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editorial

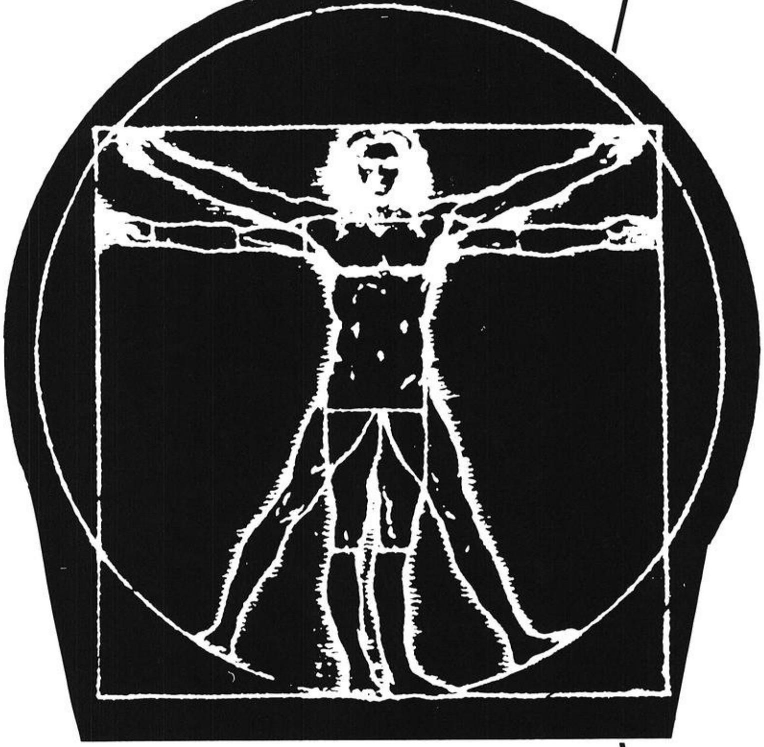
Engineering technology has modified many sports including football, skiing and parachuting. Engineering technology has also created sports such as windsurfing and computerized games.

This issue of the *Wisconsin Engineer* focuses on a few sports which have been affected by engineering. United States' athletes competing in the Lake Placid Winter Olympics have utilized University of Wisconsin engineering and biomedical research projects while training for competition. Football, one of Wisconsin's most popular spectator sports, has also been aided by developments in training and protective equipment. Articles on windsurfing, parachuting and manpowered flight show that a knowledge of aerodynamics and engineering mechanics is required in the design and use of the apparatus.

Sporting records are being broken every year. Athletes are in better condition, use more advanced equipment and are scientifically coached. Engineering plays a role in each of these aspects.

Photo by Bob Polasek

Coaching is a very important aspect of speed skating. Here Beth Heiden and Diane Holum evaluate the U.S. skaters in West Allis.



Skating on Lake Placid gold

by Bob Polasek

The U.S. Speed Skaters have attracted world attention during their recent domination of international competition. A good portion of this success has been enjoyed by Beth and Eric Heiden, who along with being World Champion skaters, are also students at the University of Wisconsin–Madison.

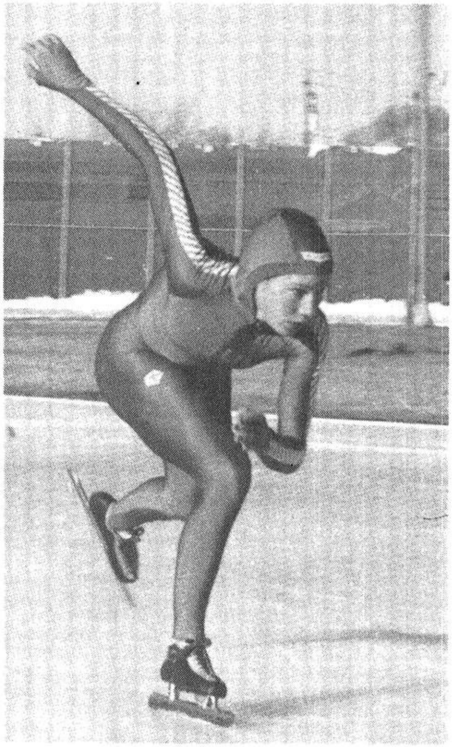
After observing the two week Olympic skating trials in West Allis, Bob Polasek, a junior in the engineering college, combined this information with a kinematic analysis of speed skating and filed this report.

When the XIII Winter Olympics are mentioned, the discussion quite often focuses on the city of Madison, Wisconsin. Although the Capitol Square's Olympic billboard labeling Madison as the "Nordic Sports Capital of the World" may be debatable, athletes from Madison and southeast Wisconsin have established themselves as top contenders for this month's Winter Olympics, especially in speed skating and hockey.

The United States' Hockey Team, led by University of Wisconsin–Madison All-Americans Mark Johnson and Bob Suter, has displayed a great deal of promise in international competition. The team, composed primarily of WCHA All-Stars, defeated the Soviet Union in a recent tournament using a strong defense and a well-organized power play offense. The team is a strong contender for the gold medal in Lake Placid.

The U.S. Speed Skating Team appears to be the strongest skating team ever. Coached by Dianne Holum, a former Olympic gold and silver medalist from Madison, and Peter Schotting, the U.S. skaters have been declared the favorite in each of the five men's and four women's events.

Photos by Bob Polasek



Beth Heiden displays her patented style of determination during the 500 meter event.

The women's team is led by Beth Heiden. Beth, a resident of Madison and a Civil Engineering major at the University of Wisconsin–Madison, won last year's World and Junior World Championships, sweeping all four events in World Competition last February and all four Junior World events in 1978. At 5'2" and 105 pounds, Beth may not be the strongest competitor, but she more than makes up for her lack of size with her intelligence, determination, and a skating style which permits her to achieve maximum efficiency with each stride. Beth is a fierce competitor who will not accept second best.

The women's team has great depth in both sprints and long distance races. Leah Poulos-Mueller, an Olympic silver medalist from Dousman, Wis., is expected to provide stiff domestic competition in the 500 and 1000-meter sprints while Mary and Sara Docter, also from Madison, have matured into contenders for the longer 1500 and 3000-meter races. Kim Kostron, Nancy Swider and Connie Paraskvin round out the women's squad.

Eric Heiden, three-time World Champion and defending Junior World Champion, leads the men's team. Eric, a premed student at the University of Wisconsin, has dominated World Speed Skating competition the last three years, winning virtually every event and setting two World and all five American speed skating records. At 6'2" and 190 pounds, Eric possesses all the strength, power, quickness and stamina necessary for both sprint and long distance competition. He utilizes an explosive start, long effortless strides, and excellent speed on turns to outdistance World competitors. Eric also has great determination as well as the ability to relax under pressure.

Peter Mueller, an Olympic gold medalist from Dousman, Dan Immerfall, an Olympic bronze medalist from Madison, and Jim Chapin should provide strong competition in the 500, 1000 and 1500-meter sprints. Milwaukeeans Mike Plant, Tom Plant and Mike Woods are expected to contend for top honors in the longer 5000 and 10,000-meter races. The team also includes Craig Kressler, Erik Henriksen and Nick Thometz.

Speed skating is a very demanding sport requiring self-discipline and training all year long. After the winter competition ends in March, the skaters rest for a period of four to six weeks before beginning a gradual spring conditioning program. As the summer progresses, the skaters begin using specific drills such as duckwalking, a leg strengthening exercise done in a squatting position with the hands clasped behind the back.

The United States Olympic Committee sponsors a two-week training session in Colorado each summer. The camp is situated at a high altitude for the purpose of building up the skaters' stamina. Olympic coaches Dianne Holum and Peter Schotting were instructors at last summer's camp, making use of drills specially designed to increase the skaters' strength and endurance. A skating simulation drill, using roller blade skates, enabled the participants to improve their stride technique.

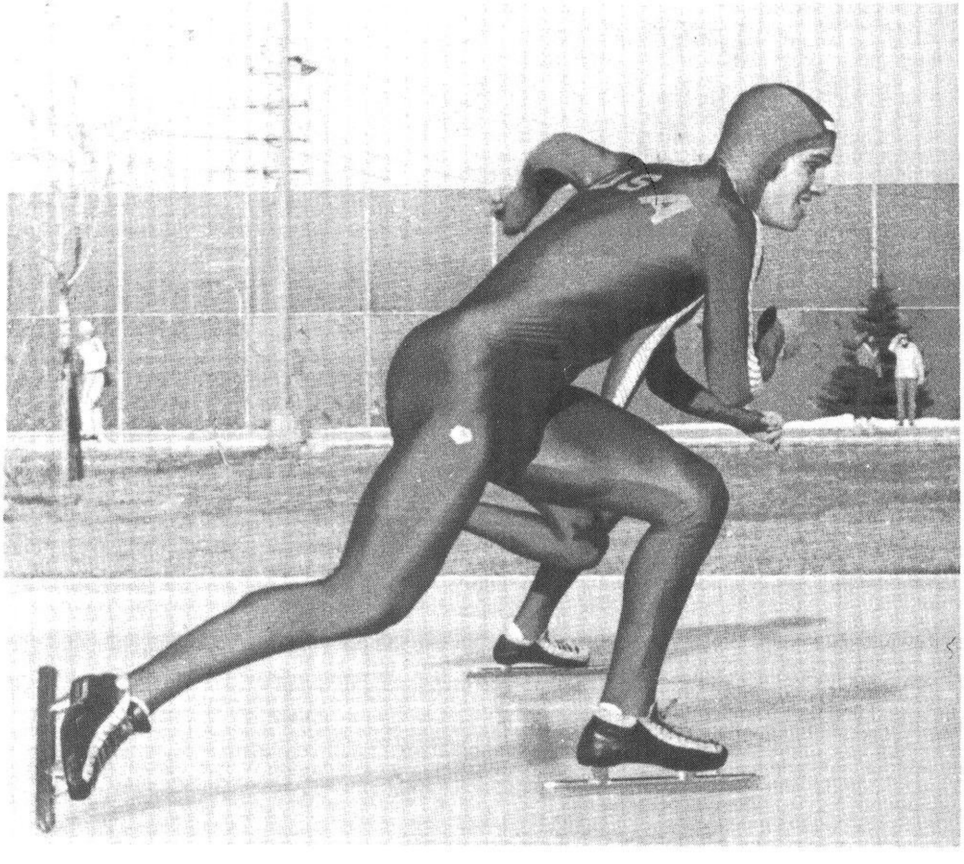
Without the use of ice rinks in the summer, the athletes compete in a wide variety of sports. Eric Heiden plays for the U.W. Soccer Team while Beth is a National Cycling Champion. The Heidens attribute much of their success to Dianne Holum, who moved to Madison following her gold medal performance in 1972. As the coach of the Madison Speed Skating Club, she has spent much of her time organizing the training program used by the Heidens.

During the early fall, the skaters train in Europe, where weather conditions permit the use of refrigerated skating rinks. The Heidens, along with Peter Mueller, Dan Immerfall and Leah Poulos-Mueller, spend a few weeks in Holland, coach Scotting's native country. Shortly after returning from Europe, the Olympic rink in West Allis is ready for use. The Heidens then travel seventy-five miles daily during the final stages of their training.

The basic equipment in speed skating is a pair of 16 to 18-inch speed skates, slightly curved near the toe, pressing down on the ice surface. This produces a layer of supercooled water between the blade and the ice. The longer blade allows the skater to spread his or her weight over more of the ice surface area, which reduces friction and increases speeds. Skin-tight, nylon uniforms reduce air resistance and allow the Olympic class skater to achieve speeds up to 35 mph. Skating efficiency is gained through perfection of fundamentals such as keeping a low center of gravity, using arms to sustain and increase momentum, and adjusting stride length and speed to individual capabilities.

A full stride requires each leg to perform both the drive and glide phases. When the right skate makes contact with the ice, the left skate is placed at a 45-degree angle with the ice and is used in a force-producing motion. The left skate then leaves the ice, allowing the skater to glide on the right skate. The same procedure is followed when the left skate again makes contact with the ice, completing the stride. Each skate contacts the ice on the outer edge of the skating blade in a *supinated (foot) position.* The skate then glides on the flat part of the blade before moving to a *pronated foot position.* The inside part of the skate is then used as a force to drive the other leg. This sequence causes a lateral deviation in the direction of the glide foot. Since each skate is used as a glide during a complete stride, the lateral deviations cancel, resulting in a net forward progression.

