# BLACK BOX

## *What happens when maverick physicists in New Mexico set out to predict the markets?*

### BY THOMAS A. BASS

April 8, 1996. All hell has broken loose in the Chicago exchanges.

A speculative tsunami from somewhere in Asia has washed over the gold market in Zurich before crashing into the pits at the Mercantile Exchange. Hundreds of men and a handful of women, packed hip to butt in raked arenas, are yelling at one another and waving upraised hands, palms out, in a desperate bid to dump Eurodollars. The market is gapping downward faster than orders can get filled. The exchange computers are overwhelmed. Traders in bright-red and yellow jackets look like life-vested sailors clamoring to be saved from a churning market. Everyone is shouting and gesticulating. Palm out means "Sell!" Palm in means "Buy!" Fingers near the face indicate quantity. Fingers to the side of the body indicate price. Upright fingers count one through five. Horizontal fingers count six through nine. Single digits are counted on the chin. Tens are counted on the forehead. A "fill or kill" order looks like someone shooting himself in the temple. "Sell two thousand" is the horns of a cuckold.

In a building nearby, three hundred men and women on the Swiss Bank Corporation (SBC) trading floor are shouting out orders with equal vehemence. They work in a big room lighted by a wall of arched windows looking down LaSalle Street, Chicago's equivalent of Wall Street. The room is dotted with twenty-five octagonal turrets, computer-laden cubbies that group together traders specializing in various markets-foreign exchange, government debt, commercial loans, and the like.

The room is wired into the markets by an electronic ticker tape of red lights dashing along the wall, hundreds of scrolling monitors, forty news channels, and scores of open phone lines. There is also the roar that comes up through the floor when the action gets really hot in the Chicago Board of Trade T-bond pit, which is directly below. Sixty-five billion dollars in United States Treasury futures are traded daily on the Chicago exchange, nearly twice the average volume of trading on the New York Stock Exchange.

For the most part, the look on the SBC trading floor is suburban casual - a lot of penny loafers, chinos, polo shirts. Each trading pod has its own character, depending on the market it plays. Equities traders are smooth talkers who know how to get a date on the phone. Forex is a zoo: traders hop up and down on their chairs. They flash their fingers at one another and yell at phone clerks around the world to buy, sell, straddle, strangle.

"In thirty seconds we're going to buy marks."

"At seventy-four oh-seven, I buy Swiss."

"We have a D-mark fill at fifty-eight ninety-five."

Next to the foreign-exchange turret is the equities desk, which will be trading several million stocks and options on the Chicago, New York, Philadelphia, and San Francisco exchanges in the course of the day. A carrot-haired man wearing bluejeans and a red work shirt sits nearby fielding orders, all the time speaking softly, in a flat, Midwestern accent, into a telephone headset that connects him to the world's major exchanges.

Near him is a fanciful-looking computer, a snappy little PC lit up in fuchsia and blue. The device occasionally makes a noise: Beep! Beep! At every Beep! the trader spins in his seat and hits the speed-dialer. From where the numbers pop up on the screen, he can tell which futures market he is supposed to call: New York for oil; the Merc for currencies; London for European bonds. And he can tell from the color - blue for buy, red for sell - what the machine wants him to do. In seconds, the trader is talking to a Swiss Bank clerk who is flashing the order into a pit. The order gets filled, marked up, time-stamped, and reported, usually within a minute, and never more than three minutes from the first Beep!

A computer like the one at the trader's elbow is called a black box, meaning that its program is a mystery to the uninitiated. The box is emotionless, opaque, obscure. It gives no winks or nods. "The magic gadget is a little threatening," the trader confesses.

And yet people on the floor are impressed by its one salient feature: it appears to have an uncanny knack for being on the right side of trades. Today, with treacherous currents catching almost everyone off guard, this knack seems particularly uncanny. It makes the trader wonder whether the black box might be a harbinger sign that financial markets are about to change the way they do business. What if there were a system for finding patterns in the swirl of numbers, a way of reliably predicting movements in trillion-dollar markets that most people assume are random? Wouldn't the predictors who discovered this Holy Grail be lords of the realm?

The black box is connected to a high-bandwidth telephone line that runs from LaSalle Street west across the Great Plains and over the Rocky Mountains down to Santa Fe, New Mexico, where it ends in a big room with hanging plants, a couch, a table, and a couple of computer terminals. The screens are glowing with the green sawtooth lines of financial markets ticking up, down, up, down.

I-A Box Is Born

August 19, 1991. Doyne Farmer pulls his Datsun 2000 roadster into a parking lot behind 123 Griffin Street - an old adobe bungalow in downtown Santa Fe next to a Chinese herb store called the Green Dragon and across the street from the Santa Fe County Courthouse. He is accompanied by Clara, a Bernese mountain dog.

One of his colleagues greets him at the door, saying, "Have you heard? The Dow is down seventy points. Gorbachev is under house arrest, and George Bush, for the first time in his Presidency, has cancelled a golf game."

Farmer shrugs. Over six feet tall, he is rangy; with slightly irregular features; various parts of him, including his nose and his fingers, have been broken several times and not always put together straight. "Unless you have a CIA mole on the ground, no one can predict a Russian coup," he says. He's confident that he and his colleagues can create a black box able to forecast certain directional swings in the world financial markets, but he knows that there are limits to what can be forecast. He and his dog enter the one-story house, which is furnished with plastic-webbed lawn chairs and folding tables holding five top-of-the-line Sun workstations.

Farmer's old friend Norman Packard arrives a few minutes later. Tall and amiable-looking under a helmet of blond hair, he has the same Western informality and directness that Farmer has. Farmer's exuberance sometimes comes across as rudeness; Packard, who has lived in Europe and is an amateur pianist and a singer of Renaissance motets, has had the rough edges smoothed. Now Packard sits down in front of Seldon, his computer which is named after a character in Isaac Asimov's "Foundation" series who "could foretell the future mathematically."

"We agree with Seldon," Packard jokes." Order must underlie everything, however disorderly it may appear.

