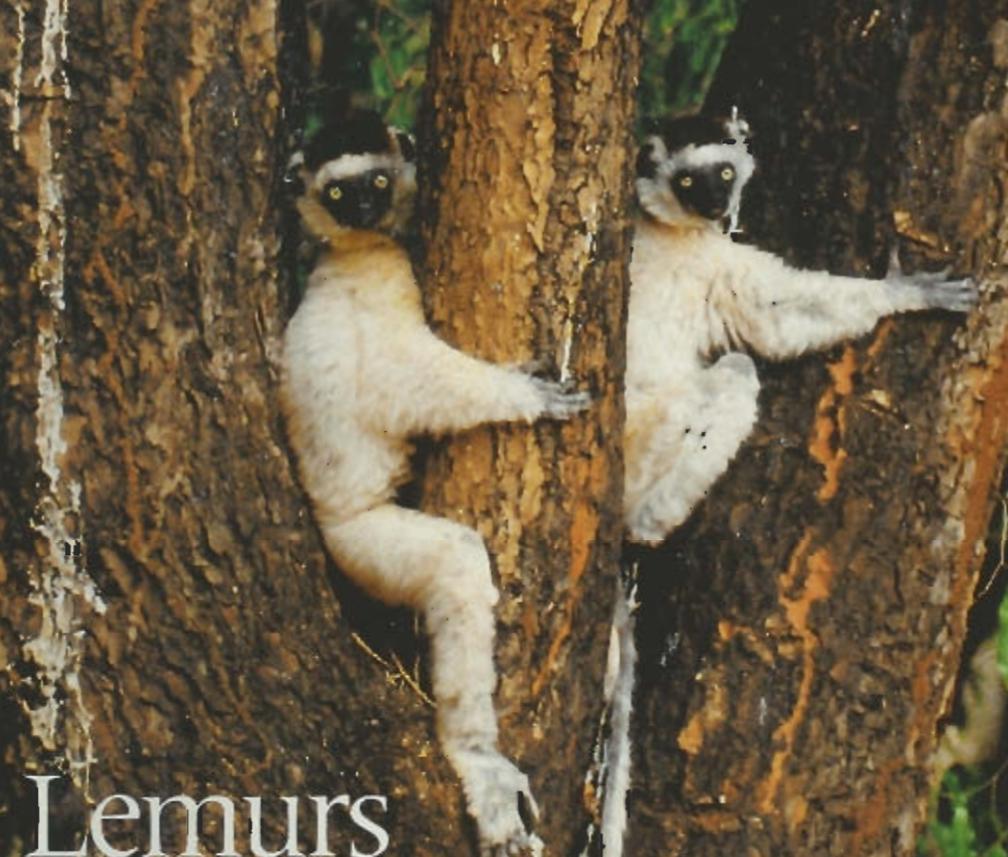


VOL. 174, NO. 2



AUGUST 1988

NATIONAL GEOGRAPHIC



Lemurs

ON THE EDGE OF SURVIVAL 132

ANNAPOLIS: CAMELOT ON THE BAY 162

TRIUMPH OF *DAEDALUS* 191

FREDERIC REMINGTON—THE MAN, THE MYTH 200

THE SOUTH KOREANS 232

KYONGJU, WHERE KOREA BEGAN 258



Triumph of *Daedalus*

By JOHN S. LANGFORD
DAEDALUS PROGRAM MANAGER

Photographs by CHARLES O'REAR WEST LIGHT

By pedal power Daedalus takes wing from Crete to the island of Santorin, 72 miles away. A Greek pilot's strong legs and Massachusetts Institute of Technology know-how combine to set a new record for long-distance, human-powered flight.



DAEDALUS! On the wings of myth he flew from the Minoan palace at Knossos in Crete, evoking wonder and awe. Though mythology is replete with flying creatures, Daedalus introduced a new dimension—man flying under his own initiative.

Thus we have given his name to a diaphanous aircraft of graphite fiber and plastic that will become one with its pilot. Perhaps the ancients, who were always combining humans with animals to create such characters as Pan and the Minotaur, would appreciate our craft—half man, half machine, each incomplete without the other.

The *Daedalus* team on Crete numbers 40, mostly faculty

members, graduates, and students from the Massachusetts Institute of Technology, where our research project was conceived and the aircraft built. Our goal is to break the distance record of 22.5 miles set over the English Channel by Bryan Allen in *Gossamer Albatross*.* But we've really set our sights for Santorin, 72 miles away.

