

Computers Amplify Black Monday

The sudden stock market decline raised questions about the role of computers; they may not have actually caused the crash, but may well have amplified it

The stunning plunge of the stock market on Black Monday last week has brought the role of computerized trading to public attention as never before. Computer programs now routinely trigger buy and sell decisions for enormous blocks of stock in large portfolios such as those of pension plans. In the aftermath of the 19 October market plunge, speculation about possible causes ranged from the federal deficit to worries about inflation. But analysts and members of Congress were quick to ask whether computerized trading was largely to blame.

The immediate answer is that no one knows for sure. However, in interviews with *Science*, analysts and computer experts indicated that the practice of computerized trading—the buying and selling of huge blocks of stock at a keystroke—had greatly magnified the market's fall on Black Monday, in much the same way that feedback in a public address system will amplify a normal sound into a screech.

As it happens, there is little hard evidence about computerized trading beyond gut feelings and anecdotes, largely because the Stock Exchange has no way of knowing which stock orders have been placed by computer and which have not. However, it is an issue worth thinking about in some detail. Large-scale, distributed computing systems have been implemented or proposed in a wide variety of applications, ranging from automated manufacturing, to automated funds transfer among banks, to automated air traffic control.

The automated stock market may thus hold some important lessons for the future. Indeed, recent scientific research suggests that large distributed systems of this kind may be governed by the mathematical theory of chaos—which means that they may be inherently unpredictable, subject to wide swings in behavior without warning or reason.

By Monday evening, dazed brokers were grouching about “inhuman machines,” and New York Stock Exchange chairman John J. Phelan, Jr., was telling reporters that the day had been “as close to financial meltdown as I ever want to see”; the next day he asked that computerized trading be suspended. By

midweek, Securities and Exchange Commission chairman David S. Ruder had ordered a thorough investigation of the affair, with computerized trading high on the agenda. Congressional finance committees were launching investigations of their own, and computerized trading practitioners on Wall Street were getting downright defensive. As one young trader put it, “We’re seeing a lot of computerphobia.”

Computerized trading comes in a variety of forms. But all depend on the fact that the securities markets of the world have evolved into one vast electronic data exchange during the past decade. What happens in London, Chicago, or Tokyo is instantly known in New York, and vice versa. On the exchange floor, meanwhile, no trader is ever more than a few paces from a terminal or a display monitor. The New York Stock Exchange has 122 Tandem minicomputers just to monitor its transactions and to keep its pricing information scrolling across the screens in real time.

In this environment it is a simple matter for an institutional investor, for example, to hedge against losses. All the investment manager has to do is program his own computer to monitor the minute-to-minute performance of his stock portfolio. If the price begins to fall below a certain trigger point, he can send a “sell” order to the floor with just a few keystrokes. If the price begins to rise again, he can likewise respond with a keystroke “buy.” This practice, known as “portfolio insurance,” is commonly followed by corporations, pension funds, endowments, and the big brokerage firms themselves; it now covers about \$60 billion in stocks.

Another strategy that is well suited to computers is known as program trading, or more precisely, stock-index arbitrage. The idea is to generate high short-term returns by taking advantage of price discrepancies between markets. (That is what the French word “arbitrage” means.) In the most popular approach, each brokerage firm will act on behalf of their institutional clients by preparing packages, or “baskets,” of stocks that duplicate the 500 stocks used in the Standard and Poor's stock index. Then each of the firms will watch very closely what is

happening in New York and in Chicago.

In New York, of course, the value of the basket will be determined from moment to moment by the value of the individual stocks. In Chicago, however, the traders at the Chicago Mercantile Exchange are dealing not in stocks but in stock futures—that is, in contracts to deliver a fixed quantity of stocks at a fixed price at a fixed time, usually a few months in the future. Since these particular futures are pegged to the Standard and Poor's index, their price at any given moment should, in principle, be equal to the price of the basket. In practice, however, the marketplace is not perfect and discrepancies do arise. The differences are usually only a few percentage points, and they rarely last for more than a few minutes. But they are exactly what the arbitrageurs have been waiting for. Within seconds of an opening's appearance, keystrokes all over the stock exchange will send electronic buy or sell orders to the floor in chunks of \$100 million and up—certainly never less than about \$10 million. If Chicago is a few points high and New York is low, then arbitrageurs sell some of the futures shares and buy into the stock package. If the spread is reversed, then they buy back the futures and sell off the stock. The net result, if everything works as intended, is to ratchet hundreds of millions of dollars worth of stock on an upward, risk-free path.