Farmer and Packard are partners in a company that as yet has no name, almost no furniture, and no money. It does, however have some of the smartest people in the new science of chaos or complex systems, or whatever one calls this branch of knowledge aimed at finding order within disorder. The immediate task is to develop models for beating the financial markets and then shop for a partner with millions of dollars to invest. Over the years, Farmer and Packard have developed a remarkable intellectual intimacy.

They finish each other's sentences, charging forward into new terrain at the mere hint of some half-formed idea. In fact, the two men grew up together, in a small mining town in the red-desert country of southwestern New Mexico. Farmer was born in 1952, Packard two years later, and both went to college on the West Coast - to Stanford and Reed College, respectively. In the mid-seventies, the two found themselves together again when they started graduate school in physics at the University of California at Santa Cruz.

It was during their graduate-school days that they decided to use their expertise in physics to develop a system for beating the game of roulette. A roulette wheel is a finely tooled machine for creating randomness, but inside this randomness lies order. The game consists of a spinning disk, or rotor, containing thirty-eight numbered pockets (thirty-seven in Europe), and, above the rotor a sloping track on which the croupier sets a white ball in motion. During a gambling jaunt to Las Vegas, Packard saw immediately which physical inputs were required for predicting roulette. Clock the ball spinning on its track. Clock the rotor spinning below. Compute their relative positions. Figure out their rates of deceleration and the arc through which the ball will travel before coming to rest in a numbered pocket. And - this was the tricky part - do all this within twenty seconds, so there would be time to place your bet.

From 1976 to 1981, Packard and Farmer and a dozen fellow-travelers spent their free time perfecting the physical equations and building the equipment to implement them. They created toe-operated, radio-linked computers that fitted into their shoes, and began making frequent trips to Las Vegas. By the end of their last assault on the pleasure palaces of Nevada, in the fall of 1981, they were on their way to acquiring fame, if not fortune, as the world's first players to beat roulette. They might have achieved fortune, too, if it hadn't been for the difficulties entailed in shrinking computers into a shoe. I was a fellow graduate student and a member of that team, and went on to write a book about the project. A decade later, I linked up with Packard and Farmer again, this time purely as an observer; to chronicle (subject to strictures regarding proprietary information) their second attempt at founding a company.

In all likelihood, the kinks in the roulette system could have been worked out with another five years' effort, but Farmer and Packard had, in the mean-time, stumbled on more intriguing problems. Expert at predicting behavior in one chaotic realm, they turned to exploring chaos itself. Specifically, they tried to understand how order emerges at "the edge of chaos" - a phrase that Packard coined and that is now one of the lodestar concepts in the theory of complex adaptive systems. It proposes that the boundary between chaos and order is the most fruitful place for complex systems to emerge. Some scientists believe that cells, brains, organisms, ecosystems, corporations, and economies all exist at the edge of chaos - in a regime not so orderly as to be sterile and not so chaotic as to be meaningless.

In 1980, Packard, Farmer, and two other co-authors published a paper en-titled "Geometry from a Time Series," an early cornerstone in the development of chaos theory. A typical "dynamical system" is water flowing through a pipe, and they showed how one might insert a probe that measured what the water was doing at one point in time and, from this single probe, begin to reconstruct the "geometry" of the water's behavior. For the next ten years, they did research and published a number of key scientific papers on finding order in chaos, until the idea of beating the markets became irresistible.

One spur to action was a 1991 conference on economics held at the Santa Fe Institute, a think tank devoted to studying the science of complexity. The conference was thronged with Wall Street traders and investment bankers, and so many of them seemed convinced that Packard's and Farmer's ideas would make money that the two men decided to quit their jobs and go into business themselves. Farmer resigned as the head of the Complex Systems Group at Los Alamos National Laboratory, and Packard left a tenured professorship at the University of Illinois, where he was a member of the Center for Complex Systems Research. They hired two graduate students, a post-doc, and two research assistants, and set up quarters in the adobe house, which they called the Science Hut.

The Science Hut, which is beginning to warm up on this August morning, looks more like a graduate-student lounge than a business. Standard dress is rubber rafting sandals, Patagonia shorts, T-shirts, and long hair pulled into ponytails. The only real furniture is a big wooden table surrounded by Mission-style chairs, bought at the insistence of James McGill, the company's president, whose job is to assemble this creative riffraff into a bankable firm. His tonsured head, round face, and wire-rimmed spectacles give him the air of a monk. "You can't run a business off folding tables," he says. "The whole operation looks like it

could be gone in a minute."

Packard shares his office, which is really nothing more than an alcove situated between the living room and a sunporch, with a researcher named Tom Meyer, who is barefoot and wearing gym shorts and a fluorescent-yellow sports watch. They sit in lawn chairs with their knees up to their chins and their backs nearly touching. Packard begins loading a model for forecasting the British pound. "When do the London markets open?" he asks.

"I don't know," Meyer replies curtly. "That's Tony's department." Tony Begg, a fortyish computer scientist, is one of the few people there who have ever invested in the markets.

Packard unwinds himself from his chair and crosses the living room into Begg's office. "When do the London markets open?" he asks.

"Six hours before Chicago," Begg answers.

"No wonder my model was so good," Packard remarks. "It was contaminated with future data. I was using opening prices in Chicago to predict the London opening."

"This will help you," Begg tells him, and hands him a dog-eared copy of "The Wall Street Journal Guide to Understanding Money & Markets." "Here's a nice diagram explaining when the markets open and close."

Farmer installs himself at the big table. His office, a small porch off the back of the house, still has no furniture, and the company's one telephone - a rotary model - is here in the living room.

"Tony, would you mind phoning Sun and reminding them to ship the rest of our computers?" he asks.

"I already have," Begg replies, clearing his throat. "They're a bit concerned about our credit rating, and the last time I looked we had one thousand four hundred dollars in our account."

Joe Breeden, one of Packard's Illinois graduate students, walks into the room and starts describing his financial problems. "I'm trying to rent an apartment. 'Where do you work?' they ask. I answer; 'The company doesn't have a name yet.' 'What's your salary?' 'I don't have one yet.' When I start telling them about my stock options and back-end payments, they look at me like I'm a nut."

