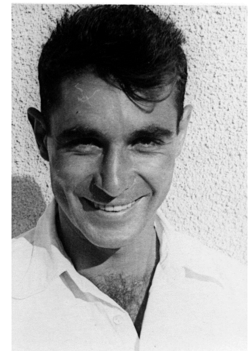
THE DISCUS THROWER AND HIS DREAM FACTORY

By

Gideon Ariel, Ph.D.

This book is dedicated to three beloved people, without whose influence t would now be trapped in a black hole rather than fulfilling my dreams:



To, my childhood hero, Dani Dasa: a creator of folk dances and my sports instructor at hadassim Dani introduced me to the discus, and strengthened my belief, as a child, that I could .one day represent Israel in the Olympics. It was only by virtue of my athletic skills that a scholarship for ' study in America -- and the infinite possibilities thereafter - was granted to me. I have never looked back.

To Yariv Oren (of blessed memory), my mentor and coach who befriended me as a young athlete, who encouraged me to overcome my shyness, and who gave me perhaps the greatest gift of all: self-confidence and hope.

To Ann Penny, without whom I would never have reached the mountaintop. After 35 years of a creative collaboration I finally married her, and for the last two years she has been — to my everlasting joy — Ann Ariel,

Introduction

What a crazy title for a book. How do sports and fantasy share the same planet let alone merge into a book? It is easy for me to tell you because this is all about me – I am that discus thrower and my mind is that factory where all of those dreams were created. To explain, you should know that with one sailing, floating throw of a discus in a single competitive event propelled me to become the successful person that I am today. Throwing the discus saved me from a life as a juvenile delinquent and one fantastic victorious throw set me on the path to become a world renowned biomechanist and operate my own dream factory.

In 2012 I received the highest award in Biomechanics as you read below:

The Geoffrey Dyson Recipient for 2012

The recipient of the Geoffrey Dyson Award for the ISBS2012 conference will be Dr. Gideon Ariel. Gideon is well known in the field of sports biomechanics due to his extensive knowledge of how physics applies to human motion, as well as his expertise in computer science. He is a former Olympic athlete, and completed his graduate and post-doctoral work at the University of Massachusetts, where he received a PhD in Exercise and Computer Science. He has published numerous scientific papers, founded an independent laboratory devoted to biomechanical research relating to human performance, and was chairman of the U.S. Olympic Biomechanical Committee.

My special discus result sent me to the Rome Olympics in 1960. From there, it is as though the discus threw me to America, the land of dreams. Once I reached the great, vast, vistas that the United States offered someone like me, a young simple athlete from a tiny country, my horizons were limitless. Suddenly, that discus throw which had launched me into a world where dreams can come true, life became full of opportunities without end. No longer was I perceived as a skinny, shy, young boy who would probably never succeed. Now, I had been an Olympic competitor. There were no limitations to what one could learn or do in the magnificent land of dreams.

My first big dream grew from a seemingly miraculous discovery I made while in Graduate School. I learned that human motion could be scientifically measured. It was possible to combine the mechanics of Isaac Newton with the biology of people. What a fabulous tool! This dream of mine was no longer just a bubble on a wish list. Suddenly, I realized that a Coach could assist a discus thrower without looking where the discus landed. The combination of scientific quantification and the rapid processing of the computer meant that sporting activities could be assessed accurately and quickly. The concept was mind-boggling and floated on air almost more as a mirage than just a dream. Could such dream really come true?

The answer resided in the sophisticated computer programming that I developed. The enhancements of sports techniques and performance analyses knew no bounds. “If it moves, it can be measured” became a legitimate mantra. So what could I do with this marvelous, newly computerized analysis system? In America, anything is possible. So I created a company.

Surprisingly for me, before we opened our office doors for the first time, we were swamped with projects. We had sporting goods companies clamoring for design assistance with golf balls and clubs, basketball structure and color designs, tennis balls and rackets, and ski boot release mechanisms. Owners of horses asked how to select the special yearling who would grow up to win the Kentucky Derby. A shoe company sought help with athletic performance shoes while another company wanted to improve their line of nursing and surgical shoes. These studies led my dream factory brain to invent an air shoe in 1974.

DAILY HAMPSHIRE GAZETTE

Established 1786 — Vol. 192, No. 303 NORTHAMPTON, MASS., WEDNESDAY, AUGUST 30, 1978 48 Pages — 15 Cents

Computer helps design shoe that walks on air

By MILTON COLE

AMHERST — Walking on air.

The very thought is so pleasurable that the expression is used constantly to describe emotionally inspiring success.

But now a computer and a former Olympic athlete have merged knowledge and technology so they could make "walking on air" totally commonplace.

Dr. Gideon Ariel of Belchertown and his Computerized Biomechanical Analysis company in Amherst have designed shoes in which one does walk on air.

How efficient the shoe

They are the result of a survey on how efficient is the design of shoes in general, and how can they be made more efficient.

The result of that survey and study could be shoes that have one walking on air.

And if the air-shoes are the most unusual of the products of CBA, they are not the only ones.

For example, there is a new exercise machine that makes it unnecessary to have a large room to house it, and makes it possible to do all your exercises in half the average-size bathroom.

There is a tennis racket with a pivoting handle that enables a player to absorb the shock of a ball hit at him and return it with maximum force and accuracy.

And there is a study being made for the Department of Defense on how to make the foot soldier more efficient as far as equipment and uniform are concerned, and what is the most efficient way to hold and shoot a submachine gun.

These are some of the more unusual studies that have been or are being made. But there are others, enough others that the business started by Ariel six years ago has now grown into a multi-million-dollar firm that is expanding.

Take the air shoe.

Originally the U.S. Bureau of Standards contracted with CBA several years ago to do a survey on the efficiency of design of the common shoe.

The study, including filming of people walking and then slowing the film down to analyze frame-by-frame what happens when a person takes a step, showed that the common shoe is not an efficient design.

The protruding heel causes a person to step onto the heel of the foot first, putting the strain of each step on it, and then expanding that strain up through the leg into the lower back.