Research conducted by Margaret Robb Mueller at the University of Wisconsin–Madison has increased the understanding of the physical aspects of speed skating. In a Master of Science thesis entitled "Kinematics of Speed Skating", Ms. Mueller cinematographically analyzed the techniques used by two World Class



During the Olympic trials, Eric Heiden broke all five West Allis track records while preparing for the Lake Placid games.

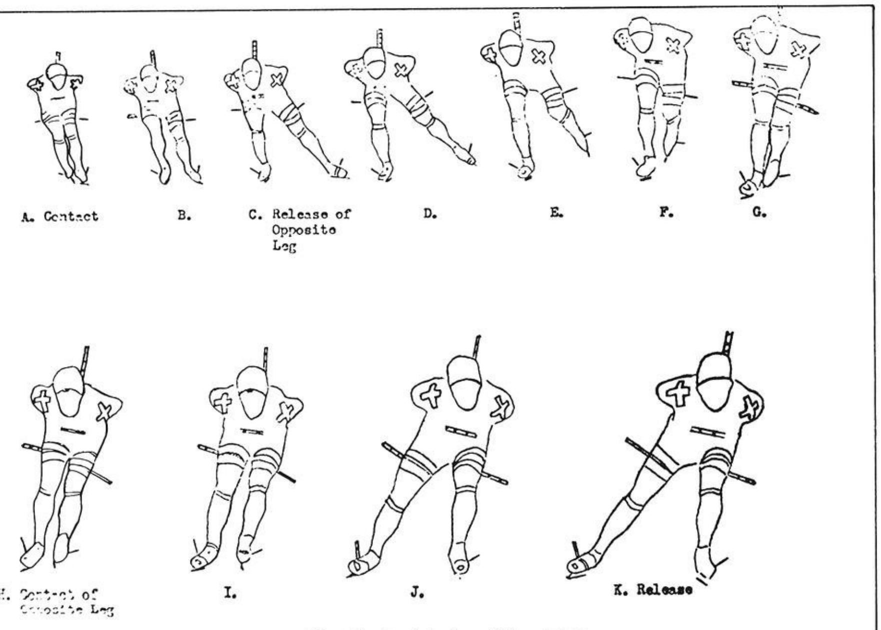


Fig. 35 Frontal view of the skater.

This excerpt from Margaret Robb Mueller's thesis "Kinematics of Speed Skating" sketches the basic motion of the skating stride.

skaters. The pacing technique, a skating position which conserves energy by resting the hands on the lower back, was used to study various leg motions. The skaters were filmed in ninety foot segments for the purpose of 1) analyzing the knee, ankle, and hip joints of the skaters' leg as well as the motion of the foot, and 2) measuring the average length, velocity, and deviation of the stride.

With the use of joint motion indicators placed near the ankle, knee and hip joints, Ms. Mueller was able to study the motion pattern of the three joints throughout the stride. The ankle joint remained stable after the drive phase and through most of the glide phase before flexing an average of 25 degrees upon completion of the glide phase. This extension was the result of the change in the drive leg. The ankle averaged a 25-degree range of motion. The ankle joint (the angle measured between the foot extension and the lower leg) tended to stabilize at a 60-degree angle during the glide phase. It then closed 5 to 7 degrees before entering the drive phase, when it opened to an angle of 80 degrees. The angular velocity varied from 325 to 525 degrees per second. Angular velocity, or the speed of joint motion, was measured to determine the quickness in joint reaction.

The knee joint also remained relatively stable after the drive phase, but then extended rapidly during the glide phase. A slight flex followed the glide phase. The knee joint then extended to a maximum as the drive phase approached. The knee joint range of motion was 65 degrees. It opened from approximately 100 degrees before the glide phase to 165 degrees prior to the drive phase. The angular velocity of the knee joint varied from 400 to 600 degrees per second.

The hip joint went into a momentary flex after the drive phase and gradually extended as the glide phase continued. When the drive phase started, the skater leaned into the stride, causing a sharp flexion of the hip joint. The range of motion for the hip joint was 45 degrees. Following the drive phase, the hip joint flexed 5 degrees to an angle of 60 degrees. It then extended to a 105-degree angle before reentering the drive phase. The angular velocity was measured to be approximately 225 degrees per second.

Ms. Mueller also analyzed the change in the inclination angles of the foot, lower leg, upper leg, and trunk resulting from the joint motion sequence. A joint extension or flexion was found to have the effect of changing the inclination of the segment directly above. Hence, if the hip joint extended, the skater's upper body would consequently increase its inclination angle. As the skater left the drive phase, the lower and upper leg segments began to straighten while the trunk leaned forward into the glide phase. These positions quickly reversed when the drive phase began. The angle of inclination of the foot increased from a flat position to an incline of 5 degrees throughout the glide phase.

The average stride length was 27 feet in length and required 1.2 seconds to complete, producing a stride velocity of 22 feet per second. A lateral deviation of 5.5 feet and a stride overlap of six feet were also discovered in the speed skating stride.

Evidence of American Speed Skating strength was recently displayed at the Olympic time trials in West Allis, Wisconsin. During the six-day trial, the U.S. men's and women's teams were selected for World, Junior World, World Sprint, and Olympic competition. West Allis track records in each of the nine events were shattered as the Heiden combination and their American teammates rapidly moved around the 400 meter refrigerated rink during ideal humid, forty-degree weather. Outstanding performances by Eric Heiden (five track records), Beth Heiden (three track records), and Leah Poulos-Mueller (500 meter track record), along with excellent showings from the remainder of the team has increased the optimism of coaches Dianne Holum and Peter Schotting as the team prepares for competition.

Regardless of the final outcome in Lake Placid, Winter Olympic viewers across the country will be proud of the competitive spirit, determination and sportsmanship displayed by the American athletes. ■

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Nordic skiing

A jump toward the winter Olympics

by Bob Polasek and Fred Best

Training and team preparation required for Olympic competition is a subject that has interested many spectators. With the assistance of the coaches of the U.S. Olympic Ski Jump team, and a valuable explanation of the U.W.'s Computerized Force Platform by Fred Best of the Space Science Department, The Wisconsin Engineer was able to assemble this insight into the training programs used by American athletes competing in the Lake Placid Winter Olympics.

Photo by Carolyn Pflasterer of Wisconsin State Journal

As any coach, athlete, or spectator would surely agree, success in Olympic competition comes from a vigorous, well-planned training program. Athletes competing in the Lake Placid Winter Olympics have spent a good portion of the last four years preparing both physically and mentally for this month's competition. The conditioning program used by the U.S. Ski Jump Team is of particular interest to Wisconsin sports fans.

Ski jumping is a sport where the skier travels down a slide 83 meters long and 70 or 90 meters high. The end of the slide forms a 33-degree angle with the level base of the hill. When the skier nears the end of the slide, he crouches into a low body position, preparing for an instantaneous push-off at the precise end of the slide. The skier then leans forward into the jump, maintaining a constant air speed and good balance. Both distance and form are judged in this event.

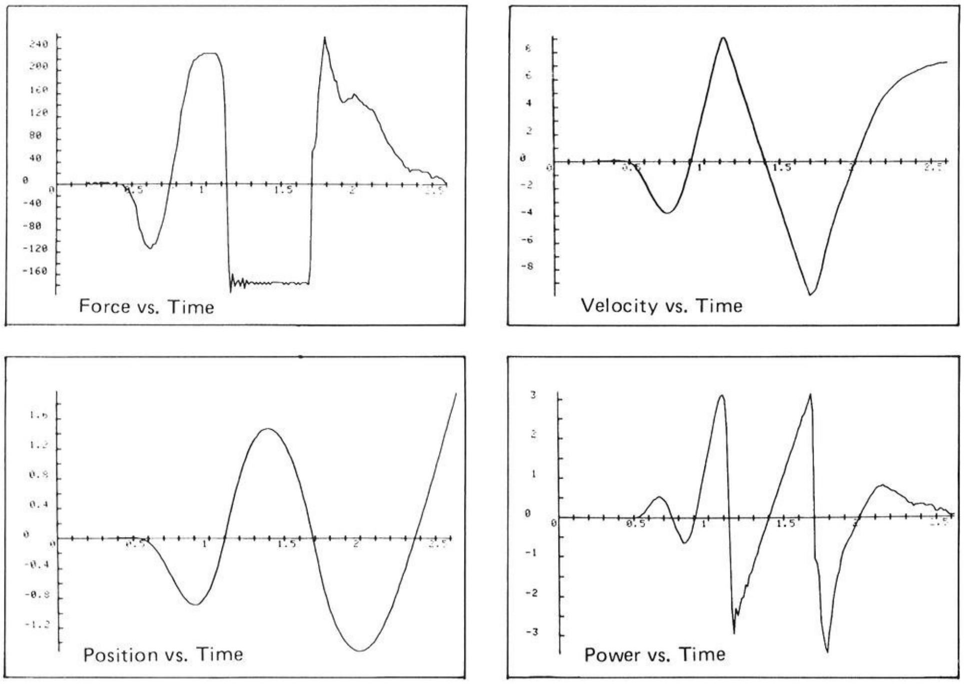
This sport requires strong legs and a well-timed jumping technique. Training includes weight-lifting and gymnastic exercises which strengthen leg muscles, agility coordination drills to improve balance and air sensitivity, speed training to improve reflexes and a great deal of ski jump practice.

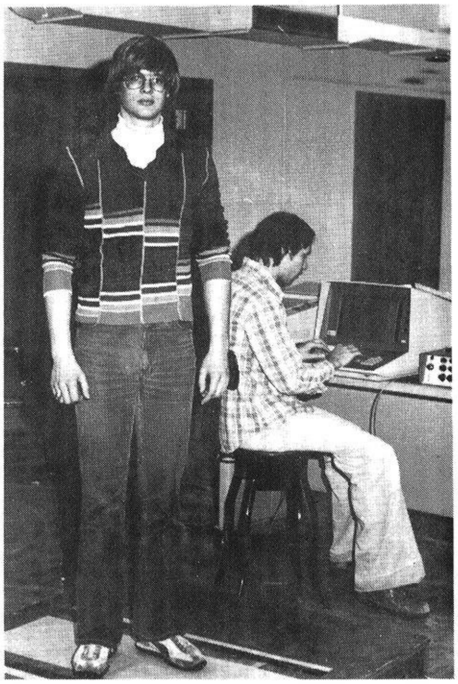
U.S. Olympic Ski Jump coach Glen Kotlarek includes frequent practice sessions at the Blackhawk Ski Jump, just outside of Madison. The team also makes use of the Computerized Force Platform System (CFP), located in the Dynamics Laboratory on the University of Wisconsin–Madison engineering campus. The CFP System, developed in 1977 by engineering mechanics students Fred Best and Brad Boyce, has provided a quantitative evaluation of the progress made during the team's training program.

The CFP System was built for the purpose of studying the nature of the forces generated during various leg motions. The system consists of an instrumented two foot by one meter jumping surface (force platform) which is connected to a Tektronix 4051 microcomputer via an analog-to-digital converter. The force platform employs electric resistance strain gauges, providing an analog voltage proportional to the force applied to the jumping surface. The analog-to-digital converter digitizes the signal from the force platform. This information is then stored sequentially in the Tektronix 4051.

With the force vs. time data of the jump in memory, the computer calculates the velocity of the jumper's center of mass vs. time by performing a numerical integration of the jumper's impulse divided by his mass. The third integration yields

Photo by Dean Kanelos





The U.W.'s computerized force platform (far right) has assisted the U.S. Olympic Ski Jumpers with their training. The system analyzes the force impact of the jump and produces graphs of force, velocity, position and power vs. time (above).

the displacement vs. time curve of the jump. The power vs. time of the jump is then computed by taking the product of the force and velocity graphs. After a jump onto the platform has been completed, hard copies of the force, velocity, displacement and power graphs are all plotted vs. time.

Having all the important mechanics perameters available instantly makes the CFP System a very useful instrument for analyzing human jumping motions. The system also has seven additional channels of data which can be sampled along with the force imput of the jump. This feature has been used by UW graduate students Paul Veers and Gene Masters to correlate electrical activities in the leg muscles during the jump.