Tom Meyer pulls his lawn chair up to his computer. It's not a good match: the chair is wobbly and Meyer is six feet seven. He starts punching in numbers and pushing the run button on programs meant to resolve millions of data points - a mess of yen-dollar rates, central-bank statistics, and ticker-tape numbers - into previously unseen patterns. He is practicing the fine art of time-series analysis. Anything of duration, from a Mozart quartet to the stock market, can be reduced to numbers and analyzed as a time series. Into the computer go strings of "1"s and "0"s; out come bar charts, moving averages, and other draw-by-number pictures that can allow even innumerate bystanders to say "Here's a blip that keeps reappearing at regular intervals. Here it comes again, right... now.

"We're not rich yet," Meyer says, still staring at the screen. "But I see some nice numbers here." He stretches his arms over his head and yawns. Then his chair collapses under him. "Worthless piece of shit!" he yells from the floor. Meyer has spent most of the previous night tweaking a computer program called Prophet, which is based on an algorithm that Packard, his dissertation adviser, developed. As a graduate student, Meyer had adapted the program to study fluid flows. One night, he took out the wave data and replaced them with football statistics. Ten years' worth of data produced some surprising rules. When, for example, a visiting team is up against a divisional opponent it has lost to at home in the previous same-season match-up, and the Las Vegas line (the difference that the Las Vegas bookies expect between the points scored by the two teams) has it pegged as an underdog by at least three points, then bet on the visiting team. Meyer, his brothers, and some friends in Las Vegas began using Prophet to run a sports-betting business. The operation cleared more than fifty thousand dollars in its first year.

Before leaving the office for a midday volleyball game, Meyer hands Farmer a report on Prophet's latest run through the currency data. "Look at this," he says, shoving forward a graph. "Futures data on the French franc, the British pound, and the Deutsche mark That's a fourteen-per-cent un-leveraged advantage. I can do better; but it's a start." Meyer hands Farmer another graph that shows surprisingly good

results. "My learning algorithm wasn't learning fast enough," Meyer admits. "So I started teaching it things."

"I hope it didn't learn to over-fit the data," Farmer says lightly. He is referring to a cardinal sin in the new science of nonlinear prediction. Nonlinear equations, when they are graphically plotted, produce curvy lines. Farmer and his colleagues have spent years honing the mathematical skills required to analyze such lines, which can represent a vast array of data points. The trouble is that some of the data are irrelevant to the patterns one is looking for - they are noise, not signal. Graphing every available data point will tell you where you have been but not necessarily where you are going.

"The fact is, we don't know squat about what factors to use in predicting markets," Farmer admits, "But certain patterns have predictive value, because they replicate themselves through time. Our assignment is to find these patterns. This is science. The rest is voodoo."

As the company develops its early models, the senior founders - that is, Farmer, Packard, and McGill - will receive no salaries, while the junior founders, who are also getting an equity stake in the company, will survive on graduate-student wages. But first they have to incorporate themselves as a legal entity. "And we can't incorporate until we have a name," McGill reminds them now. "Maybe we should take a vote on what to call ourselves."

Farmer hands out a piece of paper on which are written all the names that have been suggested for the company. They include "Prophet," "Nostradamus," "Science Hut," "Griffin Street Forecasters," "Infinite Regress," "ETR" (which stands for "eat the rich" or for "economic theoretical research"), "Clairvoyant Comrades," "The Vision Thing," and "Dukes of Destiny."

On September 12, 1991, Prediction Company is officially incorporated. The name is both anodyne and presumptuous, but it is also appropriate.

II-ROAD SHOW

Three days after Prediction Company's incorporation, Doyne Farmer is ready to go on the road. He has no experience in raising investment capital, but his first move is to buy an Italian wool suit that everyone agrees "looks like fifty million bucks." He and Packard routinely share clothing, and other people in the company look as if they, too, would be able to step into the "company suit." Before going to work at Los Alamos, Farmer had never had a checking account or a credit card, and he had never made a financial investment in his life except when he bought a house with his wife. In fact, Farmer's credit rating is worse than nonexistent because of a college loan that went temporarily unpaid during one of his frequent changes of address. Packard's financial history is no better: he owns no house, he has never bought a new car, and he, too, has a bad credit rating - from an accidentally unpaid cable-TV bill.

In spite of their financial history, an appointment has been set up in San Francisco between Farmer and Lee Prussia, emeritus chairman of the board of BankAmerica. After staying up until three in the morning to whip his presentation into shape, Farmer arrives in Prussia's office on September 15th to make his sales pitch. Prussia is interested enough to get on the phone and arrange additional meetings, including one with a Bank of America proprietary trader. Prussia thinks it might be useful for Prediction Company to shadow the guy for a day and compare notes.

This time, it is Norman Packard's turn to wear the company suit. He flies to San Francisco and reports to the bank to watch one of America's largest financial institutions play the world markets. He is surprised when he is introduced to a man and his assistant ensconced in a small room, whose walls are covered with sawtooth graphs. The trader; using a ruler and a compass, has drawn various lines on these charts, which he is using to predict whether the markets will rise or fall.

Packard has stumbled into the lair of a chartist, an occult tape reader who thinks he can predict market moves by eyeing the shape that stock prices take when they are plotted on a graph. All day, the chartist, who is a tassel-loafered gentleman in his fifties, and his assistant watch the numbers, doodle on their charts, and speed-dial orders for currencies, gold, commodities, and options.

Packard mentions that a computer; which can look at thousands of variables - as opposed to a human

being, who can look at only a few - might be good at scanning market charts and finding telltale patterns. Afterward, Packard recounts the man's reaction: "He said, 'No, thanks.' There was nothing a computer could do that he couldn't do better. He'd rather validate the numbers by intuition."

Chartists trace their lineage back to Charles Dow, who co-founded Dow Jones & Company, in 1882, and used it to publish his ideas, later called Dow Theory. Dow believed that the stock market moves in waves, which result from a Manichaean struggle between resistance and support. Over the years, chartists - and they're found at every major financial institution - have developed a curious, sexually charged vocabulary. Markets slide downward, penetrating the neckline, rebound after double bottoms, and break through resistance areas before finally attaining a buying climax. The Dow Jones Industrial Average - the very barometer of American capitalism - began its life as Dow's tool for charting stock-market patterns.