"It showed that the way we walk and the kind of shoes we walk with can be a cause of lower back trouble as well as the cause of foot and leg problems.

"The computer showed that the most efficient way to walk is the way we walk barefoot, with a rolling motion so that the force we generate as our foot hits the ground will cause a rolling motion, pushing the body forward on the foot, instead of jarring the force up the leg."

How to utilize knowledge

How to utilize that knowledge?

After the report was sent to the federal agency, Gideon and his compatriots at CBA worked on putting theory into reality.

One shoe was designed, aimed at providing the rolling motion, but still sending some of the jarring motion up the legs. Then came the idea of using that jarring action to provide forward motion.

The air shoe was born. The prototype is designed for athletes, and has been used successfully in practice by the members of the U.S. women's volleyball team.

They have found that they jump higher, and they end up with fewer leg problems, muscle pulls, etc. as a result of landing on their feet after a jump.

Basketball players are experimenting with them, along with runners.

The design is of a regular nylon-bodied running shoe, with the rubberized rippled or cleated sole.

But the inside has another rippled rubberized insert running the entire length of the shoe. In the outside of the heel of the shoe is a small air intake valve.

A rubber-bulb pump is inserted into the valve and the insert is filled with air, like filling an auto or bicycle tire or a football or basketball.

Then the shoe is put on, laced and tied. And when one walks on it, he or she is literally and actually walking on air.

Air forced out

Each step forces the air from one spot in the insert into another by use of computer-designed valves, and the result is a cushioned step whether walking or running or jumping, and a rolling effect when one walks or runs.

"They should end problems with leg muscles, shin splints, bone spurs, etc. And they should cut foot fatigue for runners," Ariel said.

Right now the design has been acquired by the Pony Shoe Company, which makes footwear for all kinds of sporting activities.

Ariel figures that the shoe will be used in Olympic and other national and international competition. He believes it will find a place in sports, particularly basketball, and perhaps football as well.

But it also should result in use in regular shoes worn by the general public, and could have the nation, if not the world, walking on air, and being healthier for it, if Ariel and his computers are correct.

"Imagine how great this would be for paratroopers or others jumping from considerable heights," enthused Ariel.

The graying but husky University of Massachusetts doctoral graduate also is enthusiastic about the exercise machine he has designed.

Originally used weights

Originally he designed one for the Universal firm, one of the top such companies in the U.S., using the established method of actual weights attached to pullies and handles.

It was different and easier to operate than others on the market at the time, but still quite bulky and space-consuming.

The latest design, made possible by the omniscient and omnipresent computer, is a simple large cylinder connected to a variety of bars or pedals or overhead handles.

The computer is hooked up on a shelf as part of the system. You press a button, and the computer asks if you want to exercise.

You press buttons that indicate that you want to do weight lifting, and how much force or poundage you want to lift.

The computer then sets the valve that controls the hydraulic fluid in the cylinder and thus the amount of force necessary to lift the piston in the cylinder.

It eliminates the need for the actual weights to be there.

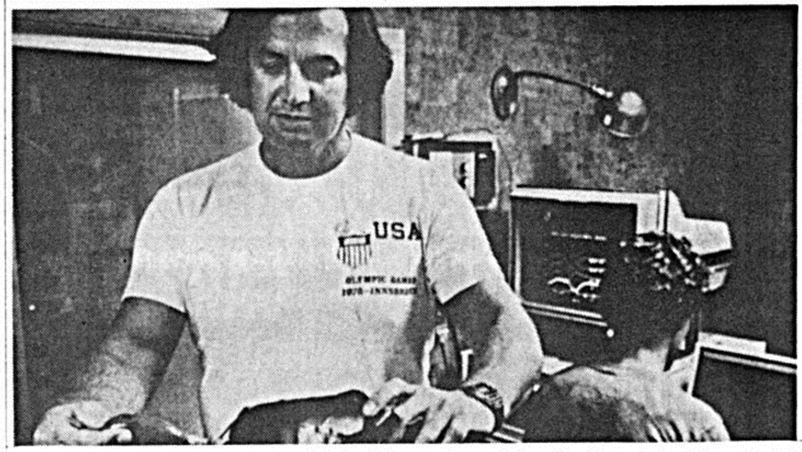
One of the people involved with Ariel in his enterprises is former U.S. Treasury secretary William Simon. He is interested in forming their own manufacturing firm to turn out the new tennis rackets that CBA has designed.

Doing research on tennis racket efficiency and how the ailment, "tennis elbow," occurs, CBA and Dr. Ariel found that the impact of a ball on the racket, sends a jarring force through the racket handle up the arm and against the elbow joint.

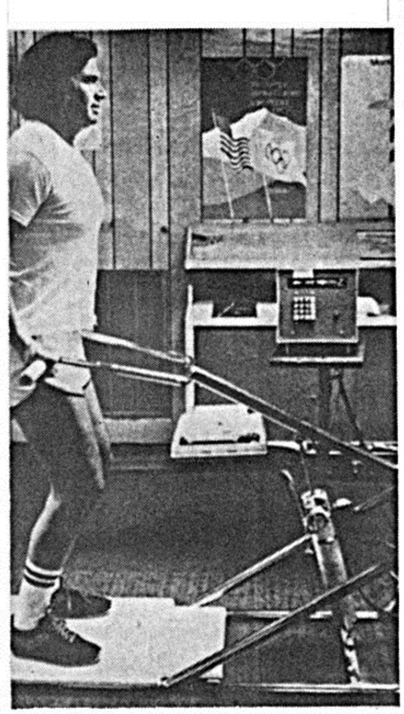
The computer suggested a rotating handle that would use that force to twist the handle, making it so the face of the racket is directly against the ball each time it hits the racket.

This not only eliminated the jarring force going into the elbow, it also made possible the opportunity for a perfect return shot.

Using that racket, which Ariel says will be produced by someone within a year, either their own firm or one of the regular sporting goods manufacturers, with the tennis ball CBA designed for Spalding, could make for much improved tennis.



PUMPING UP the sole prepares the new "air shoe" for use. It was designed by Computerized Biomechanical Analysis in Amherst, and CBA president Dr. Gideon Ariel is getting the shoes ready. (Richard Carpenter Photo).