The CFP System was demonstrated at the 1977 UW Engineering Expo. Dr. William Clancy, Director of UW Sports Medicine, noticed this system and began using it for athletic injury rehabilitation programs. Dr. Clancy selected one of his patients, who was recovering from knee surgery, to test this instrument by jumping on the force platform one leg at a time. He discovered that meaningful, quantitative data could be extracted from the CFP System, aiding in the athlete's recovery.

Dr. Clancy invited the U.S. Olympic Ski Jumping Team to test their jumping abilities on the CFP System. Biomechanics experts associated with the team found that short reaction time (the time spent while pushing off of the ski jump surface) was an important parameter in correlating force platform data with actual ski jumping performance. With slight modifications to the computer program used in the CFP System, the designers made reaction time data and other performance correlation factors available to the Olympic team.

Further experimentation with the CFP System indicated that training techniques had increased the team's jumping ability. This assessment was confirmed when the team resumed practice at the Blackhawk Ski Jump.

The correlation between the results of the CFP System and the actual performance of the ski jumpers is important to the U.S. Olympic Ski Jumping Team. During the off-season, when the team members do not have access to an artificial hill, they are able to quantify the progress of their training program by using the CFP System. The system is also helpful to coaches, since it indicates the jumping ability of each skier. While planning ahead to the 1984 Winter Olympics, the Ski Jumping team has asked Brad Boyce and Fred Best to continue developing this system for further use in training evaluation.

The future possibilities for the CFP System are unlimited. Ninety percent of the data which the system displays has yet to be utilized. Such parameters as velocity, displacement, and power may help biomechanics researchers better understand and improve jumping skills. The use of the CFP System for quantitative evaluation of rehabilitation and athletic ability is an area of biomedical research that is virtually untapped. In future years additional research and development of the Computerized Force Platform System will increase its value to many athletic organizations. This, along with continued training and determination by top amateur athletes, should enable the U.S. Olympic teams to continue the success that they have enjoyed.

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Windsurfing

Sailing on the edge

by David Shiff

David Shiff is a senior in Mechanical Engineering. He is an avid sailor and windsurfer. He has fourteen years of sailing experience, which includes racing a variety of one-design and offshore yachts ranging from two-ton ocean racers to lasers and 470's.

Windsurfer® is the registered trademark name used by Windsurfing International, Incorporated, for its "free-sail system". It was invented by its founders, Hayle Schwertzer and Jim Doeke in 1967. The sport of windsurfing has taken Europe by storm and the excitement has recently began to grow in the U.S. Between 1973 and 1977, more than 100,000 free-sail systems were sold, and the number has more than doubled in each successive year.

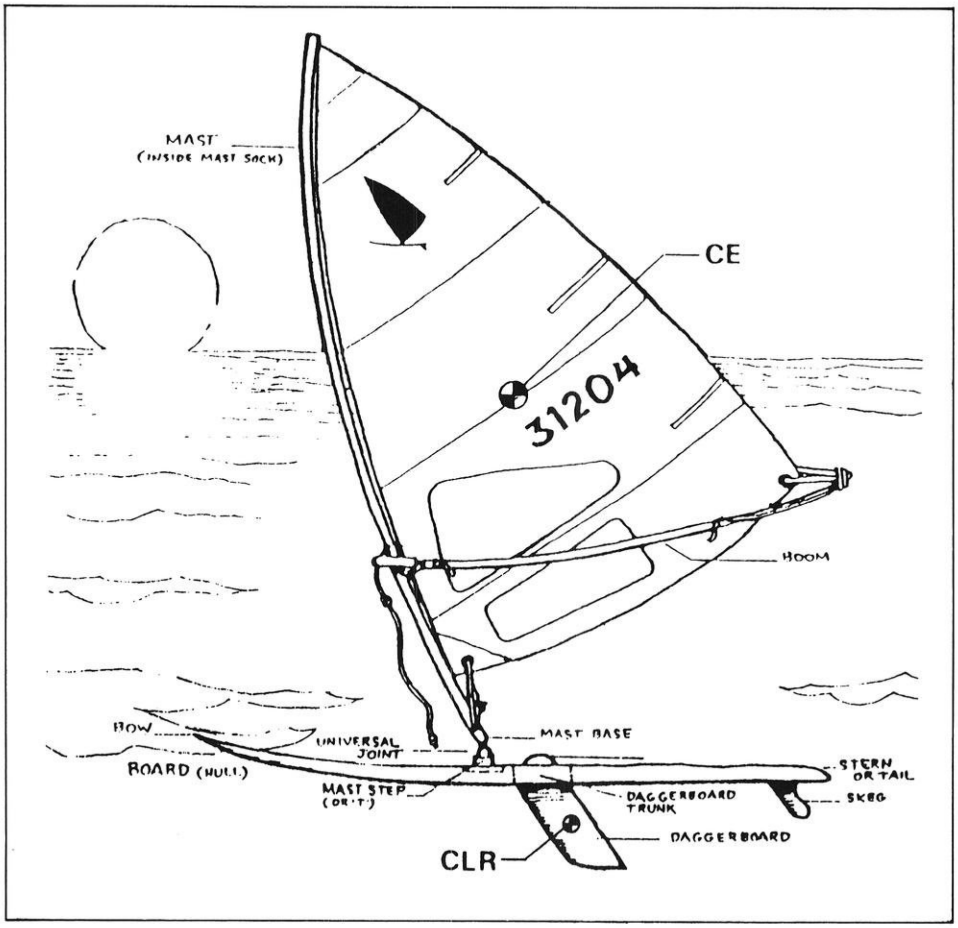


Figure 1. Anatomy of a windsurfer. Also shown is the location of the center of effort (CE) and center of lateral resistance (CLR).

Windsurfing is to sailboats as hangliders are to airplanes. It is something unique, a vehicle for getting you out there—to the edge. It is designed to emphasize the human aspect. On a Windsurfer the line between being a human being and a sailboat becomes very fine. The equipment is minimal; there is a sail, a planing surface, and you.

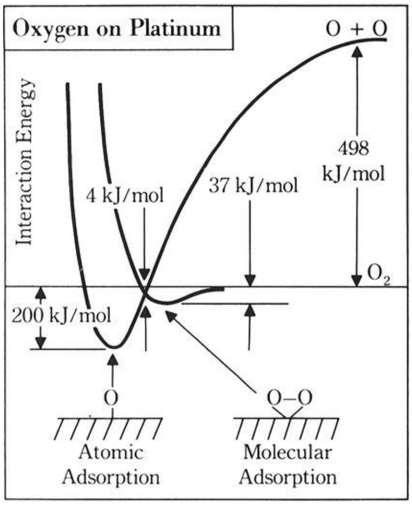
The Windsurfer is built for speed. It has a planing hull (it is *not* a surfboard— and is twelve feet in length and two feet in beam. It consists of a foam-injected polyethylene shell (the same material as a frisbee) whose surfboard shape is broken by a daggerboard trunk, centered fore and aft, and a four-inch deep mast step in the deck, just forward of the trunk. It also has a skeg at the tail.

The tapered fiberglass mast is mounted on a T-shaped insert by means of a simple universal swivel. A pair of laminated teak wishbone booms are lashed about a third of the way up the mast. The fifty-six square foot sail is slipped over the mast by means of a luff sleeve on the forward edge of the sail. The Windsurfer is ready for sailing when the mast-T is pressed into the deck step and the daggerboard is slipped into its trunk.

What could be simpler? Well, if you've followed carefully to this point, you may have noticed that the Windsurfer lacks two basic features common to all sailboats: 1) there is no rudder and 2) the mast is totally unsupported. These two features are what sets windsurfing apart from traditional sailing. These attributes, combined with the remarkable light weight of the Windsurfer, give it its amazing performance and limitless versatility to sail not only forward at hair-raising speeds but also backwards, on its edge, and in almost any other direction or style one chooses! The same

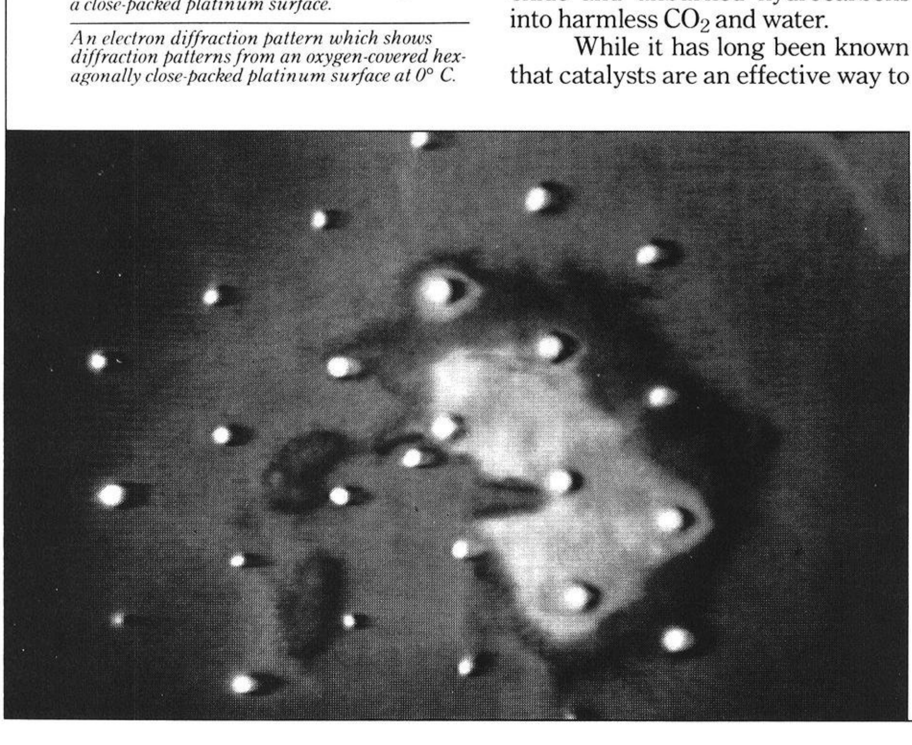
The Atomic Arrangement

In a recent experiment, scientists at the General Motors Research Laboratories studied changes in chemical bonding during the dissociation of oxygen molecules on platinum. Preliminary surface work has explored an interesting new phenomenon: the mechanism of oxygen dissociation over a wide range of temperatures.



A simplified schematic illustrating the reaction potential energy surface for oxygen-adsorption on a close-packed platinum surface.

An electron diffraction pattern which shows diffraction patterns from an oxygen-covered hexagonally close-packed platinum surface at 0° C.



UNDER what conditions will oxygen molecules dissociate into single atoms on a platinum surface? What is the mechanism for oxygen dissociation? Those are the kinds of questions that Dr. John Gland and his colleagues at the General Motors Research Laboratories are investigating to get a better understanding of the chemistry behind catalysis.

Their work has valuable practical implications for the automotive field, where catalysis is used to remove harmful emissions from automobile exhaust. Most cars built in the U.S. use catalytic converters filled with beads containing platinum to chemically transform carbon monoxide and unburned hydrocarbons into harmless CO_2 and water.

While it has long been known that catalysts are an effective way to convert these gases, little is known about precisely why and in what order the basic atomic reactions occur.

In seeking answers to these questions, surface chemists study the elemental composition and geometric arrangement of atoms in the first few atomic layers of the surface and the means by which atoms and molecules from the gas phase bond to the surface.

In his most recent work, Dr. Gland has been studying the adsorption and desorption of oxygen on platinum single-crystal surfaces. This is important because oxygen is the agent that must be adsorbed on the surface to react with carbon monoxide and hydrocarbons to convert them to CO_2.

The experiments were conducted in a stainless steel ultrahigh vacuum system equipped with an electron energy analyzer and a mass spectrometer. The electron energy analyzer allows one to measure the concentration and character of the oxygen adsorbed on the platinum surface. The mass spectrometer is used to measure the desorption of O_2 as the platinum surface is heated. Mathematical analysis of the desorption process allows one to characterize the chemical bond between the oxygen and the platinum surface.

In these experiments, the platinum surface is covered with oxygen at the extremely low temperature of −179°C (almost the temperature of liquid nitrogen) by exposing it to gaseous O_2 molecules. The oxygen remaining in the gas phase is pumped away, and then the desorption of oxygen from the surface is observed as the platinum crystal is gradually heated to 1000°C.