Wall Street investors are divided into two camps. There are fundamentalists (of whom Warren Buffett is the most celebrated) and technicians (of whom chartists are one variety). Fundamentalists pore over economic data and corporate reports, looking for "undervalued" stocks to buy and then sell when the marketplace realigns price and value. That sounds like common sense, and yet if, as many economists believe, markets are "efficient" - continually fine-tuning themselves to available information - one should not expect to find "undervalued" stocks. For every Buffett who makes a killing in the market, thousands of would-be Buffetts get wiped out.

Technical analysis, on the other hand, cares nothing for "value" or other economic fundamentals. It claims that everything one needs to know about a company's stock performance can be read from the "tape" - that is, from the history of past prices and the volume of trading at those prices. Both fundamentalists and technicians can use pattern recognition or build models to forecast market trends, and Prediction Company relies on both kinds of data. But technical analysis, as it is traditionally practiced, is a fairly mystical enterprise.

"It's like the Middle Ages again," Farmer says. "The alchemists are holed up in their caves with their 'Elliott waves' and their magic spells, searching for incantations to foretell the future. Many are charlatans or misguided numerologists. But that doesn't mean all of them are.

At the end of September; 1991, Farmer and Jim McGill fly to New York for five days. As they begin trooping through executive suites, Farmer develops an anthropology of corporate New York from the seventieth floor. "I start to tune into the layout of these places, which tells you a lot about how they're run," he says. "Most of them have glass walls, with incredible vistas. Sometimes there is an open floor plan, and everyone, even the secretaries, gets the view. Other times, there are lots of walls, and only the bosses get the view."

His first New York sales pitch is at Kidder Peabody, at 60 Broad Street, between Wall and Water Streets. Farmer is surprised to find himself ushered into a conference room where thirty traders and executives are expecting him to deliver a lecture. He grimaces on being given a rousing introduction as the man who beat roulette and invented chaos theory, and who is now going to beat the stock market.

The traders in the room are wearing broad-shouldered suits and rep ties. Farmer cuts a leaner profile in his Italian suit and an Escher necktie. He is all springy intensity, with his deep-blue eyes and his Brillo pad of brown hair curling over his ears. Combining the hard edge of a scientific skeptic with the enthusiasm of a gold bug, Farmer launches into a lecture on financial forecasting. It is a bravura performance.

Everyone knows that prices in financial markets move up and down, but no one knows why or how, he says. "Economists claim that these price moves are a 'random walk' - that they are the unpredictable product of 'efficient markets,' and that prices in these markets reflect the activity of rational, logical, and always equally well-informed investors," he goes on. "I don't know about you, but I'm not always a rational human being, and I think this is a pretty far-fetched view of the world." Prediction Company assumes that the random-walk hypothesis is wrong: "There are patterns in market data - they appear more often than one would normally expect, and they reappear in the future. We monitor many inputs, continually evaluating which ones are relevant. We look for pockets of predictability, shifting regimes where order can be found emerging from what are otherwise highly chaotic time series.

When the new technology is applied to market data, he says, it produces substantial returns, and the odds that the returns are merely the result of chance are remote. His listeners, he is able to report back to his colleagues, seem impressed.

Farmer and Jim McGill press on, shuffling from Wall Street to midtown and back, riding elevators to meetings at Citicorp, Salomon Brothers, Goldman, Sachs. Dozens of busy executives file into conference rooms to hear Farmer's sales pitch. By the end of his tour, a surprising number of people are willing to open their checkbooks and make a bet on Prediction Company. Among the contenders are Kidder Peabody, Montgomery Securities, and PaineWebber. These companies represent a thick slice of American capital, with billions of dollars among them. Unfortunately, most of them also want an ownership stake in the company, and that's something Packard and Farmer are loath to give up.

As Farmer finds himself making more presentations to Wall Street financiers, his lecture acquires illustrations. The most arresting of them is a black-and-white photograph of what looks like the chaos from which God created the world-night and day swirling around each other in an inchoate mass. But, as one stares at the picture, patterns begin to emerge. One sees vortices of night curled into whirlpools of day, and these starry patterns repeat endlessly, like a mirror image reflected back on itself. Farmer keeps a framed copy of this picture on his office wall.

The picture first appeared in a scientific paper by two fluid dynamicists, Garry Brown and Anatol Roshko, entitled "On Density Effects and Large Structures in Turbulent Mixing Layers," published in 1974 in the journal FLUID MECHANICS. For centuries, scientists have known that patterns exist in turbulent fluid flow. Leonardo sketched these patterns in his notebooks, and they can be observed by anyone lazy enough to sit beside a rock-filled stream on a summer day. The stream forms little whirlpools that come together and break apart as the water gurgles downstream. But what does one see when there are no rocks and the stream is a raging torrent?

Is there order in the apparent chaos? In the early nineteen-seventies, Roshko and Brown built a wind tunnel equipped with nozzles for mixing gases flowing at different speeds. When a high-speed stream flows next to a low-speed stream, the interface between the two becomes turbulent. Brown and Roshko's apparatus was outfitted with a high-voltage spark for a light source and a device for taking pictures of the turbulent region. Their famous image shows two gases, helium and nitrogen, flowing next to each other. Where the two gases are mixing, one sees "coherent structure" - swirling white vortices, like waves breaking in the ocean.

"I couldn't believe what I was seeing," Garry Brown recalls. "There was an organized structure in the randomness of the turbulent motion."

Imagine that, instead of blowing gas down a wind tunnel, you are blowing money - all the money in the world - and it's tumbling in great streams of investment capital: Eurodollars, forex cross rates, index funds, straddles, strangles, floaters, and other financial flows that move daily through the world markets. "What you really want is a movie that would highlight the transactions of all the traders in the world," Farmer says. "In this movie you'd be able to follow the money flowing back and forth. You'd want to probe it for evidence of large-scale structure. The trick is to find the right probes and ways to analyze the data coming off them."