DR. GIDEON ARIEL demonstrates how the computerized exercise machine his Computerized Biomechanical Analysis firm of Amherst designed, with computer operating hydraulic piston to provide the same resistance as weights used on traditional exercise machines. (Richard Carpenter Photo).

DAILY HAMPSHIRE GAZETTE August 1978

NASA posed many questions regarding performance and equipment needs for work in micro-gravity. How should astronaut suits be designed, what could be done to reduce or eliminate bone loss, and were there exercises and equipment for use in Space?

ACES** trains muscles to contract fast. The faster the muscles contract, the faster the limb moves, the faster the limb moves, the faster a person can run, the higher a person can jump, the harder they can hit, the further they can throw. The better they can functionally perform ... -* ***Dr. Gideon Ariel, Ph.D.

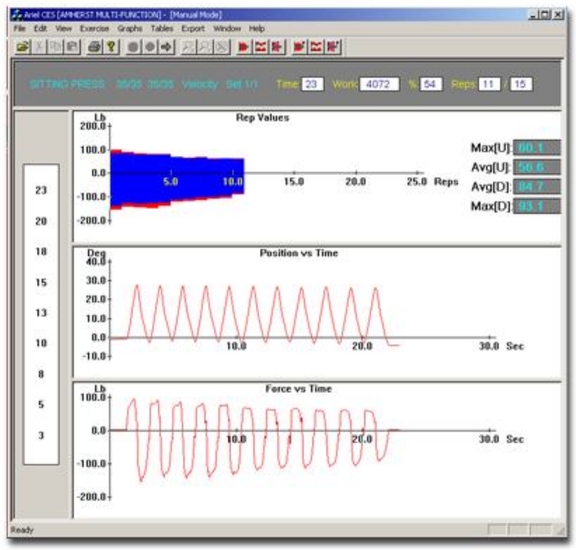
The list of applications seemed virtually endless. We worked on air bags for car safety, contributed to the development of prosthetic joints, performed forensic analyses in legal cases, and provided information for personal hygiene products as well as for baby diaper design.

Sports Illustrated in Appendix 1 described some of our activities.

My sophisticated analytic program grew and morphed into bigger and better dreams. Not just my dreams, but for everyone who worked with them. My dream factory, like the Sorcerer's Apprentice, gave birth to more ideas, concepts, and dreams.

Eventually, the US Olympic Committee followed my recommendation to emulate the East German model for training athletes, without the drugs, of course. We established the first Center in Squaw Valley, CA and then moved it to a large facility in Colorado Springs, CO where it continues today.

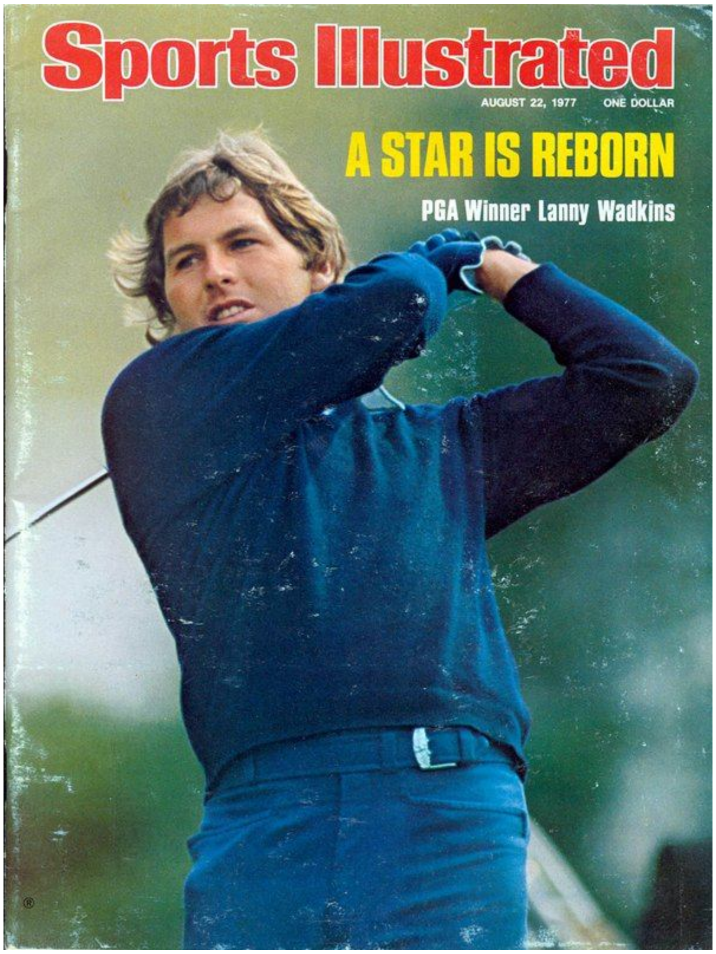
After I had developed my dream to quantify movement, I wondered whether it would be possible to use the computer to train my muscles. Needless to say, the answer was "Yes" and what a fantastic device it is. The Computerized Exercise System (CES) is currently used to train athletes, rehabilitate injuries, and develop strength. Soon you will learn more about that big dream.



Dreams have no boundaries if you follow them. Imagination, luck, and hard work are necessary ingredients for success. But, if your mind bubbles, creates, and breathes life into dreams, then dreams can become real. The mind is the factory which forges the dreams.

So this is how sports and fantasy can combine to create real life. Dreams can come true if you try.

Appendix 1 – The Sports Illustrated Article of 1977.



CONTENTS

AUGUST 22, 1977 *Volume 47, No. 8*

Cover photograph by Al Satterwhite

Credits on page 63

Next Week

THE PHILLIES ARE FLYING again, particularly when Steve Carlton is winging the ball to his personal catcher, Tim McCarver. Larry Keith reports on this batterin' battery and the defending National League East champs' surge to first.

FIDEL IS FIRST in the hearts of Cubans, but Alberto Juantorena, winner of gold medals in the 400 and 800 meters in the Montreal Olympics, may yet catch him at the tape. Jerry Kirshenbaum visits the idolized runner on his native turf.