The oxygen was found to desorb from the surface in two distinctly different temperature regimes—part at −125°C and the rest at about 425°C. By using the oxygen-18 isotope, it was established that the low temperature desorption represents oxygen that was adsorbed on the surface in a molecular form while the higher temperature desorption corresponds to oxygen adsorbed in the atomic form. From an analysis of the desorption process, it was possible to establish the complete energetics. Oxygen molecules from the gas phase strike the surface and are weakly bound (37 kJ/mol). The adsorbed oxygen molecule can either desorb into the gas phase (37 kJ/mol) or dissociate into atoms (33 kJ/mol). The atoms are bonded very strongly (200 kJ/mol) to the surface.

FROM the desorption analysis, it was also possible to deduce the mechanism for the dissociation process. The interesting conclusion that results is that the formation of O atoms on platinum is a two-step process—oxygen is adsorbed in a molecular state and then dissociates to form atoms.

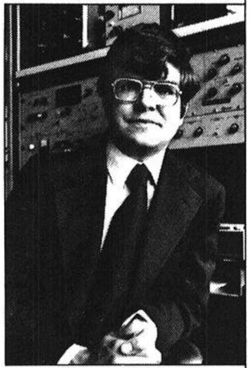
The GM scientists were most interested in learning how this adsorbed molecular species is bonded to the platinum surface. Fortunately, another technique was available to determine the bonding. The technique is called electron energy-loss spectroscopy and is quite new—there are only six or seven such instruments in the world. The measurements not only confirmed the existence of the adsorbed molecular oxygen but showed that it was bound by the transfer of two electrons from the platinum surface into the antibonding π_g orbitals of oxygen. "This was most exciting" said Dr. Gland, "because this is the first time that this type of oxygen bond has been observed on a metal surface.

"We're getting closer and closer to a more specific understanding of catalysis," says Dr. Gland. "The more we learn about simple chemical systems, the better we'll be able to control more complicated systems. That has excellent implications for protecting the environment."

THE MAN BEHIND THE WORK

Dr. John Gland, 32 years old, is a Senior Research Scientist in surface chemistry at the General Motors Research Laboratories. He heads a group of 7 investigators, 4 with Ph.D.s, all involved in work relating to the basic surface chemistry of catalysis.

A graduate of Whittenberg University in Ohio, Dr. Gland received his Ph.D. in physical chemistry at the University of California, Berkeley, in 1973 and joined the General Motors staff that year.



Dr. Gland comments: "I came to GM Labs because I wanted to get in on the ground floor of an exciting new field. The atmosphere here is very open, with lots of cross-pollination among departments. With several hundred people with Ph.D.s here, we've got a lot of human resources to draw on in all the basic sciences.

"Typically, management defines a broad problem, then we're free to tackle the solution in any way we choose. They give us the freedom, equipment and support to get the job done correctly."

In addition to his research, Dr. Gland enjoys backpacking in Wyoming and in the Sierra Nevada Mountains in California.

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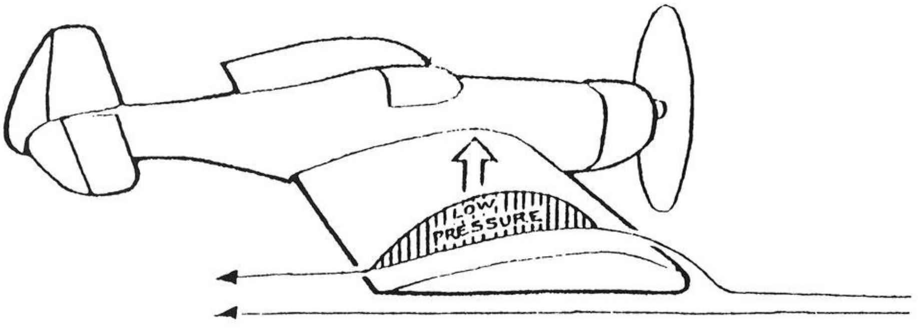

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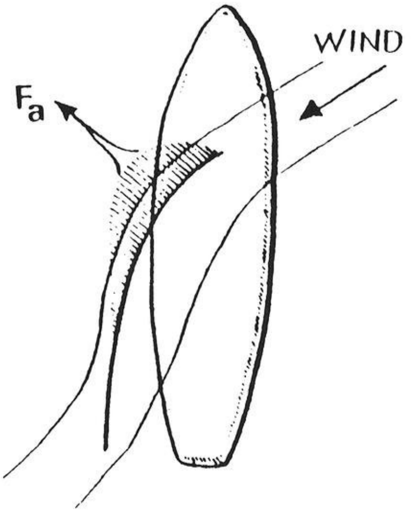
Figure 2a. Cross-sectional view of airplane wing showing low pressure region.



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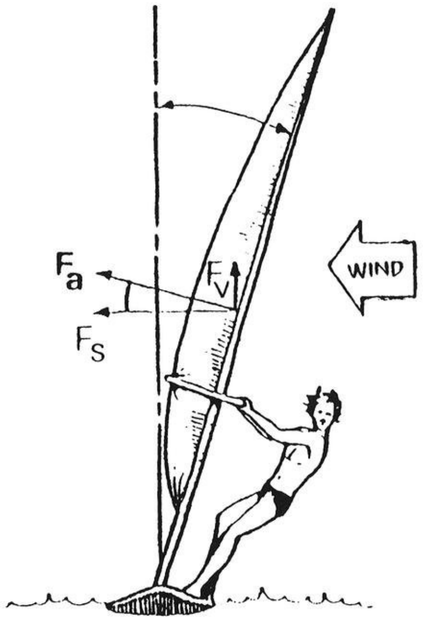


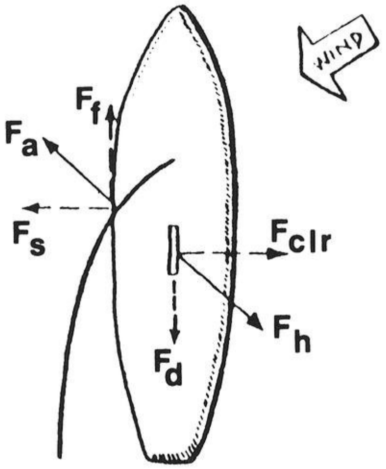
3

Figure 2b. Cross-sectional view of sail. Note the similarity to an airplane wing.

Figure 3. Front view of a Windsurfer, showing the aerodynamic force which acts on the soil.

Figure 4. Top view of a Windsurfer showing the aerodynamic and hydrodynamic forces which act on the sail and daggar board.

Figure 5. Effect of mast position on forward motion of the Windsurfer.



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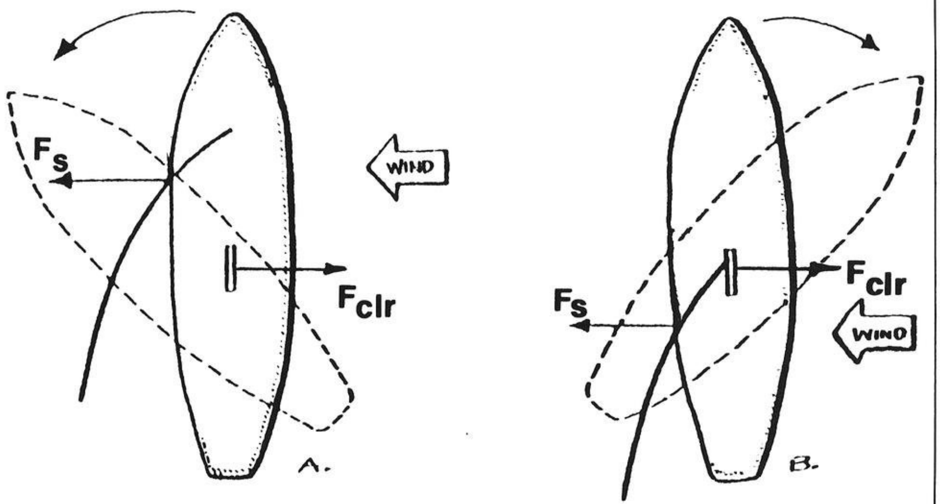

5

features, however, can cause a novice windsurfer to experience hours of frustration while trying to master this sport.

In the absence of a rudder, the board must be steered by adjusting the position of the mast while sailing. Since there is no external means of support, you must hold the mast up yourself. Therein lies the challenge of windsurfing: to keep the rig up and be able to use it to guide the board over the water at will, without being blown off the board! Although there is no substitute for practice, a thorough understanding of how a Windsurfer is sailed and steered, in terms of the forces acting on it by the wind and water, can minimize the learning time for a novice. Practice can also help a seasoned pro achieve maximum performance and responsiveness from his board.

To begin with, consider the forces acting on the sail. Viewed in a horizontal cross-section, the sail looks just like an airplane wing. Not surprisingly, it performs in much the same way. The difference in air velocity flowing over the two sides of the sail creates a low pressure region on the leeward side of the sail (the side opposite of where the wind is coming from). This low pressure results in a net force acting normal to the surface of the sail. For analysis purposes, the total force can be considered to be acting at a single point, roughly in the middle of the sail, called the center of effort (CE). Vector F in figure 26 represents this aerodynamic force acting on the sail.

Figure 3 shows the aerodynamic force F_a and its two components which act in the lateral plane, the side force F_s, and the vertical force F_v. It is the side force with which the novice windsurfer has the greatest difficulty.

As the wind velocity increases, the magnitude of F_s will increase proportionately. Eventually, the magnitude of the side force will exceed the limit of your arms and shoulders! The only recourse is to somehow reduce the magnitude of F_s. This is accomplished by leaning the sail more towards the wind ("to windward"). As this is done, F_s will become smaller and F_v will become larger. As you lean back, your body weight, which acts through your center of gravity, will assist in supporting the sail, thus reducing some of the strain in your muscles; and since the side force is reduced, there is less tendency for you to get pulled over. In addition, the vertical force, F_v, reduces the effective down force which your body presents on the board by virtue of its weight. This allows the board to plane easily, and hence attain very high speed, even in a moderate wind.

Although the concept is simple, the challenge comes when you must instantly respond to changing wind conditions, since you are constantly riding on the edge of a very sensitive equilibrium of forces. Failure to make the proper adjustment quickly enough results in either an embarrassing fall backwards or a swift whisk off your feet towards the sail! Either way it is perfectly safe, albeit a bit frustrating. Only quick reflexes, a sharp eye for the wind, and a lot of practice will reduce the frequency of falls.

Assuming that you successfully resist the side force and are up and going, it follows that there is a resultant force acting on the board itself which is causing the forward motion of your Windsurfer. Figure 4 shows a top view of the board with the aerodynamic and hydrodynamic forces labeled. In this plane, the aerodynamic force F_a, can be broken up into a component acting in the direction of motion, F_f, and one perpendicular to this direction, F_s.

Clearly, the side force, F_s, must be resisted in order to keep the board from sliding sideways. The dagger board is designed specifically to prohibit sideways motion. It presents approximately three square feet for the water to act on. Again, for analysis, the hydrodynamic force of the water can be considered to be acting at a single centralized point on the surface of the dagger board. This point is referred to as the center of lateral resistance, (CLR). This force is represented by vector F_{CLR} in figure 4. In addition, the water flow around the daggerboard causes a drag force opposing the direction of motion, shown as vector F_d. The difference between F_f and F_d is the net force which acts to propel the board forward.

With the aerodynamic and hydrodynamic forces now clearly defined, the matter of steering a Windsurfer becomes simple. Referring to figure 5a, the sail is positioned such that the center of effort (CE) is ahead of the center of lateral resistance (CLR). With the sail in this position, force F_s will cause a moment about the center of lateral resistance such that it will tend to turn the board downwind (counterclockwise in the figure). Conversely, in figure 5b, where the sail is positioned such that the center of effort is aft of the center of lateral resistance, the board will tend to rotate into the wind. Obviously, if the mast and sail are held in a position in which F_s is perfectly in-line with F_{CLR}, there will be no net moment and the board will travel straight. This is the secret to steering a Windsurfer; simply adjusting the sail so that the center of effort is in the proper relative position to the center of lateral resistance, thus causing the board to go where you want.