Why would there be structure in financial markets? Why should the data duster in predictable patterns? The short answer is simple: financial markets are the product of human activity, and human beings are trend-following, herd-driven creatures, who react and overreact en masse. "I believe in the inefficient-market theory, based on human foibles and the herd behavior of people acting in groups," Farmer declares.

Suitors have begun trekking to Santa Fe. Some are rich and smart. Some are rich and not so smart. One thing that they keep mentioning is the sheer size of the financial markets. Speculators swap more than a trillion dollars a day in foreign exchange - fifty times as much as the entire output of the American economy. One suitor; an experienced blackjack card counter who runs a commodities-trading company in California, tells Farmer that if Prediction Company plays it right the company could earn five hundred million dollars in the next five years.

"Once you hear these numbers, you realize that even a small advantage can allow you to make a huge amount of money," Farmer says. At this point, we were getting jazzed on the large numbers that people were tossing around. Even if we didn't believe it for a second, there's an undeniable adrenaline jab that comes from someone's telling you you're about to make five hundred million dollars." The predictors allow themselves to fantasize about being rich. In their customary, hyper-rational way, they begin computing how much money a person needs to be really rich.

The predictors also explore the moral issues involved in being rich. "Since most of the rich people in the world are assholes, what is the secret of being rich without being an asshole?" Joe Breeden, the researcher; wonders one day at the Science Hut. "Frankly, I have problems morally with what we're doing. The futures markets are a zero-sum game. For us to be winners, somebody else has to be a loser. We'll be taking money from orphans and widows."

Packard argues that Prediction Company will damp out the oscillations in the markets and actually make them more stable, helping companies that want to borrow money put people to work. "I'm not sure who it is we'll be taking money from," he admits. "But I think that, instead of widows and orphans, it's more likely to be short-term speculators."

All these concerns are premature, however; given that Prediction Company has yet to find a partner. There has been a lot of dating and no shortage of proposals, but none from Mr. Right. The company is spurning Lone Rangers and other rich people whose money comes with too many strings attached. "I'm totally sick of negotiating," Farmer complains. "We do a little dance where we reveal enough about Prediction Company's strategy to make it tantalizing but not enough to give away company secrets. It's an intellectual striptease."

III-THE PERFECT GIRLFRIEND

Norman Packard flies to Chicago on March 12, 1992, to do the company striptease for O'Connor & Associates. O'Connor has six hundred employees and shuffles billions of dollars through the futures, options, and currency pits. It is Chicago's biggest dealer in derivatives and "risk neutral" positions, which are hedged portfolios designed to make money whether the markets go up or down. O'Connor; which is in the process of being bought by the Swiss Bank Corporation, is the most mathematically astute and computer-intensive broker-dealer in America.

Packard is shown onto a balcony overlooking the trading floor, which is as large as a football field and is buzzing with the feral energy that comes off traders in mid-play. Next, he is ushered into a conference room with windows looking onto O'Connor's electronic ticker tape. Several of the company's partners are present, including David Weinberger, the former managing partner. Weinberger, who once taught computer science at Yale, is a trim, athletic man in his mid-forties, with salt-and pepper hair and the nervy assurance of someone who has mastered every game he has ever played. Many of the others present are M.I.T graduates, including Clay Struve, a mustachioed, ruddy-faced man in his early thirties who is drinking two Diet Cokes simultaneously He sits mute in meetings, an all-knowing sphinx. He looks like a hard-drinking frat boy in a rugby shirt, but he has a gift for doing large calculations in his head. He is the O'Connor partner in charge of "risk." The company plays the derivatives markets with leveraged portfolios whose face value is many billions of dollars. Get the numbers wrong, and you go out of business. Struve keeps O'Connor's numbers between his ears.

Packard, in his presentation to the partners, describes how market data seem to hold predictive patterns. Struve is generally silent, with nothing moving across his rosy face except the hint of a smile. At the end of Packard's presentation, though, he delivers some remarks that his colleagues interpret as wild enthusiasm. "We believe there are edges that can be collected because the market is not quite efficient," he says. "The anomalies are hard to find and take advantage of, but with the right microscope and the right hedging you might be able to do it. You people are on the right track. It looks good."

"This is a religious issue," Weinberger adds. "Either you believe there is structure in the markets or you don't."

Struve wants to do a deal. Weinberger and the other partners want to do a deal. Jim McGill is instructed to

negotiate a contract. All the money is there, in exactly the kind of hands-off arrangement that Prediction Company has been searching for. "It's like meeting the perfect girlfriend," McGill says, back in Santa Fe. "I've done lots of deals, but this one is making me nervous.

In April, it is agreed that Prediction Company and O'Connor will sign a five-year contract. O'Connor will put up the money to fund the development of Prediction Company's trading technology. A much larger chunk of capital will be used to deploy the system. Prediction Company will get a slice of the profits. (A figure between ten and twenty-five per cent is typical in the industry.)

Prediction Company starts designing the black box that will be placed in the middle of Swiss Bank's trading floor. July 1, 1993, is the predictors' self-imposed deadline for going live, which means a lot of tweaking in not a lot of time. Soon after they first set up their lawn chairs and folding tables down on Griffin Street, the predictors learned an essential truth about financial forecasting: there is no single best model for this kind of work. There are good models and, for certain kinds of markets, there are very good models, but the best results come when you keep generating models and selecting the "fittest" among them. So one feature they're refining is a mechanism for nurturing populations of models that are continually being blended and recombined before they are polled for their best opinion.

The predictors are also developing artificial neural networks - systems designed to recognize patterns and devise general rules for acting on these patterns. In the end, such a neural net might have six inputs: the yen-dollar rate, the Deutsche-mark-dollar rate, the yen-Deutsche-mark cross rate, the yen bond, the three-month interest rate, and a figure describing the Japanese money supply. But pumping raw numbers into a neural network is like pumping raw sewage into a water system. It gets murky fast. So the numbers have to be transformed in ways that enhance their significance. Closing prices, for example, might be combined with trend and volatility indicators. How one transforms the data going into a neural network is the real trade secret that differentiates the work of amateurs from that of pros. Prediction Company, as it develops its tradecraft, will eventually compile a hefty manual of statistical transformations.