On the whole, the financial community loves this kind of thing, not least because it brings in fabulous profits. Furthermore, say computerized trading practitioners, this kind of high-stakes, high-speed activity is fundamentally good for the market. Portfolio insurance offers protection to investors, they point out, while computerized stock-index arbitrage and related strategies are simply high-tech ways of bidding the Chicago prices up or down to keep them in line with New York. This is what a marketplace is supposed to do. “The arbitrageurs are trying to keep the market in balance,” says Michael Alex of Jefferies and Company, who has taken the lead in forming a computer trader's user's group on Wall Street. “Restrictions on computerized selling would make the market a much less liquid place than it could be,” agrees R. Steven Wunsch,

Pandemonium in the Pit

Wall Street traders try desperately to keep up on Black Monday, 19 October 1987.



who is developing new computer market systems for Kidder Peabody, and Company. "That would increase the risk for investors, which in the long run would result in lower prices for everyone."

However, other observers are skeptical, most notably New York Stock Exchange chairman Phelan. Long before 19 October, he was warning that stock-index trading not only holds the potential for manipulation and fraud, but that computerized trading practices in general are a stabilizing influence only when the market itself is relatively quiet. When things become unsettled, computerized trading could all too easily become destabilizing.

Phelan and others pointed out a number of ways for that to happen. With portfolio insurance, for example, investors always sell in a declining market; if enough of them were to do so at once—and computers make that very easy—the effect might be to push the prices down still further until they were well below their natural range. Meanwhile, stock-index arbitrage might also spin out of control as traders turned to the futures market to unload big blocks of their portfolios. Granted, the same thing would happen in reverse in a rising market; the net result in either case would be a speed up and amplification of the market's natural movements—its "volatility."

As it happens, a number of studies of computerized trading have been conducted by the Securities and Exchange Commission in recent times, and several more have been commissioned by the large trading firms. None has found any concrete evidence that computerized trading increases market volatility, with the sole exception of the "triple witching hours": those four Fridays per year when futures contracts fall due. And even those limited gyrations have been damped this year by technical fixes in the way the final prices are set.

Nonetheless, Phelan continued to fret about computerized trading. In an interview

with *Business Week* published 23 March 1987, he worried that program trading could trigger a "financial meltdown," in which the stock market could sink 150, 200, or more points in a day. On 19 October, those words seemed prescient. With the futures market leading the way downward, the stock market went into something resembling a free fall. By the end of the day the Dow Jones average had dropped 508 points or 22%, and the futures market had dropped 30%. The fall was so rapid that the market was already down by 200 points before the computers even began to kick in—a fact that led some observers to blame the remaining 300 points on the computers alone. By the time the market opened on Tuesday, Phelan had ordered a temporary halt to the practice of transmitting buy and sell orders electronically, in effect pulling the plug on computerized trading. Some people think it was no accident that the market began to recover almost immediately.

Whatever the truth about computerized trading on Black Monday—a full evaluation of its role will have to wait for the completion of the Securities and Exchange Commission study—the practice quickly became a target on Capitol Hill. "On Monday, we all discovered that program trading was like an incompletely designed new car," said Representative Edward J. Markey (D-MA), chairman of the House Telecommunications and Finance Subcommittee, in a statement to the House floor on 21 October. "It had a great engine that provided tremendous acceleration with little safety risk as long as you were in an up market. But it provided the same tremendous acceleration without a braking system when you were going downhill. We are going to find out how to retool this car with brakes." Markey promised an extended investigation.