In the most general terms, the mechanics of Windsurfing requires you to continuously balance aerodynamic and hydrodynamic forces in order to maintain equilibrium. There is a whole array of more complex matters which effect the operation and performance of your board, such as the effect of sail trim and adjustment, mast bend and daggerboard type and setting. In any case you must constantly use all of your senses to monitor the changing effects of the wind and waves on your Windsurfer. Understanding how the wind and water act on you and your Windsurfer will minimize the time necessary to learn how to windsurf and help you to get the maximum performance out of your board. Windsurfing is an exciting sport offering the joys of personal challenge to both novice and expert.■

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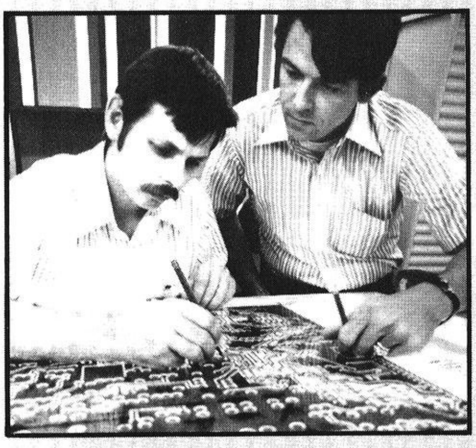

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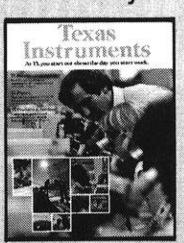

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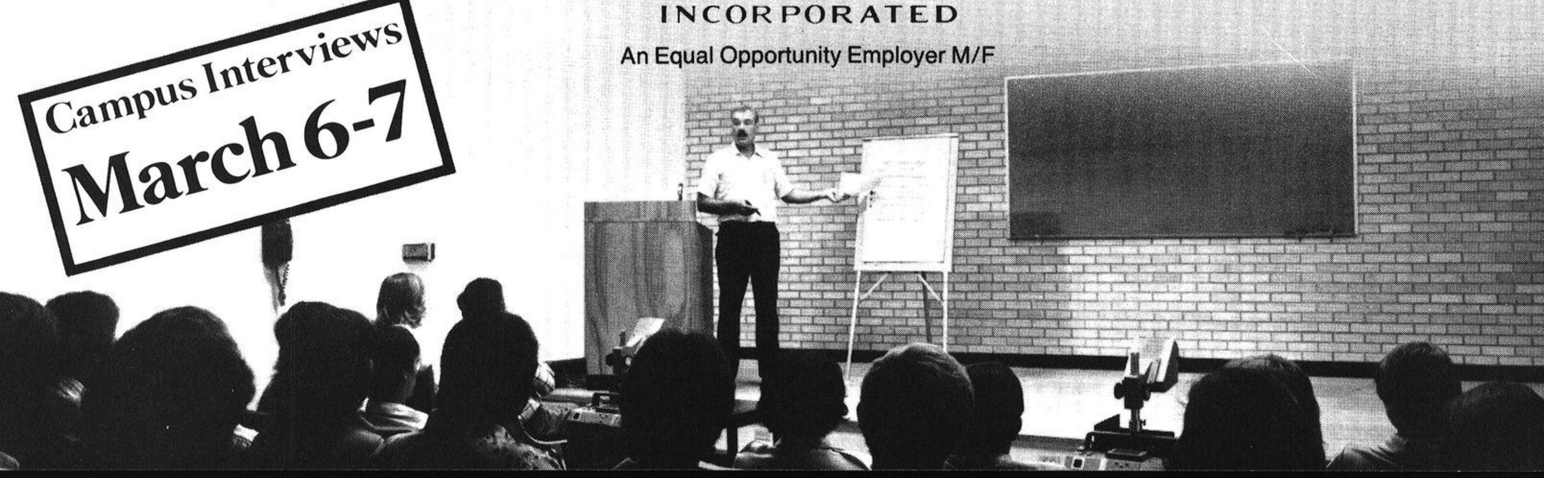


Micromouse mania

by Kathy Howard

Kathy Howard is a graduate student at the University of Wisconsin studying electrical and computer engineering. She was a member of Professor Willis Tompkins' Microprocessor Applications class when the micromouse was built.

The air was filled with expectation. The amazing Micromouse contest, sponsored by the Institute of Electrical and Electronic Engineers (IEEE), was beginning at the National Computer Conference in New York City. Six thousand entries from across the United States arrived at the headquarters of *Spectrum* magazine, the monthly publication of the IEEE.

The challenge was to design and construct an electronic mouse possessing artificial intelligence and a microprocessing computer. The mouse was required to work its way through a foreign maze while recording mistakes, correcting them along the way. Awards would be presented to the engineers of a micromouse capable of completing the course.

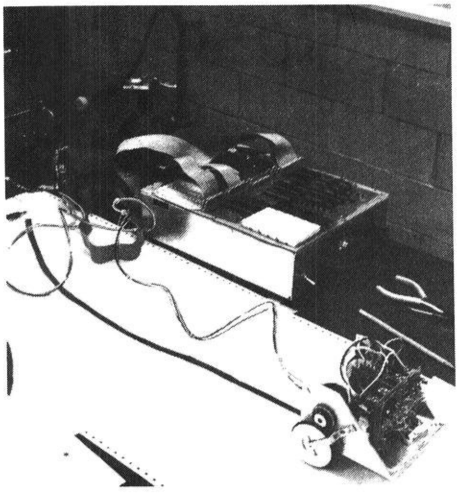
The University of Wisconsin–Madison has its own brand of micromouse technology. The Electrical and Computer Engineering Department offers a microprocessor design course that features the micromouse as one of its projects. ECE students Chung Ming Ching, Eric Chan, Sanjay Dyer, Yannis Pandelidis and Terry Hinderman combined their ingenuity in building the UW's microprocessing device.

The UW micromouse propels itself on a sheet of white paper in search of a black line. When it encounters this line, the mouse turns in a right circular motion, attempting to discover the direction of the line. It then follows the line to the end, rotates 180 degrees, and follows the same line back. The micromouse can also travel in a closed loop, making the decision of whether to turn right or left. Its memory bank stores all information for the purpose of altering its direction and solving the maze in future attempts.

The micromouse is powered by two stepping motors, driving two sets of gears and wheels. Each motor is controlled separately, enabling the mouse to rotate about a point while avoiding lateral movement by directing one motor forward and the other backward. A free pivoting third wheel in the front is used for support. Four light sensors are located on the underside of the mouse for the purpose of detecting the black line. The mouse is controlled by an Intel 8085A microprocessor on a SDK-85 kit. The microprocessor is connected to a power supply and to the kit through a bundle of wires disguised as the tail of the mouse.

The mouse uses the light sensors to detect the decrease in reflection caused by the presence of the black line. Four sensors are situated near the front of the mouse. These sensors relay a message to the microprocessing computer which results in the mouse moving forward, backward or rotating.

At the beginning of the event, the mouse is in a searching mode. It moves around in a random path until a light sensor detects a black line. When this occurs, the mouse will rotate right until the middle sensor also detects the line. At this time the mouse is pointed along the line in a parallel position. The mouse, now in the tracking mode, proceeds forward in the direction of the line. If the line is curved, the mouse will detect this condition and alter its path through the use of the light sensors.



You don't have to reward this mouse with cheese to get it to run a maze.

In a series of motion procedures, the mouse tracks the black line to the end. Once the light sensors leave the line, the mouse reverses its direction until the line is again detected. A 180-degree rotation follows before the mouse begins tracking toward the other end of the line.

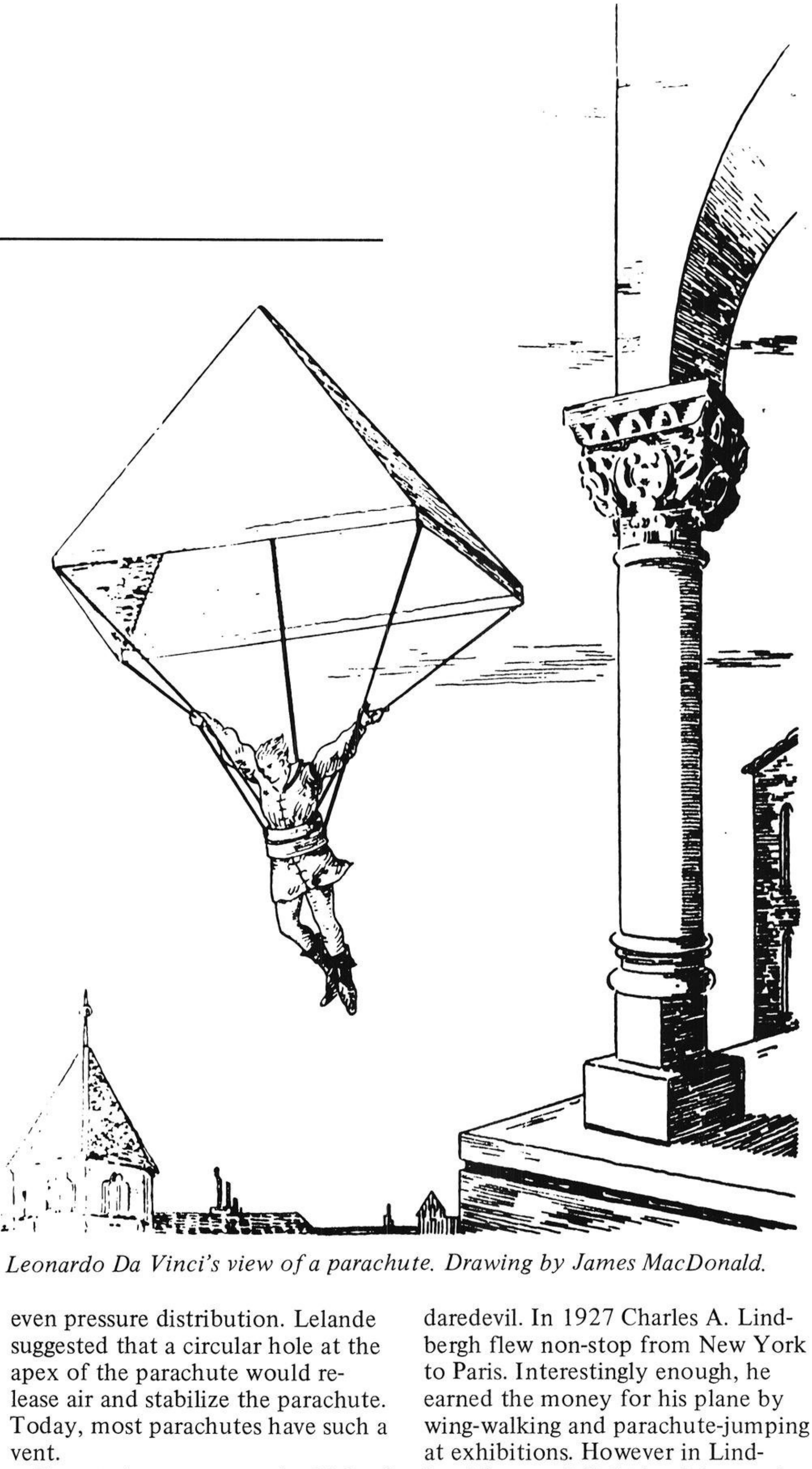
During its UW demonstration, the mouse successfully completed several mazes. Judging by the results of the trial period with continued efforts on the part of the ECE Dept., the IEEE Micromouse champion could quite possibly come from the University of Wisconsin–Madison in the near future. ■

Parachuting

by Michael Pecht

The four-seat Cessna jump plane had only the pilot and myself left in it. The pilot reduced the plane's speed from 110 to 70 m.p.h. and opened the passenger door. The sound of the wind was deafening even though I was wearing a helmet. From three thousand feet above the ground I could see small rectangles of farm land and plenty of water, which I was assured was miles away. Suddenly the pilot shouted, 'Stand by' and I prepared myself for my first parachute jump . . .

When or where the first parachute was developed and used is unknown. The Chinese invented the umbrella which supposedly led to the construction of the parachute. In the late 15th century, Leonardo Da Vinci, a genius in the analysis of flight mechanics, sketched a man descending from a pyramid-shaped parachute. In 1783, Sebastien Lenormand, professor of Technology at the Paris Conservatory of Arts and Handicrafts, claimed to have jumped from a tower with a fourteen-foot diameter cone-shaped parachute. Many historians, however, believe the professor only dropped animals.



Leonardo Da Vinci's view of a parachute. Drawing by James MacDonald.