Though some myths say Daedalus landed in far-off Italy, we chose Santorin because it is the first major landmass north of his takeoff point at Knossos. Ironically, this volcanic island that the ancients called Thera convulsively exploded in the second millennium B.C., belching a deadly cloud of ash that affected the whole Minoan world.

In the glare of automobile

lights (below) on a calm April morning at the Greek Air Force Base near Iraklion, team members ready the aircraft for flight. Offshore the support flotilla waits: a patrol boat of the Greek Navy, two coast guard cutters, two photographic boats, a command boat carrying Steve Bus-solari—an MIT professor who directs *Daedalus* flight operations—and me.

In three inflatable craft that will shadow *Daedalus* closely, students check provisions for the ride to Santorin: fuel, life-jackets, rescue gear, smoke markers, and snacks. They also check airplane disassembly kits:

*Bryan Allen described the "Winged Victory of 'Gossamer Albatross'" in the November 1979 NATIONAL GEOGRAPHIC.

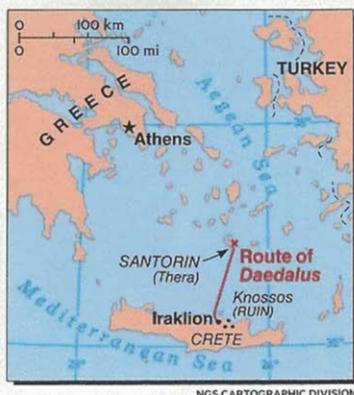


hacksaws, wire cutters, and pliers for dismantling *Daedalus* in the event of a water landing. Though we are confident of our craft, the flight is no sure thing. I give us a 50-50 chance.

As we wait, the calm gives way to a breeze that increases to more than five knots, the upper limit of wind that *Daedalus* can tolerate without risking structural failure. Reluctantly, Steve broadcasts, "Let's scrub it."

Three years of weather observations in the Aegean have taught us that, in the six-week period we have budgeted for the flight, perhaps only two days will offer the nearly calm conditions we require.

What we don't know now is that we won't awaken to one of those days for 20 mornings.

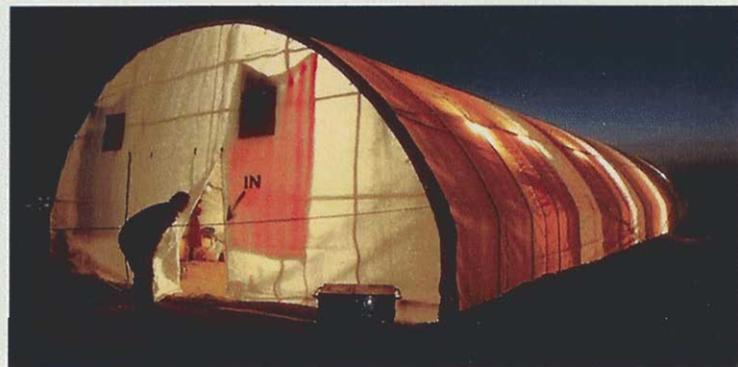


In a way *Daedalus* is the result of several years of work on human-powered aircraft by MIT students. We got airborne with *Chrysalis*, a biplane that made more than 350 flights with 45 pilots and taught us a lot about low-speed flight. With *Monarch* we won the Kremer World Speed Competition,

attaining 21 miles per hour, or, as one MIT wit observed, "Mach .03."

With a wingspan of 112 feet, *Daedalus* required a special hangar (below, top) that we shipped to Crete and anchored in concrete as protection against occasional high winds. Inside the hangar, Greek pilot Kanellos Kanellopoulos tests the plane's seat for comfort and then eases out of the fuselage pod, assisted by professor Mark Drele and student Tidhar Shalon.

When the weather turned favorable, it was Kanellos's turn in the rotation of our five pilots. During seven months of training he had bicycled more than 10,000 miles. "My legs feel good," he said before the flight. "I am ready to go."



FLEXING like a bow, the *Daedalus* wing bends in a test (below) of its graphite epoxy spars at the MIT-Lincoln Laboratory Flight Facility near Boston. As structural engineer Juan R. Cruz checks for stress, water-filled bottles simulate air loads encountered during flight. Two aircraft were built with funds donated by United Technologies Corporation and named for their year of construction, hence *Daedalus 87* and *Daedalus 88*.