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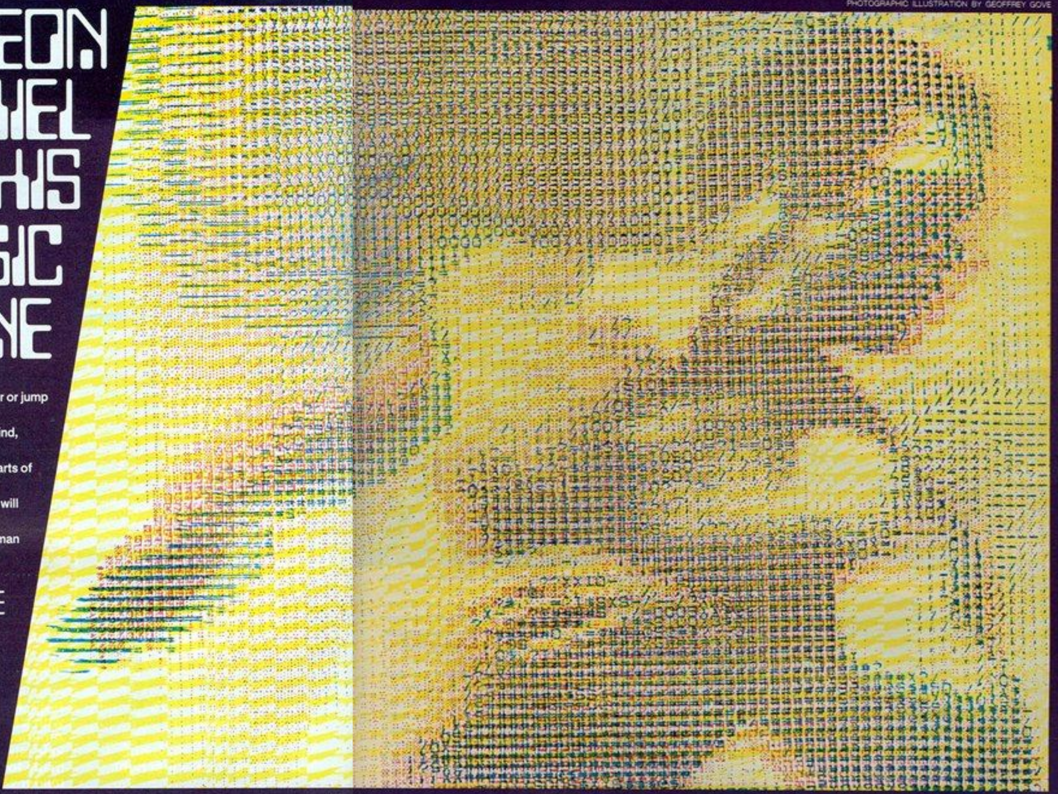
GIDEON ARIEL AND HIS MAGIC MACHINE

If you want to run faster, throw farther or jump higher, call on this electronic mastermind, who will photograph you in action, digitize the moving parts of your body and feed the data into a computer, which in turn will spew out reams of athletic advice no human authority can provide

by KENNY MOORE

PHOTOGRAPHIC ILLUSTRATION BY GEOFFREY GOVE



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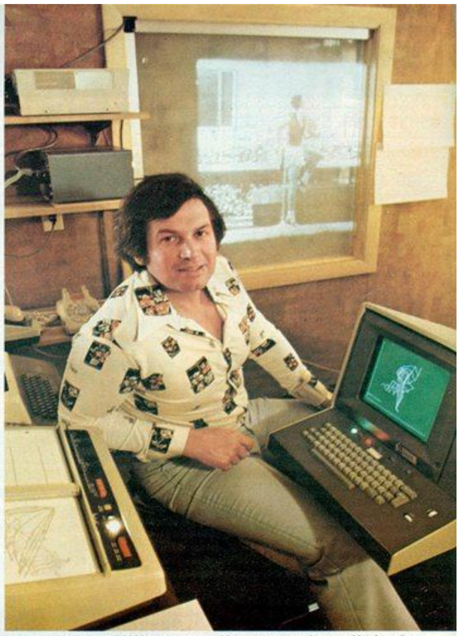
It took Ariel more than 10,000 hours to program his computer to analyze an athlete's motions.

"Faith" is a fine invention
When Gentlemen can see—
But Microscopes are prudent
In an Emergency.
—EMILY DICKINSON

Around Amherst, Mass., colleges run into colleges—the University of Massachusetts, Hampshire, Amherst, Mount Holyoke, Smith—leaving little room for a real town. The population is incessantly changing, fresh ideas flowing through a setting that has a history of assisting clear thought, elegant patterns. Emily Dickinson wrote and is buried here, and Robert Frost's birches are still bending.

Working today in Amherst is a man who would hardly consider himself poetic, but Gideon Ariel has been a leading figure in taking the great raw minds of computers and bringing them to bear on movement. In so doing, he has for the first time let us see the line and meter of human motion. Sport can never be the same.

In the first place, it seems that we have been proceeding on a false assumption. We have believed that trained observers can discern the crucial elements of athletic performance, that coaches can see what their athletes are doing wrong. "The human eye cannot quantify human movement," says Gideon Ariel, ponderously, because he is a big man who threw the discus and shot for Israel in two Olympics, because he still struggles with his Hebrew accent after 14 years in this country, and because that sentence is the foundation of his revolutionary advance. "The important things in performance, the timing, the relative speeds of dozens of limb and body segments, the changes in centers of gravity—these all must be measured, weighed, compared to be of any use."

Ariel is a natural teacher, reaching always for images so vivid the dumbfounded or skeptical will be forced to see. "Compare coaches with bridge engineers," he says. "Suppose an engineer finishes the bridge and says, 'Wait, remove that beam.' You ask why, and he says, 'I took a survey of 100 drivers, and 75 said it looks better without the beam.' That is how coaches coach. What looks best. But if an engineer did that there would be a lot of cars in the river. And he would

find himself in the nuthouse, because he is required to measure the strength of his materials and design against the weight of his load."