The first undisputed parachute jump was made in 1797 by Andre Jacques Garnerin. He descended from more than 2,000 feet above Paris from a parachute suspended from a balloon gondola. He landed without injury but became violently airsick due to parachute oscillations. The French astronomer Lelaude later suspected that air pressure built up in a falling parachute spilled out the sides, causing an uneven pressure distribution. Lelande suggested that a circular hole at the apex of the parachute would release air and stabilize the parachute. Today, most parachutes have such a vent.

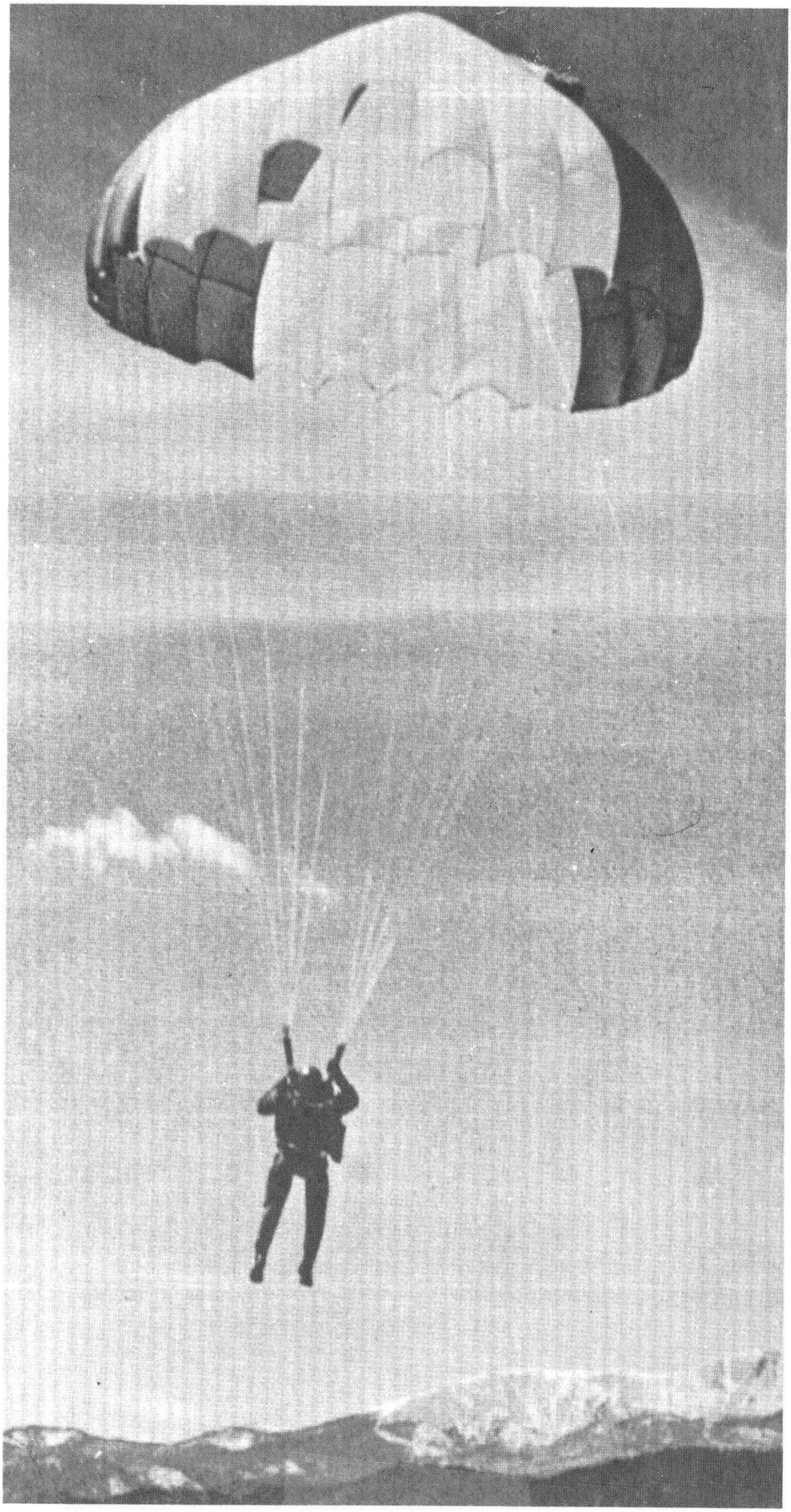
Even today, most people think of parachutists as entertainers. Parachutes are considered unsafe and anyone making a jump is labeled a daredevil. In 1927 Charles A. Lindbergh flew non-stop from New York to Paris. Interestingly enough, he earned the money for his plane by wing-walking and parachute-jumping at exhibitions. However in Lindbergh's record flight he did not take along a parachute.

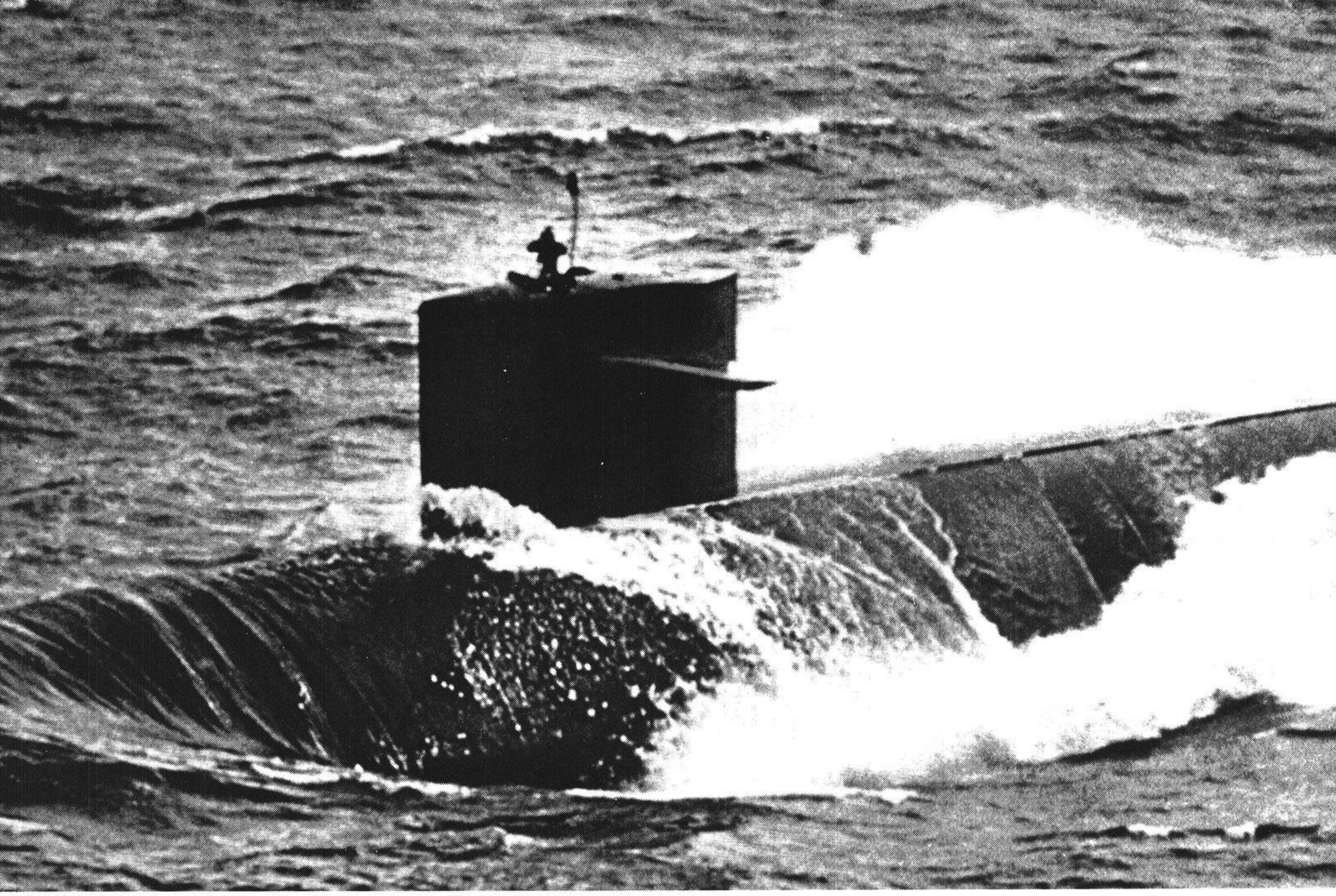
Today the parachute has many applications besides that of a required safety device in planes. Smoke jumpers in the Forest Service use parachutes to get to fire-infested areas quickly. Paratroopers use parachutes for military operations. Parachutes are also used to drop mail to out-of-the-way areas of the Appalachian mountains, to land satellites and to slow down airplanes which must land on a short runway. Recently a parachute was used to slow down the "land vehicle" which broke the sound barrier.

Perhaps the most interesting use of the parachute is for sport. Why would anyone want to jump out of a perfectly good airplane for the fun of it? Jumpers describe the floating sensation, the feeling of being suspended in space without any attachments. Parachuting is not like riding a roller coaster. There is no noise. Everything is calm and relaxed.

The ultimate parachute jump was made by Captain Joseph W. Kittinger on August 16, 1960 from al altitude of 102,800 feet. After thirty seconds of free fall he reached a top speed of 614 m.p.h. After four and one-half minutes of free fall his chute, a standard 28-foot back pack, opened. Nine minutes, fifteen seconds later he safely landed.

What about my jump? Well, when I jumped, I back-somersaulted out of the plane which is not at all recommended. Fortunately, my chute opened after about three seconds and then for the next two-and-a-half minutes, I floated towards the ground, laughing during an enjoyable moment in my life. ■





Football

An inside look at the technical aspects of today's game

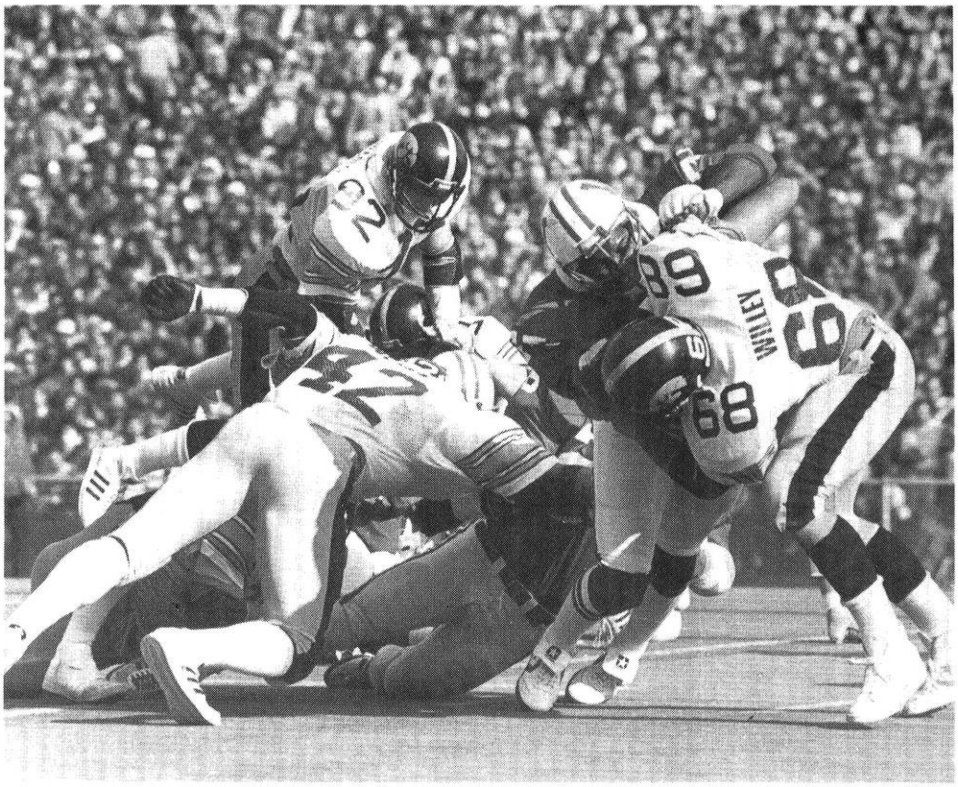
by Mike Zambrowicz

Mike Zambrowicz is a senior in electrical engineering and an avid football fan. Before leaving for a year of study in Germany, Mike looks at a seldom-seen side of "America's Game".