Each revolution of the pedals (top right) was translated by gearboxes into one and a half revolutions of the propeller. An upper gearbox—this one from a *Daedalus* prototype (bottom right)—transmits power directly to the propeller. A technician's index finger points to a bell

crank that enables the pilot to adjust the propeller's pitch to regulate the "bite" of air it takes during flight: low pitch for power on takeoff, higher pitch for endurance during cruise.

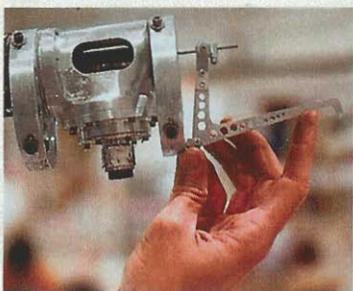
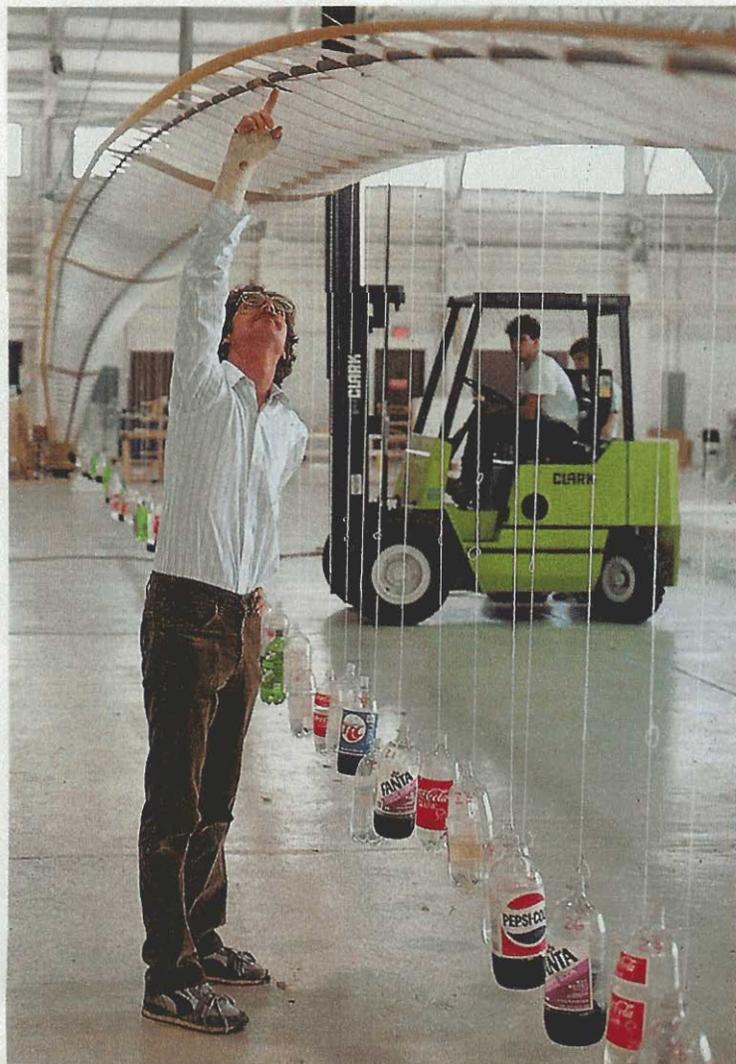
The aerodynamic design of *Daedalus* was by Mark Drela (middle right), an MIT assistant professor of aeronautics and astronautics, who uses Kevlar yarn to lash fuselage tubes made of sheets of a superlight, super-stiff graphite epoxy that are layered, shaped, and baked in an oven. The thickest graphite piece, a section of the hollow main wing spar, consists of 12 layers but is as thin as a dime.

Surely the gods smiled at *Daedalus*, in flight (right) over the Aegean between the command boat and one of the inflatables. And mortals can almost