People are subject to the same physical laws as bridges. Indeed, Leonardo da Vinci believed mechanical science the noblest, "seeing that by means of it, all animated bodies that have movement perform all their actions." Isaac Newton described the laws of motion in 1700, but not as vibrantly as does Gideon Ariel. "It doesn't matter if you lift a cow, or throw a chair, or punch your girl friend. Everything is according to Newtonian physics."

The problem, until now, has not been that we haven't believed this; it has been that too many things happen too fast for us. The sheer complexity and velocity of a javelin thrower's movement in the final quarter second before release, for example, preclude comprehension of what is going on.

Technology helps. One of the earliest uses of photography was to settle the turn-of-the-century question of whether all four hooves of a galloping horse ever were off the ground at once (they are). In the 1930s, high-speed cameras provided slow-motion photography to offer a clearer view of the action. Dozens of limb and body parts accelerating and decelerating could be seen and measured and charted against one another. Patterns of successful athletes began to appear.

"The better the athlete, the more sophisticated his timing," says Ariel. "The one basic principle of all sports—hitting or kicking balls, punching, throwing, jumping, breaking karate bricks—is a coordinated summation of forces."

But so delicate are the relationships between an athlete's many moving parts that they cannot be assessed simply by looking at the slowest of motion pictures. A process of frame-by-frame, body segment-by-body segment analysis is necessary to make optimum use of cinematography, work that is painstaking, dreary and absurdly time-consuming. Gideon Ariel gave that work to the computer and suddenly the maddening complexity of human motion could be matched by the awesome memory and speed of the machine. Well, not quite suddenly. It took Ariel some 10,000 hours over seven years to create the programs that instruct his computers. Now he offers the sporting world a chance to lift itself from, as he puts it, "the dark ages, a witchcraft business where everything is made of thin air." Over those years, Ariel transformed himself as well, from a carefree discus thrower to a compelling, caprizant fig-

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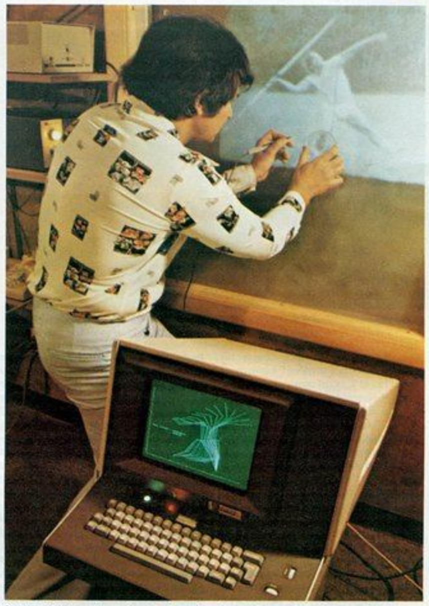

Digitizing, Ariel uses his sonic pen to determine the coordinates of javelin thrower Bill Schmidt.

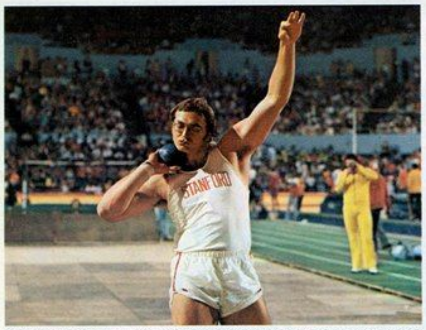
ure, half academy lecturer, half medicine-show barker, a character entirely appropriate to spark the gap, to complete the circuit between science and sport.

Gideon Ariel is a fleshy man, with direct, hazel eyes and a shock of black curls graying at the temples as he enters his 39th year. His accent bears a resemblance to that of Alan Arkin playing Freud in *The Seven-Per-Cent Solution*, but he shouts more. Occasionally brilliant explications to visitors or students are followed by awkward silences because his Hebraic rhythms have made "quats" and "kets" of quartz and cats. Because photography is crucial to biomechanical analysis, Ariel speaks often of "fillums." But it is Ariel's work, not his speech, that has made him a hero to hundreds of athletes.

In November 1975 the U.S. Olympic Committee assembled the 12 best American discus throwers in Los Angeles where high-speed cameras photographed them in action. The film was flown to Ariel's lab in Amherst, where he calculated the forces and accelerations of the athletes' body segments. Ariel himself flew back to California with the results, plopping 50-to-80-page computer print-outs into the bemused throwers' laps. One recipient was Mac Wilkins. The sheets of numbers meant little to him, but not Ariel's interpretation. "He pointed out that my front leg was absorbing energy that could go into the throw," says Wilkins. "I had to begin to change my whole conception of throwing. I used to think I had to put as much of my speed as I could in the direction of the throw."

Ariel, citing Newton's law about every action requiring an equal and opposite reaction, said no. "It's vital to have everything *stopping* in the discus. In the best throws, we found a pattern. It is like using a fly rod, or snapping a towel. You have to decelerate the heavy parts, the legs and the trunk, so you can accelerate the light parts, the arm and the discus." Ariel spoke to Wilkins with special care, because the analysis had shown him generating incredible speed in one section of his spin. "He was like 30% faster than the rest, even though he was dissipating it at the end. But if you see that, you know the potential is there." The computer found that with a perfectly timed summation of his forces, Wilkins could throw the discus 250 feet.

"It seemed a little far at the time," says Wilkins, whose best was 219′ 1″. Indeed, the world record was 226′ 8″. But the second and third times Wilkins put Ariel's advice into practice, he broke the world record, eventually reaching 232′ 6″ and winning the Olympic gold medal at Montreal. He continues to throw, calmly maintaining he has not lived up to his potential, and for once that is a judgment supportable with clear evidence.


After Terry Albritton quit bending his left knee on Ariel's advice, he set a world record in the shot.

Shotputter Terry Albritton's mistake was similar to Wilkins'. "That front leg has to be the solid block you throw from," says Ariel. "What Terry was doing, bending that knee, was like trying to throw from a trampoline or shoot a cannon from a canoe." A year ago Ariel told Albritton he could be the next world-record holder if he'd stop doing that. A month later Albritton was the next world-record holder, with a put of 71′ 8½″.