Football. The game began as a group of men pushing and shoving each other to gain control of a funny looking melon-shaped ball. The necessary requirements to play the game then were few: a pigskin football, a grass-covered playing field and a determination to ignore the inevitable bumps and bruises.

Sixty years have passed since the National Football League's season opener in 1919. Football has grown in popularity. With this growth rules were introduced and changed to make the game more multifaceted, exciting, and safer for its players. The players still run, pass, block, and tackle, catch heck from their coaches, and receive praise from their fans. However, the quality of the player and the quality of the equipment he uses has developed. Oh, and one other thing, the ball is no longer made of pigskin—it's made of cowhide and it's not nearly as melon-shaped as it used to be.

Today's player at the professional and college level is bigger, stronger, and faster than his counterpart of twenty years ago. The action on the field has thus become faster and more violent. Injuries are more likely to occur as bigger players propel themselves at each other at greater speeds. On the other hand, players are better conditioned and protected, partly as a result of modern engineering technology.


Hard hitting action is common in Big Ten football.

Top physical condition is of the utmost importance when playing football. Generally a player's size and speed are natural abilities which cannot be significantly increased. However his strength can be greatly improved by weight training. Basically a player has at his disposal either free weights or weight "machines," such as the physical conditioning equipment made by Universal. Many of today's college football trainers, such as Gordon Stoddard of the University of Wisconsin, place the emphasis of weight training on the use of the free weights and the traditional weight machines. At the professional level many NFL teams have switched their emphasis from free weights to the equipment manufactured by Nautilus. Nautilis equipment represents a major change in the approach to weight training, brought about by changes in the method of muscle strengthening, and the use of state-of-the-art engineering technology.

Unlike the traditional weight machines, according to the Nautilus brochure, "Nautilus equipment continuously regulates its resistance throughout the movement in order to keep the machine's resistance in proper proportion to the person's available strength". Although the Nautilus equipment represents the most productive type of weight training device, it has not replaced the usefulness of the free weights. The Green Bay Packers utilize Nautilus weight machines as well as the free weights in their program. According to Packer trainer Domenic Gentile, the big advantage in using Nautilus equipment is that a player can essentially prevent personal injury such as muscle damage that can occur from improper lifting techniques when using free weights.

The increased size, speed, and strength of today's football players have produced a much more exciting brand of football as is evident any Saturday or Sunday on television or at the stadium. The game is faster, more unpredictable, and thus more interesting. A very noticeable aspect of the game today is its hard-hitting nature, a direct result of the development of the athletes. Unfortunately an increasing number of injuries are the result of this more violent form of play on the field. Appropriately the methods of treating and preventing these injuries have improved.

The knee is the most used and yet the most abused part of the football player's body. Besides its normal motion, the knee is constantly being subjected to undue stress from the sides. Once it is injured it requires special care and treatment. In the case of successful knee surgery the knee is reconditioned along with the rest of the leg before it is strong enough for the player to use it again.

A brief summary of the post-surgery rehabilitation program used by Packer trainer Domenic Gentile goes like this:

1. The injured leg is put through limited exercises with light weights. This begins strengthening the muscles around the knee.
2. When the leg has been sufficiently strengthened so it can move well in light weight exercises, heavier weights, such as the Nautilus machines, are used for further strengthening.
3. Once the injured leg has successfully completed its reconditioning with weights in slow motion, it must be treated in fast motion. Both the Packers and the Badgers use a device called the Orthotron which monitors the injured leg in fast motion. This machine points out improvement in the movement, speed, strength, and endurance of the injured leg, but its biggest advantage is that it allows the running motion without the severe shock which occurs from running on a hard surface.

The University of Wisconsin uses the compression boot and the Fitron Cycle-ergometer for rehabilitation. The compression boot uses both pressure and low temperatures to disperse accumulated fluids present in an injured leg. The Fitron cycle is a type of endurance exercise cycle which also provides fast running motion without the impact for which the knee may not be prepared.

The football player not only has at his disposal equipment for training and rehabilitation, but also equipment that he wears during the game. This equipment represents the culmination of engineering research, manufacturing and testing, necessary to assure that the player has enough protection to play the game. Research and testing continues each year as new equipment is checked for quality of design, manufacturing, and performance.

The helmet and shoulder pads are the most noticeable and important protective gear. The weight of the helmet used by the Wisconsin Badgers is comparable to that of a small bowling ball. Its interior is covered with a combination of foam padding and plastic water-filled pods, designed to absorb shock and safely dissipate the force of impact. Shoulder pads protect the player's upper torso by distributing the force of the impact throughout the arches of the plastic pads.

Some devices are used in conjunction with regular equipment in preventing further injury to an already injured player. Quarterbacks are particularly susceptible to painful rib injuries. The previously heavy and cumbersome vests used to protect their ribs have been replaced by the so-called "flak" vests. Both the Packers and the Badgers have this type of vest available, but its most famous user is Houston quarterback Dan Pastorini who wore one in last year's playoffs. According to Frank Deford, Pastorini's vest was made of nylon coated with urethane. A valving effect made it crunch-resistant by spreading the impact of the blow.

Photo courtesy of Nautilis Equipment Co.

Nautilis equipment provides safe and effective training.

Another device is the knee brace worn by players with injured knees. The derotation brace made by Lenox-Hill permits forward and backward movement but protects the knee from side impacts. Lynn Dickey of the Packers wore a Lenox-Hill derotation brace on his injured leg last season. Joe Namath also wore a pair of braces to protect his chronically troublesome knees.

The list of technical equipment and modern safety materials also includes ultrasonic guns, astroturf, Plastazote, Orthoplast, and much more. However the nature of the game is still the same.

In years to come twenty-two men will still be playing the game, with a ball, and on a playing surface surrounded by cheering spectators, but the equipment available to the player will continue to change and improve. Training, rehabilitative, and protective gear will continue to develop as new approaches to the play and preparation of the game are introduced. ■

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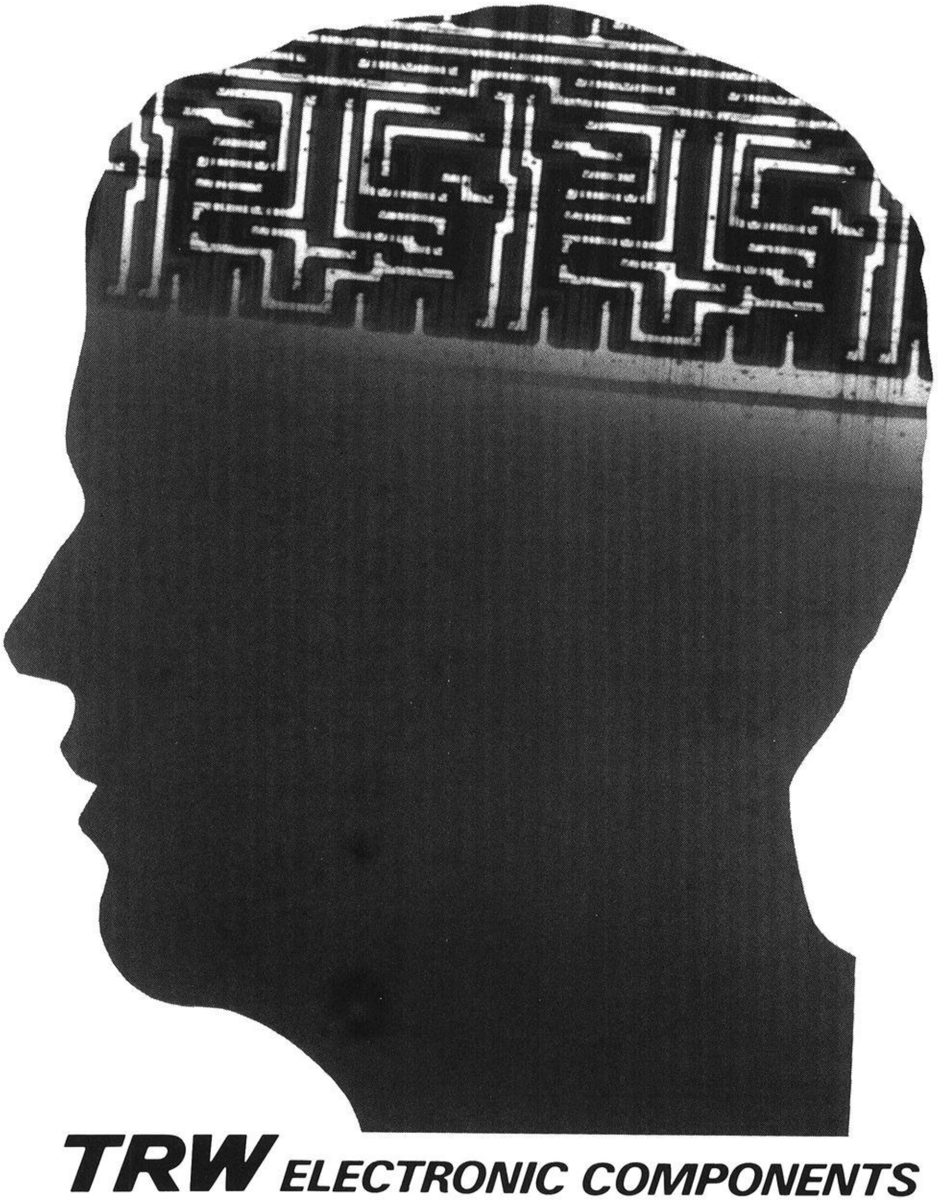

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Manpowered flight

by Dan Griswold

Manpowered flight has progressed from Kitty Hawk to the Spirit of St. Louis in less than three years.

In 1977 the Kremer Course was conquered after 18 years of futile efforts, and last summer one of the great feats in aviation history took place over the English Channel. On June 12, 1979, skinny Bryan Allen of California peddled the *Grossamer Albatross* from near the white cliffs of Dover to the coast of France—23 miles in the face of choppy seas, super tankers, and finicky winds.

Conquering the Channel with a manpowered aircraft (MPA) was hailed as an engineering marvel, as well as a feat of human endurance. Comparisons were even made with Lindbergh's historic solo flight across the Atlantic in 1927.

The designer of the *Grossamer Albatross,* and probably the biggest name in MPA engineering, is Dr. Paul B. MacReady Jr. MacReady, 53, an aeronautical engineer from Pasadena, Calif., teamed up with Allen in 1977 to hurdle the first great barrier to manpowered flight—the Kremer Course.

Laid out in Shafter, Calif., the 1.15-mile, figure-eight course was conceived by British industrialist Henry Kremer, who, in 1959, offered 5,000 pounds sterling to anyone successfully traversing the course with an MPA. Kramer doubled the prize, then raised to it to 50,000 pounds ($86,000), but after 18 years, the course was still unconquered.

Popular Mechanics, in its April 1979 issue, said the cash offered by Kremer "seemed to symbolize the futility of the manpowered flight concept rather than its promise."

In August 1977 the promise came through. Bryan Allen, a man of 26 years and 140 pounds, peddled the MacReady-designed *Grossamer Condor* successfully through the Kremer Course. The *Condor* was only airborne 7 minutes, 20 seconds, but manpowered flight had notched its first great triumph.

Before MacReady and Allen could divy up the 50,000 pounds, Kremer slapped down another challenge, through the Royal Aeronautical Society of Britain: 100,000 pounds to the first MPA that crosses the English Channel.

Kremer's rules were simple. The machine must be heavier than air, launched, powered and controlled solely by its crew (no limit on crew size), and must contain no energy-storing devices. The MPA must leave British soil from no distance exceeding 98 feet (including the Dover cliffs), there could be no intermediate landings or physical assistance along the way, and no equipment or crew could be dropped along the way. Maximum altitude for the flight was 160 feet—a limit to discourage glider pilots from seeking a thermal current and gliding across the Channel. Anywhere in France was a permissible landing zone.

MacReady's assault on the Channel would be made with an MPA that was basically a modification of the *Condor* Allen had flown in 1977 to conquer the Kremer course.

MacReady used a computer to simulate stress, winds and other forces. Some basic changes from the *Condor* included: primary fiber composite replaced aluminum to cut weight (at least 10 pounds), wing ribs were moved closer together and spaced differently for better control, and the pilot-motor, Allen, sat upright, rather than semi-reclining, for more power.