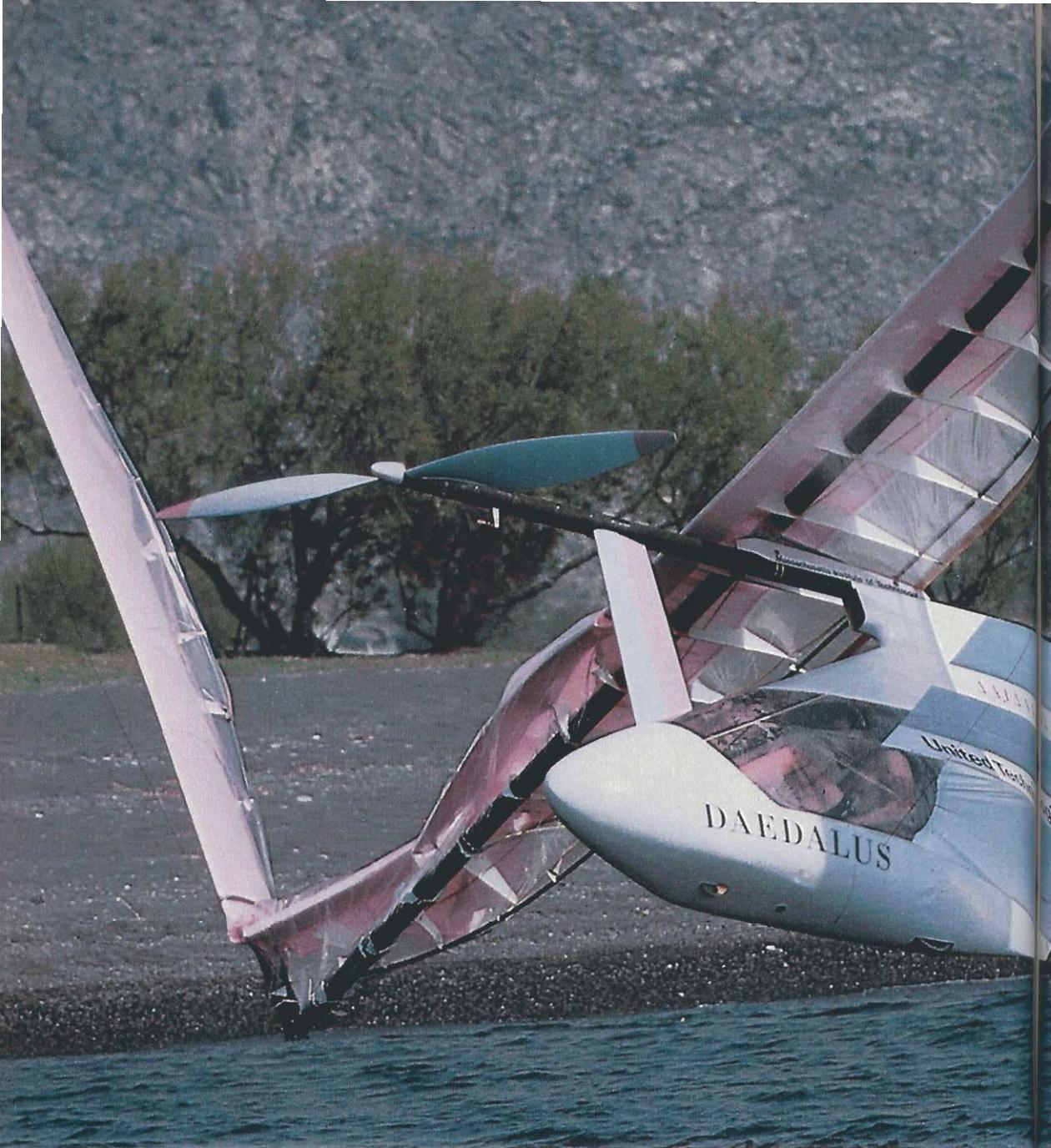
count the 102 wing ribs, each precisely cut from $\frac{3}{16}$ -inch-thick polystyrene foam. The fuselage pod is suspended beneath a 29-foot boom, which supports the 11-foot propeller turning at about 105 revolutions per minute. The airplane's skin is Mylar, a thin plastic film.