On Wall Street, meanwhile, the practitioners of computerized trading are in a defensive crouch. Alex, for one, continues to argue that the computers are a stabilizing

force. "People worry about program trading because they don't understand it," he says. "Also, they know we move big blocks of money around and they somehow find that disturbing. But think about what it means when you execute a program trade without using the computer system. The broker has to take the orders for 500 different stocks and give it to all these runners. The runners go screaming out onto the floor, pushing up to the specialists' desks and shouting. That alone can create panic—unnecessary panic."

Along with others, Alex is convinced that the real problem with the stock exchange is not the use of computers, but the fact that every transaction of a given stock has to be funneled through one "specialist" in that stock. (Often the specialist is actually a group of several individuals.) It is the specialist's job to match up buyers and sellers at a mutually agreeable price. If a sale is offered and no purchaser is available at the moment, the specialist is supposed to keep the market going by making the purchase himself and reselling the stock later. As a reward for shouldering that risk, the specialist takes a cut of each transaction.

To Alex, this kind of system is simply a bottleneck. His answer, like that of Kidder Peabody's Wunsch and many others on Wall Street, is to streamline the system with still more computers. The kind of "third party" system they are envisioning would take buy and sell orders from brokers all over the country (or the world), and match the orders directly. In effect, the specialists would be cut out of the loop. "There's no question that this would enhance stability," says Alex.

The momentum for further computerization on Wall Street is clearly high. A number of brokerage houses are developing third party systems and there is a possibility that the New York Stock Exchange itself will eventually install one.

On the other hand, that momentum is also leading Wall Street to delegate more and more of its day-to-day decision-making power to the computers—a prospect that many people find troubling. Of course, a hypercomputerized Wall Street might not be so different from the Wall Street of today. Brokers are already making \$100 million decisions on 60-second time scales, using nothing for input but the flow of numbers on a computer screen. It is hard to imagine that they are giving those decisions any deep thought, or bringing any considered judgment to bear. What the prospect does do, however, is to throw a spotlight on the kind of economic models being used to program these computers. The economic assumptions may be valid enough in normal times. But as 19 October demonstrated, computers can be thrown into a world where their

assumptions are false, and where they can end up blindly following strategies that border on the lunatic.

"A systems analyst who computerizes an organization may only be there long enough to see the normal operation of that organization," says John L. King, at the University of California, Irvine, who has focused much of his research on the impact of computers on social processes. "But it's like a nuclear power plant—the emergency system may be very important, even if you only use it once a year."

The idea of an emergency system takes on additional significance in light of some recent theoretical work done by Bernardo Huberman and Tad Hogg at the Xerox Palo Alto Research Center. They are quick to point out that they have not explicitly modeled the stock market. Nonetheless, their approach to what they call "computational ecologies" does seem to be relevant.

The underlying theory is nonlinear game dynamics, explains Huberman. To begin with, he says, "imagine that you have a bunch of interacting agents, each choosing a strategy. The important thing is that the payoff of each strategy depends on what the other agents are doing." As an example, each agent might have to balance the benefits of collaboration with the fact that too many agents using the same strategy might use up finite resources. Next, he says, assume that each agent has imperfect knowledge about what the others are doing, and assume also that each agent's knowledge is slightly out of date—that there are delays in obtaining information. Then finally, model the whole thing on a computer, extracting the aggregate behavior of the agents as a group.

"What you find is that you can get very weird behaviors," says Huberman. The system may settle down for a while and seem stable—and then suddenly go into a period of nonlinear oscillation with sharp under-shooting and overshooting. In the language of dynamic systems theory, such behavior is described as a so-called strange attractor. In practice that means that its sudden excursions are inherently unpredictable.

So is this what is happening in the stock market? Maybe, says Huberman, although for now, the theory is only a metaphor.

On the other hand, the possibility does lead to an intriguing thought: for all the pundits' efforts to explain the gyrations of the stock market, most of those gyrations may not have an explanation. Following the course of its strange attractor, the market may rise and fall simply because that is the way such systems behave. As Irvine's King points out, "what Monday illustrates to me is just how little we know." ■

M. MITCHELL WALDROP

Gramm-Rudman-Hollings Strikes Back

Despite the positive actions by House and Senate appropriations committees, growth in many basic and applied research programs funded by the federal government will be limited, if not reversed, this year. The gloomy budget outlook for fiscal year 1988 is driven by two factors—the remodeled Gramm-Rudman-Hollings deficit reduction law and the chaos in the nation's stock markets.