But the main improvement in MacReady's MPA design, and the general reason behind the exciting leap to reality of manpowered flight, was the availability of space-age materials.

Replacing aluminum as the skeletal material was fine carbon-filament tubing, which is lighter and stronger. The wings and cockpit were sheathed in Mylar, a transparent film only .0005 inch thick, but sturdy enough to negate the need for other supporting structures. Steering controls and many of the chord reinforcements were made of Kelvar, a space-age fiber. The 20 pulleys used in the steering system were molded Derlin, another plastic.

The completed *Albatross* had a wingspan of 96 feet, wider than a DC-9. A urethane chain transferred the pumping power in Allen's legs to a huge plastic propeller behind the cockpit. An airfoil mounted on the front provided stability and control. The landing gear consisted of two tiny, plastic wheels weighing one ounce each.

By using materials donated by Dupont, and trimming weight "an ounce at a time," MacReady pared his completed *Grossamer Albatross* down to 55 pounds—13 pounds less than the *Condor.*

The completed plastic bird required about a half horsepower to take off and about 0.3 to maintain a speed of 11 mph. Allen said that compared to pedaling a racing bike at 20 mph on a level road with no wind.

MacReady and Allen weren't the only MPA team working on the "Channel Challenge."

Nick Goodhart, a retired Rear Admiral, had spent 3000 hours building the two-seater *Newbury Manflier.* The *Manflier* had two pilot pods 70 feet apart and equidistant from the center of a 138-foot-wide pair of wings. Each pod sprouted a vertical stabilizer, propeller and boom extending back to a horizontal tail assembly. By slowing one pilot/engine, the plane could bank and turn. The two pilots communicated by shouting.

Multiple-pilot MPAs have the advantage of more horsepower per pound. Their longer, thinner wings also give them the advantage of a deeper "ground effect."

Often described wrongly as an "air cushion," ground effect can be more correctly summed up as "downwash interference." It's an important concept to understand, because no MPA could have flown over the English Channel without its help.

A simple description of ground effect is as follows: "Air flows around a wing, producing lift and drag, and then is deflected downward as net effect of the wing's passage through it. When this aft-flowing downwash stream is interfered with by the ground, the result is an upward rotation of all the aerodynamic forces acting on the wing. To picture this, you must keep in mind that air has properties of a fluid. It means that drag is reduced as the net forces vector moves more towards the vertical."

Ground effect works on an MPA —or any other aircraft—up to a distance equal to about half its wingspan. Because two-pilot MPAs have longer wings, they can go higher and still feel the extra lift. In general, ground effect significantly reduces the power it takes to keep an MPA airborne.

Ground effect, a little luck, and Allen's well-conditioned legs were all working well for the *Grossamer Albatross* the morning of June 12, 1979.

Dressed in shorts, crash helmet, cycling shoes and lifejacket, Allen pedaled the first half of the crossing at a steady 10 knots and an average height of 10 feet. The former high school and college bicycle racing champion concentrated on turning the pedals at a steady 70 rpm.

A normal Channel crossing over that section of the sea is 22 miles, but to avoid the wake of a supertanker, Allen was forced to go an extra mile out of his way.

At the halfway point a head wind rose up cutting the *Albatross'* speed from twelve mph to a dangerous nine-and-a-half mph. The tiring Allen signaled a support boat to give him an air tow—he was abandoning the attempt. But when he picked up his altitude to let the boat underneath, he discovered calmer air. He decided to go on.

After coming within six inches of the choppy surf during the harrowing brush with failure, Allen found clear flying and a burst of energy. Two hours and 49 minutes after leaving the coast of England, the *Albatross* softly touched down on the beach of Cap Gris-Nez, France.

Manpowered flight had survived its initiation into the world of aviation.

MacReady, a soft-spoken Yale and Cal Tech graduate, refused to be made a hero or genius for his accomplishment. "In a project like this," he said, "it isn't the final object that is important, but the techniques you develop along the way. Seeing how far you can go with the horsepower a person puts out is great mental discipline. On the way you get to think, what if you had a three-horsepower engine. Then you wouldn't need a 96-foot wingspan, but a 45-foot span, and you would have a practical vehicle. You might get a streamlined bicycle on which you could commute at 25 mph without working up a sweat."

Allen's reaction to the accomplishment was less analytical. "Wow," he said. "Oh, wow." ■

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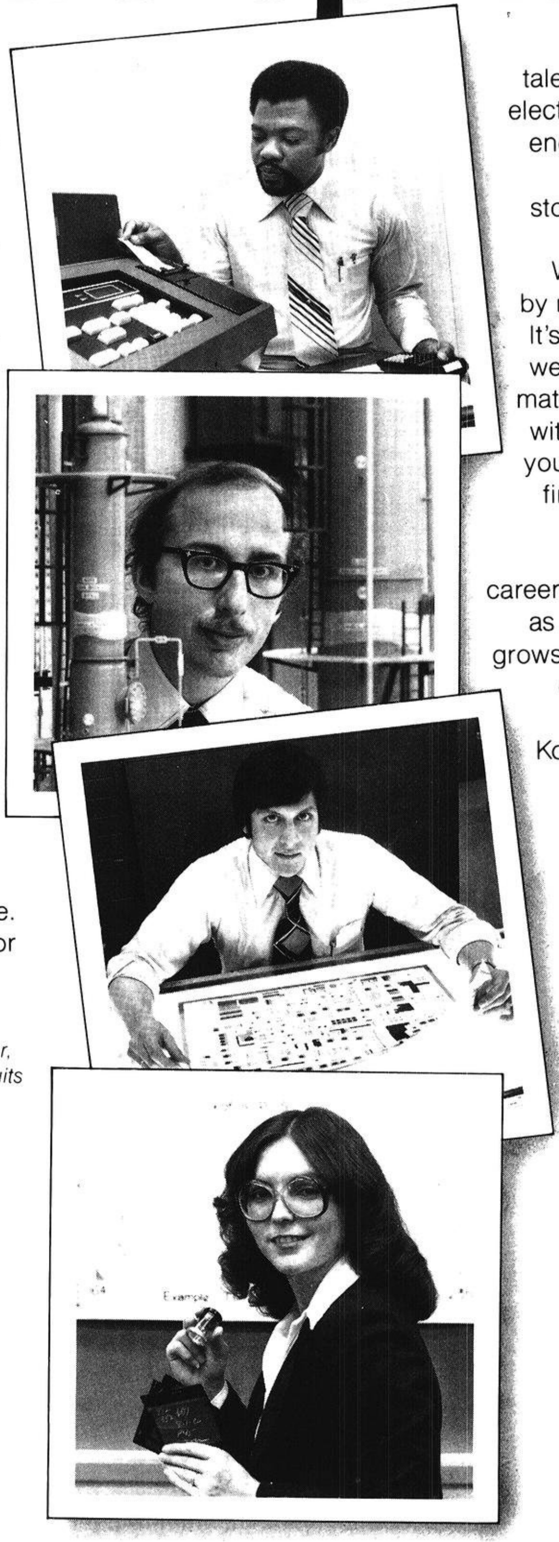

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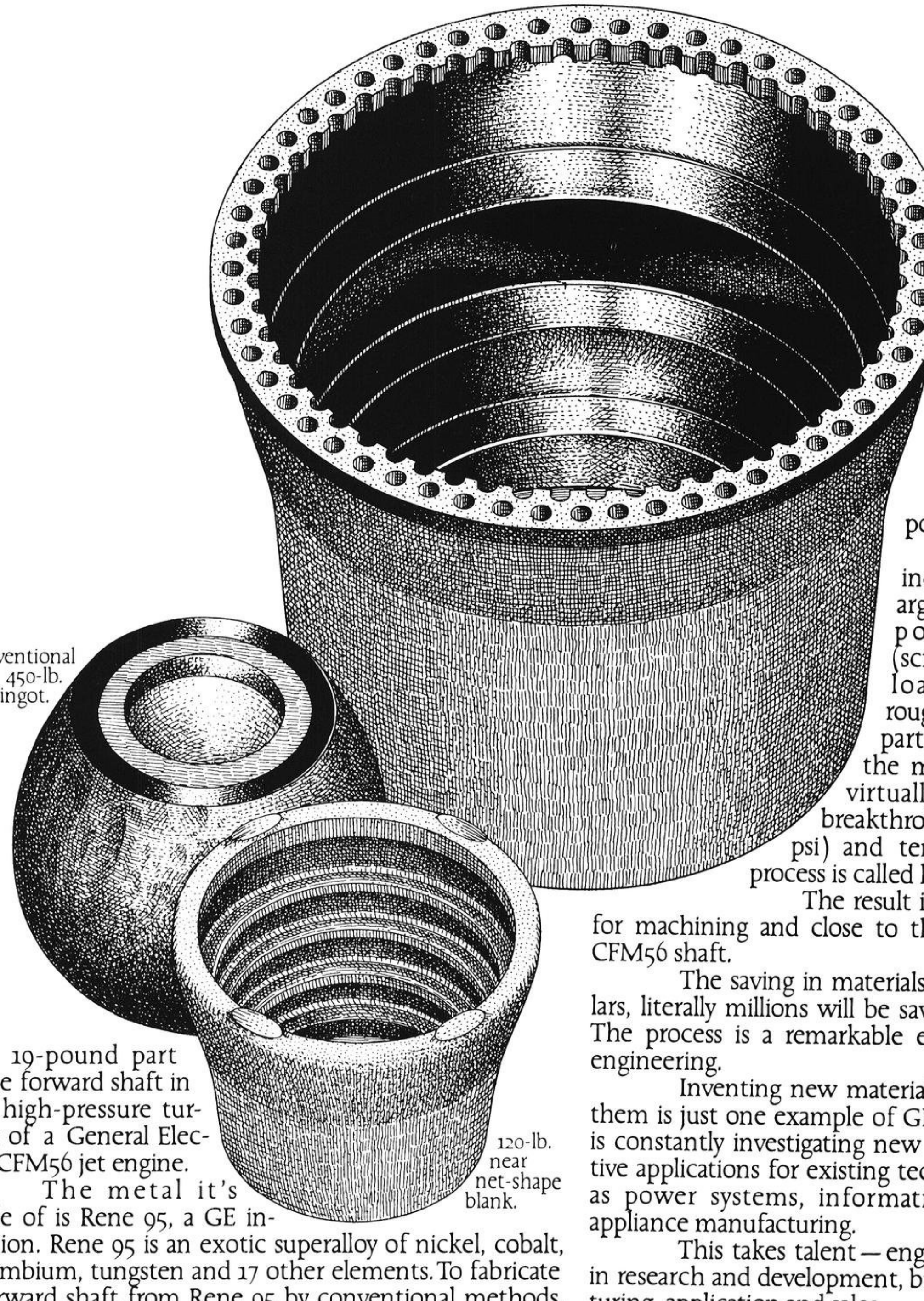

The 19-pound part is the forward shaft in the high-pressure turbine of a General Electric CFM56 jet engine.

The metal it's made of is Rene 95, a GE invention. Rene 95 is an exotic superalloy of nickel, cobalt, columbium, tungsten and 17 other elements. To fabricate a forward shaft from Rene 95 by conventional methods, you start with a 450-pound ingot. After forging, pressing and machining, you end up with a single 19-pound shaft...and more than 400 pounds of expensive scrap.

That's a distressing waste of critical raw materials and of the energy it takes to mine and refine them.

So GE engineers turned to near net-shape forming: fabricating the finished part from a blank shaped as closely as possible to the shape of the finished part.

But how could such a blank be created without starting with a 450-pound ingot? To solve that problem, GE engineers developed a truly unique application of powdered metallurgy.

Virgin or vacuum induction-melted Rene 95 is argon-atomized to create a powder. The powder (screened for particle size) is loaded into containers roughly shaped like the final part. Then, in an autoclave, the material is consolidated to virtually 100% density (that's a breakthrough) at high pressure (15K psi) and temperature (2000° F.). The process is called hot isostatic pressing.

The result is a 120-pound ingot ready for machining and close to the shape of the finished CFM56 shaft.

The saving in materials is more than 70%. In dollars, literally millions will be saved over the next decade. The process is a remarkable example of cost-effective engineering.

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