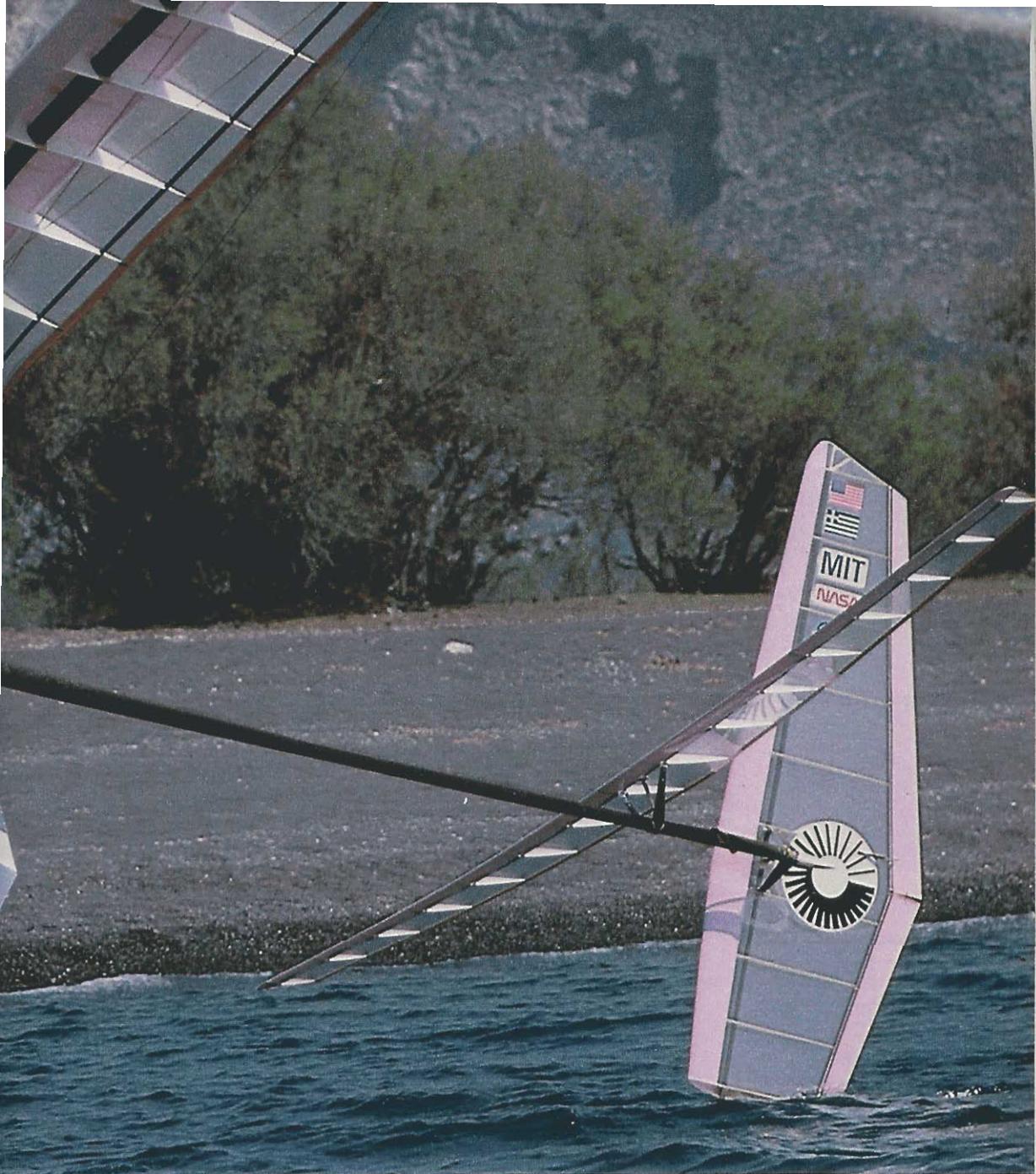
With a small control stick in his right hand, the pilot maneuvers the rudder and elevator. Except for a few metal screws, everything in the airplane has been handcrafted and meticulously screened for weight—even the glue was weighed.

Director of engineering Harold H. Youngren wagered "a roast pig" that the airplane would not come in under 70 pounds. He lost. Flight-ready, *Daedalus 88* weighed in at 68.5 pounds.









THE FIRST HINT of trouble after a flawless flight: As Kanellos turns into the wind to land on the beach at Santorin, the airplane's ground speed begins to drop until the aircraft is almost hovering. "Right rudder, right rudder," cries Steve Bussolari, hoping to slip the aircraft over to the beach.

Then a gust of wind seems to lift *Daedalus*. Kanellos hears a loud crack, and Tidhar Shalon, in an inflatable boat nearby, sees the tail twist as the graphite in the tail boom splinters just aft of the elevator.

The control stick goes limp in Kanellos's hand, and a second, sickening crack ensues as the wing spar fails on the right side.

The plane rolls slowly to the right. Impact is soft and the fuselage begins to fill with water. Instinctively Kanellos pulls his feet from the pedal stirrups and dives through the Mylar, an act he later cannot remember.

Grant Schaffner dives from an inflatable and swims to the rescue (left), but Kanellos has already surfaced with a smile.



HITTING THE BEACH at Santorin, Kanellos is escorted by, from left, student Grant Schaffner, pilot and University of Connecticut medical student Glenn Tremml, student Siegfried Zerweckh, and pilot Frank Scioscia.