Sometimes the camera and computer happen upon events that bluntly refute accepted theory. Long jumpers have all trained by rising to their toes under heavy weights, strengthening their calves for the last push from the board. Ariel's analysis showed, however, that the best jumpers don't point their toes until the pushing foot is already two feet off the ground. "Far more important than the jumping leg is the free leg," says Ariel. "It and the torso accelerate as the planted leg decelerates. Then the jumping leg is yanked off the ground. That leg isn't pushing, it's trying to catch up."

In a study of Kansas City Royals pitchers, another commonsense belief fell to clear measurement. "You'd think if the forearm muscles that flick the wrist were stronger, you'd move the wrist faster and throw harder," says Ariel, illustrating by flapping a limb in the manner of a rather aggressive princess thrusting her hand out to be kissed. "But no. Because of the whip action, the concentration of force from the legs and back and shoulder, the forearm is like the end of that snapping towel, the wrist snaps far faster than any muscle can contract. It just goes along for the ride, so it is absolutely useless to train the wrist."

No sport is immune to Ariel's iconoclastic examination. Not long ago, he and his staff spent 4,000 hours analyzing the behavior of tennis balls, filming them at 10,000 frames per second as they struck rackets and assorted surfaces.

"Tennis people think they can feel the ball on the racket. They talk as if they can do things to control it then," says Ariel, waving an imaginary racket. "We

discovered that a tennis ball is on the racket approximately four milliseconds. Four one-thousandths of a second. Human reaction time is 120 milliseconds or more, so that ball is long gone before anybody feels it. It is off the racket even before the racket gives." Such a sharp jolt obviously packs a great deal of energy into the briefest of moments. "The muscles can't react to it, so the elbow, which is a single plane joint and can't pass any of the shock along, can briefly receive a hundred times the force it does when you throw something. No wonder people get tennis elbow."

The tennis ball study was commissioned by a manufacturer who will use the results to design balls that remain on the racket longer. But Ariel was most fascinated by having to devise a new equation to describe the behavior of elastic objects colliding at oblique angles, because these didn't seem to follow textbook physics. "The point of maximum compression is not the point of maximum force," he says excitedly. The commercial overtones of the research did not hold his interest. "They talk about light balls, heavy balls. Such craziness. All the brands were so much the same it was like they were made by the same machine."

Because so many of the body's reverberations end up in the feet, Ariel has long been interested in athletic shoes. "That is the witchcraft business, for sure," he says. "Shock absorption is the key to better distance running, no question, but look." He flips through a book of data. "Some brands absorb 2,300 newtons, some only 1,000. That range! And the manufacturers don't even know what their own shoes do."

Ariel, using an exquisitely sensitive $25,000 force plate, which transmits readings of four kinds of pressure—vertical, forward, sideways and twisting—to an oscilloscope, charted the forces of footstrike in different shoes at every point of foot placement. "You see pictures of runners, it looks like they're landing on their heels, but they're not. The good ones don't. They flick the foot down flat at the last instant. All these companies are making wonderful heels and the best runners are never coming down on them." One company, Pony, bowed to Ariel's advice and has brought out a shoe tested in his lab.

Visiting Ariel's office and laboratory, tucked away in a storefront between Erik's Giant Subs and Radio Shack, one sees wonders everywhere, like the electronic display on which he can call up the style of a shotputter or quarterback in the form of a sequence of glowing green stick figures. "You have to be very responsible to change the form of any good athlete," he says. "The better the athlete, the more it seems wrong to fool with him." So Ariel has programmed the computer to fool with an electronic copy of the athlete instead, changing angles, timing, even weight, and with each change he computes how performance would be affected. Seeing that, the imagination goes spinning off into a giddy future, where performance can be predicted years in advance, where technique and training can be fitted to individual talents. It turns out that Ariel is already disappearing into that future.

"We examined film of Dick Fosbury winning the Olympic high jump in 1968 and of Valery Brumel jumping his earlier world record of 7′ 5¾″. We found that of the total forces generated, the flop style has a higher vertical component. The computer had Brumel use the flop. Had he known about it when he was jumping, Brumel could have cleared 7′ 11″. So we will one day see an eight-foot high jump."


When Mac Wilkins heeded the advice of Ariel's computer, he set a world record in the discus.

Bud Greenspan, who produced *The Olympian* series on PBS television, provided Ariel with slow-motion film from 1936. He wanted to know who was the better sprinter, Jesse Owens or Eddie Hart, the present coholder of the world record for 100 meters at 9.9 seconds. Owens had run 10.2 on cinders, without starting blocks, Hart on polyurethane, with blocks, but Ariel saw no problem. "We knew the angular displacements, so we knew how many degrees per second their ankle, hip and knee joints displaced. We knew the length of the bones and the speed of the film frames, so we knew how much distance was covered per second. We let each man cover 100 meters and computed the time it took him." The winner? Jesse Owens.

The precision with which Ariel's machines can trace movement patterns has widespread application in injury prevention and treatment. "Any little pain will change the pattern of locomotion," he says. Just now, Ariel has finished an analysis of film sent by the Dallas Cowboys, who wanted to find out if injured players were returning to normal patterns.

The possibilities for rehabilitation, or

continued

the teaching of any sort of muscular coordination, are enormous, especially now that Ariel has a little computer that can take instructions from a stick. Unlike the $8 million University of Massachusetts computer that Ariel dealt with through telephone connections and a Telex keyboard, his new one, the size of an electric stove and costing only $60,000, displays a set of functions on a screen and the operator selects the one he wants performed by directing a floating indicator light with a lever Ariel calls a joy stick. In a slot goes a black, magnetic insert that can hold nearly a million bits of information. The term for these is flexible diskettes—"floppy disks," in Ariel's argot. "In scientific training, a man will have his own floppy, containing his whole athletic history and an individual program computed for his needs. As he works in the gym or on the field, the computer will monitor him, giving him instant feedback directions . . . congratulations." Dr. Gerry Purdy, author of *Computerized Running Training Programs* and one of the few men in the field who share Ariel's dual expertise in computers and exercise science, says of this, "My first reaction is that he's bordering on artificial intelligence. Academically, it's not unreasonable, but from a practical standpoint, it's like *Star Wars.*"

Yet clearly the last obstacle to such an instant system is the fact that film takes time to be developed, and video tape is not yet a suitable replacement because of insufficient clarity and speed. But we are at a stage now where a computer can divine an athlete's optimum technique in an event and coach him toward it. "Of course, if a high jumper doesn't *want* to land on his back, that's another problem," says Ariel. "That's psychology. We can't do anything about that."

