muscles than a 175-lb. member of the afterguard.

"For strength and power, the grinders work out with heavy weights at low repetitions, while the afterguard do 'circuit training' with moderate weight and high repetitions for endurance and alertness."

. . . Diane Wall, PACT 95 physical trainer

News Explorer

Cut out pictures of, and references to, foods and food products from the newspaper and construct a collage of the basic food groups.

"Grinders"

▼

photo: David J. Shuler

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Share the Adventure!

Watch **"America's Cup: War in the Wind"** May 2 on PBS. Check local listings.

Join PACT 95 online. Home page address: http://www.delphi.com/young-america

Navigating

by Robert Hopkins, Jr.

The America's Cup race course is like a big baseball diamond: our start and finish is at home, and the turning mark is at second, three miles upwind. As navigator, I must find the quickest path up and back.

We can't sail directly into the wind, but we can zigzag at about 45 degrees to the wind. It's as if we must round first or third to get to second. When we can tack (at first or third) and head directly to the mark, we are on a layline. Yet as the wind direction changes, our boat direction changes, and therefore the laylines change. Consequently, our target zigzag points at first or third (already invisible) are always moving! Even if we and our opponent are sailing at the same speed, a wind shift will give one of us an advantage.

Since we don't want to sail extra distance by sailing past a layline, an on-board computer helps by graphically displaying our boat's position and the laylines as if drawn in the dirt. For precise calculations, we need precise data. A Global Positioning System (GPS) calculates our latitude and longitude within six feet by timing radio signals from satellites and applying "distance = rate x time." This position is fed each second to our computer. As the position changes over time, speed and direction are calculated.

It's not always obvious who's ahead or who's faster. I monitor range and bearing to our opponent with a pistol-shaped instrument containing a laser and an electronic compass. At the squeeze of a trigger, it transmits a harmless laser pulse and measures the time to reflect back from them, and records the compass bearing. The computer uses trigonometry on this data to calculate who's ahead and by how much. With enough study and effort, it should be *Young America.*

Robert Hopkins, Jr. is navigator aboard YOUNG AMERICA and a founder of PACT 95.

News Explorer

Find stories from five different countries in today's newspaper. Using an atlas, locate the capital of each country and determine its latitude and longitude.

◄ *Kevin Mahaney (left), Robert Hopkins, Jr. (center) and John Kostecki (right)*

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Ask the Team

Q. What navigational information is most useful in making tactical decisions?

A. "The most important information, derived from the laser gun, is whether we are gaining or losing compared to our competitor.

"Using the computer, Robert [Hopkins, Jr.] also gives me time and distance to each layline and to the next mark, so I know how much room we have for tactical maneuvers."

. . . John Kostecki, *Young America* tactician

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Measuring Success

by Neil Ressler

Racing has always been close to the heart of Ford. It challenges our engineers to devise and experiment with cutting-edge technologies and continually to "push the envelope" in pursuit of victory. The technology lessons learned often flow into production vehicles.

Our work with PACT 95 reflects this racing tradition, only the tarmac of Le Mans has been exchanged for the blue waters of the Pacific. It has given Ford engineers a unique opportunity to confront challenges in familiar technologies, but in new and thought-provoking ways.

By providing advanced technology support to PACT 95, Ford is gaining significant new insights into many innovative technologies, such as aerodynamics, composite materials, structural dynamics and global positioning systems. These technologies are crucial not only to PACT 95's quest to build a high-performance, lightweight, durable and competitive IACC boat, but also to advance Ford's design and production.

A determined commitment to teamwork is a prerequisite for technological success. The collaborative process, whether in designing and engineering *Young America* or a Mercury Mystique, requires maximizing each team member's contribution toward the common objective and responding quickly and positively to changing circumstances. The attainment of both defines an efficient, winning team.

Ford is looking to the future in its technology partnership with PACT 95 – a future which hopefully will see the America's Cup stay America's cup. Regardless of the outcome, the partnership has already helped Ford to build even better vehicles for our customers around the world. That's how we measure success.

Neil Ressler is Vice President of Advanced Vehicle Technology, Ford Automotive Operations, and an advisor to the PACT 95 Design Team.

Share the Adventure!

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Join PACT 95 online. Home page address: http://www.delphi.com/young-america

News Explorer

PACT 95 and Ford have both benefited from their partnership in this year's America's Cup. Search today's paper for another successful collaboration.

Ask the Team

Q. What was the most significant PACT 95 design decision?

A. "Our biggest decision was to build *Young America* without tank testing the final hull shape.

"Our Design Team has relied heavily on computer simulation for every step of the design process. And our faith in this technology is reflected in our willingness to build our only hull without ever testing it in the towing tank."

. . . John Kuhn, PACT 95 Design Team manager

Last in a Weekly Series of 11

PACT 95

YOUNG AMERICA

America's Cup Defense Team

A Newspaper in Education program produced by Ocean Challenge, Inc. and PACT 95.

PACT 95 is a non-profit foundation using its effort to defend the America's Cup to excite students about science, math and technology.

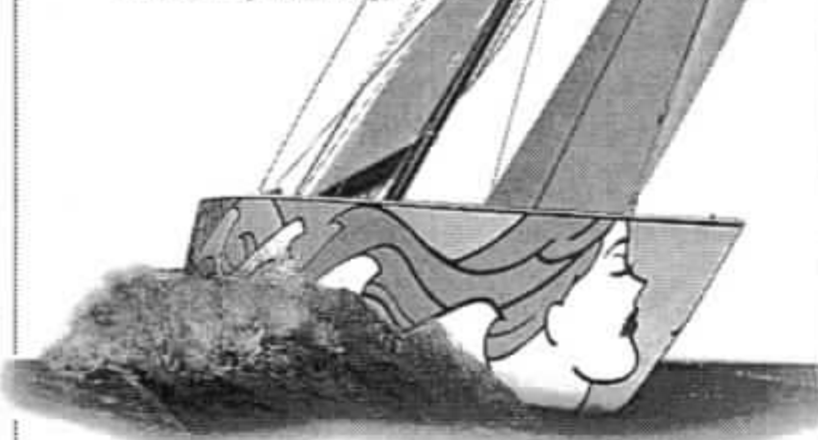

photo: David J. Shuler