Kanellos wears shorts in which he cut dozens of small holes as a joke to show the extreme measures taken to conserve weight. Chest electrodes recorded his heart rate.

Looking like a shopper at a rummage sale (top right), Tidhar Shalon helps gather the remnants of *Daedalus* for shipment back to Crete.

To power the aircraft, we searched for the world's best human engines. Ethan R. Nadel, professor of epidemiology

and physiology at the Yale University School of Medicine, joined with Steve Bussolari to devise a series of tests to measure the pilots' maximum mechanical power output and endurance, to screen pilot candidates for aerobic capacity, and to explore avenues for extending their endurance.

Glenn Tremml and Lois McCallin, a triathlete from Boston, emerged from this program to set world distance records in 1987 for men and women in *Light Eagle*, the *Daedalus* prototype.

Kanellos, cycling champion of Greece 14 times, stood out among the Greek applicants. From hundreds of others, we selected Frank, Greg Zack, and Erik Schmidt, all U. S. national-class cyclists, and

retained Glenn. The ability of these pilots to process oxygen—twice that of most people—is a gift of genes honed by years of aerobic exercise. It was nothing for them to cycle 60 to 100 miles a day in training, much of it uphill. Frank casually mentioned one evening in Crete that he had done 145 miles that day.

We had earlier determined that the energy budget for the flight would be equivalent to pedaling a racing bike at 23 miles an hour for six hours. Without glucose replacement this output would exhaust the body's reserves in three hours. Ethan, with the help of the Shaklee Corporation, developed an in-flight drink that replenishes fluids and salt and nearly doubles the amount of glucose delivered to the bloodstream by

IN ADDITION to team members already mentioned, these also played crucial roles: Mary Chiochios, Tom Clancy, Jean-Joseph Coté, Stephen Darr, Brian Duff, Steven Finberg, Jack Kerrebrock, Sarah Morris, Peter Neirinckx, Robert Parks, Claudia Ranniger, Tom Schmitter, Christine and Peggie Scott, Marc Schafer, Bryan Sullivan, Matthew Thompson, Louis Toth, Timothy Townsend, Dave Watson.

off-the-shelf drinks. With "Ethan-ol," as it was dubbed, the pilots' glucose levels were sustained for six hours.

Lean as greyhounds except for bulging thigh muscles, the pilots recycled food into energy at fantastic rates. Onlookers were amazed as they consumed up to 7,000 calories a day.

Les Wong, a Shaklee nutritionist, supervised the pilots' high-carbohydrate, low-fat diet. When he ruled Crete's nutritious but fat-rich olive oil off-limits, the Greek chefs at our hotel were astonished.

The conditioning program was put to the test when, after three weeks of cancellations due to weather, Steve announced the arrival of a high-pressure system that promised light winds, perhaps even tail winds from the south. The next morning, with Kanellos in the cockpit and everyone on station, the promise came true. A thrill of expectation surged through the flotilla as team member Dimitra Pavlou reported from Santorin, "Winds 1.4 meters per second, from the south." Steve broadcast, "The research part of this project is now officially over. Let's take off."

At first I could see only the flickering-propeller, then the thin white line of the wing across the horizon. Kanellos was airborne at 0703 local time on April 23, 1988. As he soared



over the water, he exclaimed, "It is better than perfect!"

Indeed it was. With the lead inflatable pointing the way to Santorin, the rest of the flotilla tucked in behind our airplane, translucent in the early sun. Kanellos reported an airspeed of 14 knots, while we noted a healthy tail wind. We had been prepared for failure, but were we prepared for success?

As Kanellos churned out the miles, pedaling nonstop, Steve radioed minor course corrections and prompted Kanellos to keep up his drink schedule. "Don't worry. My stomach is full," he responded.

At 0829 Steve called Kanellos: "You have now flown 23 miles, breaking the straight-line record for a human-powered airplane."

A bulky container ship angled

across our course, leaving a wake that would threaten the low-flying *Daedalus* as well as the inflatable boats. Crisp Greek commands filled the air as Capt. George Foussianis steered his patrol boat, churning a boisterous wake, directly toward the intruder. The ship altered course.

At 0952 we broke the record for time aloft and would set a new one of 3 hours, 54 minutes, and 59 seconds at Santorin. The flight also validated a highly efficient airfoil design for human-powered aircraft. And most important, our fragile low-flying plane had accumulated data that could be useful in construction of high-altitude endurance aircraft. Never mind that splash-dunk off the beach. The *Daedalus* had triumphed. □