Gideon Ariel's own psychology is nearly as fascinating as his science. A clumsy, shy boy, he grew up in a boarding school near Natanya, about 20 miles north of Tel Aviv. Poor in sports, he nonetheless longed to be an athlete, and in 1956, when he was 17, he found that the best Israeli discus man had thrown less than 160 feet. Something clicked. "I can do better than that," he said and embarked upon four years of training, almost demented in his intensity. Speaking to a class at Amherst, he said, "If you want to be a discus thrower, you have to live with the discus. Carry it with you. Sleep with it."

That is what he did, with both shot and discus, throwing them as much as eight hours a day. "I threw from pictures. Coaches meant well, but one would say one thing, another would contradict him. It was all opinion. How did they know?"

One who knew a lot more than the rest was Dr. LeRoy Walker of North Carolina Central, who later became head coach of the 1976 U.S. Olympic men's track and field team. In the late '50s Walker coached Israel and Ariel. "He told us to do things we never did, like sprints and weight lifting, and we were all so sore after the first day we said, 'This guy is crazy.' But he had a method. He said, 'Go throw 500 times and we will talk. I can't tell you anything now because your variability is so great.' It worked. I got a pattern down and we could go from there. We talked about forces and angles. It was the beginning of a scientific approach."

They also talked about college scholarships, and after Ariel had taken part in the Rome Olympics and spent three years in the Army, he came to the University of Wyoming. "My life was just to throw the discus," he says.

When he graduated in 1966, it was found that Ariel had spent three years at Israel's Wingate Institute, earning a Diploma of Physical Education degree in 1960. He had never thought to tell anyone about it and had thus completed three years of U.S. college athletic competition without being eligible for it. "Wyoming was fun," he says now, "but the coach wasn't like Dr. Walker. It was back to opinion."

Ariel applied to the newly created School of Exercise Science at the University of Massachusetts, got his master's degree in nine months, became an assistant track coach and then plunged into an eclectic set of studies with all the fervor of his early years with the discus. "There had to be 20-hour days for him then," recalls University of Massachusetts Track Coach Ken O'Brien. "I'd find him sleeping at his desk in the mornings. A professor in one of his classes would mention some advance in an allied field, like calculus or cybernetics, and Gideon would go over and take the course."

One such suggestion came from the head of the computer science department. "He said, 'Why don't you apply computers to your mechanics?' " recalls Ariel, who was sick of laboriously tracing every joint on paper, limb by limb, frame by frame. But how? How to find a way of getting all this raw information into the computer? The answer was a device called a digitizer, a screen lined on two sides by 20,000 tiny directional microphones. The coordinates of any point on the screen touched with a sonic pen are automatically registered and fed into the computer. While visiting the Dartmouth Medical School, Ariel happened across one of these instruments, which looks not unlike a movie screen mounted in a console. "Then in 1968 Dartmouth started the computer time-sharing concept. The potential was unbelievable. All I needed was a $50-a-month rental to put a terminal in my house and I could do anything."

With his keyboard terminal installed, Ariel plunged into writing computer programs. "The whole idea is simple," he says. "Human beings are creative, but we have terrible memories. Computers are dumb, but their memories are perfect. You have to guide them, lead them step by step, channel your creativity through the software, the programs, till you have created a monster. It grows and you have to write more and more programs so it can do more and more things." What sustained those thousands of hours of labor? "It is fascinating work, and frustrating. For example, the equipment in our lab, which comes from 10 or 12 different companies, all had to be electronically interfaced. That was hard to figure out, how to get them working together without burning everything up. The exciting part is the conceiving, the finding out what you think you can do. Then it takes a long time to get the computers to actually do it." In other words, this is exactly like any other worthy craft.

In 1971 Ariel founded Computerized Biomechanical Analysis, or C.B.A., and landed a few contracts testing basketballs for Spaulding and shoes for Uniroyal. This allowed him to purchase more advanced equipment. Purdy predicts that Ariel is now about to reap rewards far above professional satisfaction. "If he's solved those problems of practical application, he'll find a ton of marketable uses. Look what digitizing analysis could do for the sports that are now judged subjectively, like diving or gymnastics. For the first time we could really measure how close a performer comes to perfection. Think of that, we wouldn't have those prejudiced Russian judges in there messing up results."

And there is always the lucrative world of product development. The key to opening it is the software, those valuable programs that are generally not copyrighted (one tiny change in a lengthy series of instructions to a computer obviously can cause drastically changed results). Add the fact that few scientists in the field are business oriented, least of all Ariel, and the situation seems ripe for corporate wrangling. Since receiving his Ph.D. in exercise science in 1972, Ariel has been involved in a train of legal skirmishes with an exercise-equipment company that couldn't stomach his analysis of its product (settled out of court with a public apology to Ariel), and with a colleague and one-time professor over some rights to C.B.A. Possessed of an unshakable faith in his own rectitude, Ariel will surely live out his life as one of those litigation-prone scientists—da Vinci was one—who feel somehow unclothed unless they have six lawsuits pending.

Gideon Ariel does not claim to be a true pioneer in biomechanical analysis. Sweden's Ingvar Fredricson has been studying the motion patterns of standardbred horses with a computer for 10 years, predicting lameness from minute stride irregularities, and discovering that most trotting tracks are banked too much on the straightaways and too little on the turns, placing dangerous stress on delicate forelegs. At Penn State, Peter Cavanagh is well along in a study of human stride patterns. But as Ed Burke, the U.S. record holder in the hammer throw and a close friend of Ariel's, says, "A lot of biomechanical people are contributing in their own quiet way. Gideon is contributing in his own, uh, inimitable way."