The company fails to meet its self-imposed deadline, though. It is not until the fall that SBC begins tentative live trading of Prediction Company's signals. After that will come another year of low-level testing, debugging, fire drills, and jumping over numerous performance hurdles before trading even remotely approaches the value of Doyne Farmer's fifty-million-dollar suit.

IV-DRAWDOWNS

On August 9, 1994, with models for oil, currency, and equity futures running faultlessly in a rebuilt trade engine, Prediction Company flips the switch on a new set of programs. Orders flow out to buy and sell contracts whose face value is measured in the millions of dollars. A big cheer goes up among the predictors, who are crowded around the trading console. Finally playing with real money in real time, they watch the numbers spiral upward and imagine the same thing happening to their bank accounts.

A few days later, as soon as Farmer and his dog walk in the front door; he knows that something is wrong. The researchers who have gathered around the trading console are wearing long faces. Farmer strides toward the monitor. He can tell at a glance what's going on. "We're getting creamed!" he shouts from halfway across the room.

"The Fed is adjusting short-term interest rates, and the bond markets are going crazy," says William Finnoff - a recently hired researcher. He's a dark-haired, wiry, Olympic-level athlete who once hoped to be on the American luge team. "It was a surprise announcement."

The monitor offers a bright-colored display of what is happening, tick by tick, in Chicago, New York, and other major markets. Yesterday, the trend lines were tilted nicely upward. They augured clear sailing through light seas. But today the markets are plummeting so fast that the green trend lines are beginning to break apart as they fall relentlessly toward the bottom of the screen. "The market always overreacts," McGill cautions, his eyes impassive behind his round spectacles. "Don't be surprised if you see it turn around as fast as it's dropping."

By the end of the day, the crowd huddled around the trading console has watched the portfolio lose more than a hundred thousand dollars. By the end of the week, it will have lost a good bit more. Nothing is

going according to plan. This is real money getting sucked down a hole.

In order to steady people's nerves, Packard tapes to the wall above the trading console a graph showing Prediction Company's probability of taking losses of different sizes. Today's drawdown is a one-in-twenty event. It could have easily happened at random, which makes it a cause for concern but not for alarm.

To smooth out the ride, Prediction Company is relying on the law of large numbers. With one coin flip, there is a fifty-fifty chance of getting heads. With ten coin flips, the chance that all ten coins will come up heads is roughly one in one thousand. Similarly, if ten Prediction Company models are trading in ten different markets the chance of them all losing at once is much smaller than the chance of any one of them losing.

After the initial fright, the predictors are pleased to see their system right itself. Fall shades into winter, and Prediction Company is cruising along, with the portfolio making a few hundred thousand dollars a month, when one day David Weinberger has an angry confrontation with Packard. "What the hell is going on?" he demands. "I just found out you guys cut the position in half. We won't stand for it!"

Packard tries to calm him down, but Weinberger is on a rampage. The problem is Prediction Company's use of "interventions." These occur when Prediction Company asks SBC's traders to override the models by cutting orders in half or abstaining from the markets altogether. This substitution of human judgment for computational analysis is supposed to be reserved for rare occasions, such as major "number days," when federal statistics like the unemployment rate are announced. News events can drive the markets in unforeseen directions, and it sometimes seems prudent to stand clear of these oscillations. But Weinberger is convinced that the predictors are trigger-happy - far too ready to intervene.

"This is no time to lose your nerve!" he yells at Packard. "This is an experiment. You're building an automated system. You don't put your finger in the middle of it and diddle the results. You play it where it lays. The one thing we demand in our business is absolute discipline!" Weinberger is pacing from wall to wall, jangling the change in his pocket.

"Discipline," Packard agrees. He knows that when Weinberger starts shouting, the best response is to roll into a ball and sit there like a hedgehog. "We could all use some discipline."

The upshot of the discussion is that the people at Prediction Company are supposed to work more closely with SBC's traders and keep interventions to a minimum. This is another important step on their way to becoming seasoned professionals. Later, when they study the numbers, they realize that the portfolio would have made a lot more money if it had been allowed to run hands free.

"You have to be willing to put all your money in the pot and see what happens," Farmer says. "Our roulette experience is good training for this business. It's scarier than hell, hanging out in the breeze, but when the odds are in your favor you have to swallow your fear and hold on."

In the three days before Thanksgiving, 1994, the portfolio makes a few hundred thousand dollars in profit. By the end of the year, it is solidly in the black. "It's almost scary how our predictions are coming in right on the money," Finnoff muses, standing at the trading console and watching the numbers tick down to the last trade of the year. He cracks a big smile as the models record their final win. To celebrate their good fortune, Farmer hosts a New Year's party at his house. They all join in to sing "Wabash Cannonball" and "Bye, Bye Love" as they work their way through a case of champagne.

V-MARKET FORCE

The Swiss Bankers are visiting Santa Fe at the end of January, 1995. In preparation, there is a big push to get the old models functioning faultlessly and new models on line - including models for trading equities on the New York Stock Exchange. Farmer and Packard and their dozen colleagues are staying up nights trying to hack the new models into production. Researchers jog in and out of one another's offices, speaking in rapid-fire bursts about "fat tails," standard deviation, and "degrees of freedom." They realize they need more researchers, a larger staff. They're hoping the Swiss will agree.

"Weinberger has been talking to me about what he calls the 'million monkey' phenomenon," Packard tells Farmer. If a million monkeys start typing, one of them may tap out some lines from Shakespeare. "How do

they know we aren't making a million models and just showing them the best ones? Our profit was good for the year, but, for all they know, it could have been luck, rather than skill."

"This is why we need to raise our draw," Farmer answers. "With more people, we could develop better tests for knowing whether we have winning models or lucky monkeys."

Prediction Company is now installed in an old Coca-Cola warehouse down by the Santa Fe railroad yard. Part of the ground floor is rented by a bearded psychic called White Buffalo. In addition to selling crystals and incense, he offers something called White Buffalo Transforms, which take place in a small room in the back of his store. According to his literature, these "transforms" are capable of channeling "healing energy to your physical, emotional, and spiritual wounds."