The revitalized Gramm-Rudman law, known officially as the Balanced Budget and Emergency Deficit Control Reaffirmation Act of 1987, has been looming in the background of budget deliberations since Congress adopted it in September. Like the budget act passed in 1985 (*Science*, 25 October 1985, p. 421), the new Gramm-Rudman-Hollings law sets a schedule for reducing annual federal spending deficits to zero. The goal is to eliminate budget deficits by 1993.

To enforce the schedule for reducing deficits, the law contains a provision to automatically withhold sufficient funds from federal programs when necessary. This "sequestration" mechanism kicks in if the Office of Management and Budget (OMB) concludes by 20 November of each year that deficit limits are being exceeded.

For fiscal year (FY) 1988, which began 1 October, Congress stipulated that only \$23 billion had to be cut from the deficit. The goal is to shave it down to \$144 billion, but the target is not legally binding this year. For 1989, however, Congress has set a firm target of \$136 billion. Thereafter, the deficit must be lowered \$36 billion annually.

If Congress and the White House cannot figure out how to cut the 1988 deficit by \$23 billion in the next few weeks, most Department of Defense (DOD) programs will be subject to a 10.5% across-the-board reduction in FY 1988. Civilian programs will face reductions of 8.5%, according to OMB estimates. These percentage reductions could change, pending final OMB estimates in mid-November.

Under the sequestration process, budget reductions are achieved by taking half the funds from DOD activities and the remaining 50% from nondefense programs. Social security, federal retirement, worker disability, and a number of other social programs, which account for half of the federal budget, are exempt from sequestration.

If FY 1988 appropriations bills are enacted and subject to an 8.5% reduction, here is how some research programs might be affected:

■ **National Institutes of Health (NIH)**

programs would emerge with an estimated budget of \$6.3 billion, about \$600 million less than what the House and Senate appropriations committees have called for NIH funding in 1987 was \$5.94 billion.

■ **Office of Energy Research** spending at the Department of Energy would be about \$173 million less than the \$2-billion appropriation that the House and Senate have approved. This would bring spending to \$1.87 billion, close to 1987's budget of \$1.86 billion.

■ **National Aeronautics and Space Administration (NASA)** activities would be substantially curtailed. The agency's budget would fall from about \$9.3 billion to an estimated \$8.5 billion. NASA's budget was \$10.5 billion in 1987.

■ **National Science Foundation (NSF)** support for research and other scientific undertakings would be lower than expected too. The budget could be reduced to about \$1.67 billion compared to a potential figure of \$1.83 billion that House and Senate appropriations committees might agree on in conference. NSF's budget for 1987 was \$1.62 billion.

Automatic spending reductions can be avoided if Congress and the President enact appropriations bills that achieve the required \$23 billion in deficit reduction. House and Senate Democrats have sought to address part of this challenge by imposing new taxes that would generate about \$12 billion in new revenue.

Before the stock market went into a nose dive last week, President Reagan steadfastly refused to consider new taxes. But, under pressure from House and Senate Republicans and Wall Street, Reagan has indicated that he will accept some new taxes.

Even if Reagan goes along with some new taxes, it is clear that about \$11 billion in spending reductions will be necessary. That could translate to reductions in FY 1988 appropriations bills on the order of 4%. These reductions might be deeper—even with a tax increase. Congress could change its mind and decide to cut more than \$23 billion from the deficit, as many in the financial community have urged.

At *Science's* press time, it appeared likely that House and Senate leaders and the White House would attempt to reach an agreement before the 20 November sequester deadline. In fact, OMB contends that this year's deficit target of \$144 billion can be met. But, the Congressional Budget Office is pessimistic. It projects the deficit at \$156 billion after accounting for \$23 billion in reductions. ■ **MARK CRAWFORD**