Ariel has had occasion to see what he might have ended up doing had he not harnessed the computer. "In 1972 I was in Spain and met with some East German coaches. I looked at the East German shotputters and saw that they all threw with exactly the same form, as if they had been molded that way. They all lifted their back legs before they re-

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leased the shot. I mentioned this and a coach said, 'Oh really? We'll have to correct that.' I said, 'Don't give me that. It's good.' I knew we had something in common, a shared knowledge. Equations of motion are equations of motion. I saw notes from years before. Those men began long before I did. But they'd been doing it *by hand*. Imagine 15 engineers working a month to chart one shotput!"

There are times when Ariel becomes unabashedly sentimental about his U.S. experience, and this memory triggers a paean to the American system. "There was a time when we needed to know relative weights of body segments. We wrote to NASA research and they sent back books of data. No charge. That was a tremendous help. We couldn't have gone on without it. But in East Germany they would say, 'Confidential, classified.' Here, people are open-minded."

As if in recompense, Ariel has offered his services at cost to the U.S. Olympic Committee as it readies for the Moscow Olympics. "Until 1964," he says, "talent alone still worked. Since then sport has been a science, not an art. There is no way anyone is going to beat the talent in this country if it is properly prepared." Since May, Ariel has been spending half his time at the newly opened Olympic Training Camp at Squaw Valley, Calif. (*page 46*), working with field hockey players, soccer players, women's basketball players, kayakers and swimmers. As usual, he has doled out hours of fascinating advice. What is the optimum free throw? "The more limb segments you use, the more chance for error in coordination," he says. "The best players just use the knees for lift, and flip with the forearm. Simplest is best." In a skill as basic as jumping, Ariel brought about a two-inch improvement in one female basketball player whose coach had had her bending her knees too deeply before ascent.

The ice hockey coaches were reluctant to use Ariel's services until he explained to them, for the first time, just how it is that a slap shot by a small player can attain much greater velocity than a sweep shot by a monster. "The better shooters hit down on the ice behind the puck and bend the stick so it becomes loaded with energy. Then they flick the puck, like this," he said, flipping paper balls at the astonished and somewhat embarrassed coaches.

Indeed, Ariel's findings and progress in biomechanical research present a challenge to all coaches. After he stops calling them witches and predicting that a computer-monitored individual training system will do away with them, he backs down a bit, saying, "I can't coach the Dallas Cowboys, but I can give them more information. I can tell them where and how to hit the other players, how to create the greatest force in blocking, how to brace knees, improve helmets. People cry about removing the art from sport. But they started it. Why do you time a runner, or measure a jumper, or count goals? Maybe we shouldn't. But once you decide to use all those numbers, O.K., let's really use them." This has some added force, said as it is while Ariel dramatically unfolds a printout of thousands of multidigit measures of Offensive Tackle Rayfield Wright's center-of-gravity fluctuations, the paper spilling across his desk and onto the floor.

Ariel's old boss, Track Coach O'Brien, has thought about the threat he poses to old-school coaches. "Gideon assumes, rightly, that most coaches don't know biomechanics, physics or biology, and haven't got a burning desire to learn. Coaches just use what has seemed to work in the past. It's true that you can't see enough. We see positions, we see lines, but we don't see magnitude, how hard that foot is pushing. If we are willing to admit we're inadequate in those areas, we will use the techniques he has developed."

O'Brien sees a possible source of resentment in the necessity of coaches relinquishing athletes to outside analysts like Ariel. "Nobody likes to share the credit." O'Brien has observed Ariel's presentations to several coaching clinics. "He's a good entertainer. You pretty much have to respond to the force of his personality, so it is illuminating to watch the people when he's done. Some rush him for more and more. They're all saying the same thing. 'Where can I use it? How the heck can we make it available?' The others are turned off. They drift out shaking their heads, sullen."

One sees the same dark clouds on the brows of corporate sporting-goods executives that fogged the brains of Galileo's judges. Science is no respecter of tradition, and Gideon Ariel is a man of pure, almost innocent, science. In his lab is a scientifically designed shotput shoe. It has laces inside its laces and is twisted, as if a truck had run over it. "Did you ever see anyone put the shot while standing up straight? No. This shoe cocks the foot into position and the double laces save energy. It works." No manufacturer will touch it. "'It wouldn't look so good on display," Ariel says. "And how many shotputters are there in this country?"

A maker of golf shoes wanted C.B.A. to prove its shoes were the most comfortable, comfort being the basis of its advertising. Science had other ideas. "What is 'comfortable'?" Ariel demanded. "Does that mean a man can swing better? What if the best shoes for golf shots make a man limp down the fairway? You cannot high-jump in comfortable shoes. You cannot shoot a cannon from a canoe because the canoe is going under the water. . . ." The golf-shoe people departed with pinched expressions. Later they retained Ariel's services, warily.

A ski-boot company once got Ariel up to Vermont to analyze the forces on the ankle joints of a downhill skier. He proposed, for safety, the use of electric strain gauges on the bindings. "It was as if someone said to General Motors, 'Make an electric car.' It was too revolutionary. There is one word that seems to paralyze these people—that is 'retool.' "

Yet Ariel does not brood over temporary setbacks. His company owns outright all of his equipment, so if contracts or grants should dry up, he could press on with research. And his own competitive juices still surge. Recently, he got a call from an old hero of his, Al Oerter, the 40-year-old, four-time Olympic discus champion. "We, he and I, are going to reenter the ring," Ariel says, his eyes gleaming. "We will put him in a more efficient position. We will cut down on shoe friction. We will overcome physiological deterioration with scientific advance!" Ariel listens to his own echoes in the lab. "He was so nice on the phone, I had to say yes. He told me, 'We competed in the same Games.' But I didn't ever make the final."

Ariel—the scientist who is revolutionizing sport with his sonic pens and slow-motion cameras and computer printouts—smiles, seeing, perhaps, a pattern. "I was always too emotional in the big meets." END