Every so often, one of White Buffalo's clients accidentally walks into Prediction Company. "We're developing strong psychic powers of our own," someone jokes. "White Buffalo transforms. Prediction Company transforms. There's powerful stuff working here."

On January 23rd, when David Weinberger, Clay Struve, and the other Swiss Bank people take their seats at the conference table, Farmer tells them where the company is headed.

"All the data agree," he says. "The key to success is to spread ourselves over as many models as possible." He projects a schematic diagram of the company's Deutsche-mark model. "We create a little competition among the dozens of models that are working inside this one big model. We round up the usual suspects and let them trade against each other. It's survival of the fittest, with the best models reproducing themselves and populating each successive generation of models with more of their offspring."

Farmer shows a slide summarizing Prediction Company's recent research accomplishments. The final bullet on his slide announces, "The Holy Grail of market prediction has been reduced to a software problem." This elicits a few chuckles from the audience, and even Farmer admits that market prediction is not yet the kind of science that allows one to sleep peacefully at night. "I'm scared to death about hitting bad luck in live trading," he admits.

Weinberger is enthusiastic but cautious. "We have to think big and aggressive," he says. "But nothing proceeds until the models kick in and we start making money.

Three miles up a winding mountain road that leads to the Santa Fe ski basin is a Japanese bathhouse called Ten Thousand Waves, which offers hot tubs that are shrouded in mist and are blissfully calm; only the sound of prayer bells tinkling in the hills disturbs the silence. Early the following afternoon, when the Swiss Bankers have flown home, Farmer and Packard swap their clothes for kimonos and climb a shale footpath that winds among the hot tubs and cold plunges. When they reach the communal tub, they drop their kimonos and sink into the hot water Steam rises around them. The water is fragrant with the smell of cedar. They drape their arms over the sides of the tub and let their legs drift weightless in front of them. They stare into the mountains.

"Sometimes I think we're crazy to be doing this," Farmer says. "Every time we finish one of these meetings, I have to fight an adrenaline letdown. Last night, I felt so lousy I was ready to quit." A little later, he muses, "I sometimes wonder if we took a wrong turn, into an intellectual backwater."

"What do you mean?"

"We've had to learn a lot of useless stuff, like the fact that a tick for a German-mark contract equals twelve dollars and fifty cents."

"There is a lot of arcane stuff in physics, too, like Reynolds numbers," Packard reminds him.

"But Reynolds numbers are universal," Farmer protests. "They know on Mars what Reynolds numbers are."

Packard laughs. "You're only saying this because you're a physicist."

"Getting a degree in physics is more mind-altering than three years of brainwashing by the KGB."

"One could say the same thing about founding a company," Packard replies.

VI-Money On The Floor

In June, Prediction Company gets another rude lesson in the distance between theory and practice, when its crude-oil model, which looked good on paper, gets pummeled in the futures market. The trouble is that the prices at which contracts are actually traded are not always the prices quoted over the satellite feed. The gap, which traders call slippage, or market friction, can be as much as two hundred dollars for a contract.

Prediction Company dispatches someone to New York to find out what's going wrong. It doesn't take long. On the trading floor of the World Trade Center, there is the usual hurly-burly of traders bellowing at one another and flipping hand signals off their noses until 3:05 PM, when the order based on Prediction Company's signal arrives. Amazingly, the market quiets. Everyone turns to look at the broker fielding the order. He is trying to buy three hundred futures contracts. Each contract equals a thousand barrels of oil. This three-hundred-thousand-barrel order, in a market whose total daily volume is about ninety million barrels, represents a significant piece of the business on the floor.

As soon as the trader makes a move, everyone piles onto his order, and the market price starts gapping up ten, twenty, thirty dollars, before the order is finally filled. Then, as soon as his business is out of the way, the locals let the price fall, having scalped out the profits that will allow them to go home happy men.

Farmer has been developing a new theory of "market force," and, though he never intended to test it by dumping money in the markets, this scene provides a case study in how market price is pushed around by order flow. One solution to the problem is to break up orders and trade at different times of day. Soon the market friction generated by Prediction Company's signals drops to nearly zero, for savings of close to a million dollars a year.

In August of 1995, everyone at Prediction Company flunks the quarterly objectives. The members of the software-modeling group, still debugging a hundred thousand lines of code, miss the 2.0 release date. Their aim is to combine the company's historical and real-time data in one package, or platform, which is a standardized set of tools designed to crank out thousands of predictive models for everything from American stocks to Japanese bonds. "It's nice, very nice," McGill says, watching a demo. "But you get a zero for missing the release date."

The members of the research group are faring no better. Their current project is to model the most actively traded stocks on the New York Stock Exchange, but it remains a gleam in their eye while they wait for 2.0 to come on line. The company is currently trading models in a range of futures markets, including T-bonds, oil, Deutsche marks, yen, the S. & P. 500 index, and German bonds. The P. & L. is up a few million dollars, but every one of those dollars feels as if it had been laboriously hand-printed in Ye Olde Prediction Shoppe.

Things get worse. August is a good time for the Federal Reserve Board to intervene in the currency markets. Traders are on vacation, and the markets are thin, so the government's money stretches farther. The Fed tries to prop up the United States dollar by selling Japanese yen and German marks. Central-bank interventions are like the hand of God reaching into the Newtonian universe to jimmy the mechanism. This month, when the Fed reaches into the market and changes the settings, Prediction Company's models are on the wrong side, losing a bundle of money in the process.

More than half a year later, on April 8, 1996, the predictors find themselves bracing for another unforeseen disruption. Panic strikes the Chicago exchanges as a wave of sell-offs spills from foreign exchange into commodities and the bond markets. Traders in Chicago are drowning, but all morning Prediction Company's models have been recommending short selling - dumping shares in markets predicted to fall. Farmer and Packard head out to lunch. When they return, they glance at the computer screen where the portfolio's profits are tallied. "Not bad," Farmer says, smiling. "That was a million-dollar lunch."

Later in the afternoon, the predictors grab some champagne and head upstairs to their rooftop gazebo to celebrate. Below them lie the red adobe houses of Santa Fe, over which hangs a leafy gauze of cottonwoods and willows. Off to the east rise the snow-covered peaks of the Sangre de Cristo - Blood of Christ - mountains. Falling away to the west are the layer-cake mesas of the Rio Grande valley. The air is tangy

with the smell of burning piÔon.

"Who knows? Maybe we've finally cracked the problem," Farmer says to Packard, who is stretched out beside him on a lounge chair "In any case, it sure beats losing."

He pours another round of champagne. Packard raises his glass. "To the next million," he says.

VII-Escape Velocity

October 27, 1997. Almost sixty-eight years to the day since the crash that marked the onset of the Great Depression, the Dow-Jones Industrial Average plunges five hundred and fifty-four points, with the market losing seven per cent of its value. This is the worst day in a decade, and the twelfth-worst day in the market's history. The 1997 crash follows a tumultuous autumn, with massive devaluations and collapsing markets in Thailand and elsewhere in Southeast Asia, but once again the experts are mystified by the day's events. Why should the markets crash? Why today? The only thing they know is that markets display a greater than normal predilection for extreme events, and it is these events that can wipe out all but the most cautious of market players.

Prediction Company's models are supposed to have winning days whether the markets go up or down; the strategy is designed to be "market neutral." Even so, it is with trepidation that the company's employees gather around the trading console to watch the markets crash. William Finnoff directs a fierce gaze at the numbers. Packard paces the room. Farmer and his dog, Clara, stare at the screens. Everyone watches the green lines break up and gap downward as the markets plummet. The predictors hold their breath, waiting for the first signs of how their orders are getting filled.

Suddenly, a big cheer goes up, and they begin clapping one another on the back as the prices tick upward and the daily P. & L. clocks a tidy multimillion-dollar profit. This is the portfolio's best day yet.

"Way to go!" Farmer shouts, giving Clara a hearty rub behind the ear. "Not bad," Packard acknowledges, with a broad grin on his face.

By mid-December; Prediction Company has switched to a new trade engine, which allows for fully automated trading on the New York, NASDAQ, and other exchanges. The predictors take a much needed week's vacation between Christmas and New Year's. They return to work in January to find that the portfolio has been clocking a steady succession of wins.

Toward the end of the following year, financial markets around the world begin to tumble, along with the speculators who play them. George Soros loses two billion dollars in a bad bet on Russia. The news contains some cautionary tales. D. E. Shaw & Co., a sophisticated user of mathematical algorithms which is run by a former computer-science professor, loses several hundred million dollars of Bank of America's money. And Prediction Company's Swiss partner - known, since a merger earlier that year, as UBS - takes losses, too. It turns out to be a major investor in Long-Term Capital Management - a Greenwich, Connecticut, hedge fund that would have gone belly up without a three-billion-six-hundred-million-dollar rescue package brokered by Alan Greenspan, the chairman of the Federal Reserve. It is an anxious time, and yet Prediction Company keeps quietly racking up its winning bets to close out its most successful year to date.

Prediction Company's strategy for going forward is to model all the world's stocks that are traded with some frequency, and then go back and rebuild the company's foreign-exchange and futures models, which, after their initial success, suffered a bumpy ride. Packard and Farmer could never shake the fear that these models, built in haste, had become "overfit" from peeking too many times into the future. The company's stock models, on the other hand, look better and better all the time, even against the background of an unprecedented bull market.

But the process of fine-tuning the models continues. Packard is designing filter models that are good at weeding out losers. Farmer and the research group are cranking out new models for a few thousand of the most actively traded stocks in the United States. They are even thinking about designing a black box for doing inter-bank currency trading electronically. The idea is to trade all foreign currencies in a rapid-fire system that simultaneously buys and sells the same currency. The world has a dozen banks with pockets deep enough to play this game, and War-burg Dillon Read - the UBS investment bank that actually man-

ages the Prediction Company portfolio - is one of them.

The push to develop black-box financial systems is an arms race that the world's major financial institutions have joined. The bulge of credit that moves around the globe with the sun and the time value of money, whose bits and bytes are flowing with ever-increasing velocity, dictate that success goes to the swift. Moving with equal rapidity are the risks that can wipe out unsuspecting players. "Less sophisticated technology will lose out over time to more sophisticated technology," says Andrew Lo, who directs the financial-engineering program at MIT. "This is why the Old Boy network is being replaced by the computer network. Call it revenge of the nerds, but everyone on Wall Street is scrambling to develop computer-driven trading programs." Physics and finance are converging in what might be called "phynance."

Success in this endeavor can have paradoxical results. For one thing, success invites imitation, which in the world of black-box financial forecasting is a liability. Your edge is dulled as competitors pile on to your strategy, and if the strategy is too widely adopted it is no longer useful for playing the market; instead, it becomes the market. To continue winning, one has to keep a few steps ahead of the competition. "It takes a huge amount of work to build this kind of infrastructure, particularly here in Santa Fe," Packard says, evaluating Prediction Company's progress over the years. "We went from not knowing what a stock option was to being market players. We pulled it off. We did everything we set out to accomplish, save for making ourselves filthy rich, but, hey, tomorrow is another day."

The latest reports from Santa Fe are encouraging. One sign that you've found structure in the markets is that your balance sheet turns an inky shade of black. Packard has bought his first house, an old adobe with a walled yard, just down the hill from Farmer's. Farmer has refurbished his Datsun 2000, which is kitted out with a cherrywood dashboard and a leakless top, and he has built a new office, in the yard behind his house. Most of the quarterly objectives are being met. Financial reports are getting filed on time. The model builders are picking up speed, and, though the figures are confidential, they say the P. & L. is looking good. Over the past year; the company has outrun the indexes, Packard reports, and made returns on capital which place it near the top of its field. "We're reaching escape velocity," Farmer declares. It's clear that he and Packard are looking forward to spending more time in their gardens thinking about the evolution of complex systems, rather than living in the middle of one.

"We have a long list of things to do if we ever have enough money to do them," Packard says. He is talking about funding research projects - maybe even building an institute to work on complexity and other hard problems.

"Yes, it's a long list," says Farmer, glancing over at the monitors, with their sawtooth lines ticking up and down.