Power Peg and Knight Capital Group, 2012

Unbeknownst to the average high school student struggling with the intricacies of mathematic algorithms, their collective confusion was created by a late eight-century Persian named Al-Khwarizmi. Well, not exactly. He was really just the one credited with inventing the work. The man, Abu Abdullah Muhammad ibn Musa Al-Khwarizmi was born in 780 AD and was a brilliant mathematician, astronomer, and geographer. He had built upon the work of the Indian mathematician Brahmagupta and wrote a book entitled *The Compendious Book on Calculation by Completion and Balancing* in approximately 820 AD, which spread algebra – meaning "Arabic arithmetic" – to Europe. By any account, spreading algebra around the world would be a monumental achievement, but Al-Khwarizmi took it one step further.

Five years later, around 825 AD, Al-Khwarizmi made perhaps his greatest contribution to math when he described a series of repetitive mathematical calculations. When it came time to credit him with the invention, Al-Khwarizmi's name was mispronounced and the invention became known as the Algorithm. And with that malapropism, an entire field of mathematics was born. Ironically enough, once again Al-Khwarizmi was again credited for inventing the work, though he was still not the true inventor. The first algorithm goes back to the Greek mathematician named Euclid in approximately 300 B.C. who wrote what's called the Euclidean Algorithm, used to describe the process for finding the greatest common divisor of two integers.

The term algorithm that we use today refers to a set of rules for performing arithmetic, though there's no generally accepted definition. It commonly refers to any set of

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procedures used for solving problems or performing tasks. Informally, it's mostly used to explain a step-by-step process in either mathematics or computer programming. Think of it as a set of instructions for calculations with a number of steps that terminate at an ending point. The most common component of an algorithm is the "if-then" statement - IF the kitchen is floor is dirty, THEN you should mop it. A daily chore defined within the context of an algorithm.

Algorithms are graphically illustrated through the use of flowcharts. They show the individual steps as boxes connected to one another by arrows. A rectangular box is a single step and a diamond denotes a decision. That decision is a yes/true or no/false. Using the dirty kitchen floor algorithm, we have the question of whether or not the kitchen floor is dirty, with an arrow pointing to a diamond with a yes or no. From there, an arrow leads us to a final box telling us to either mop the floor (if the answer was yes) or to go to another chore (if the answer is no).

While the flowchart is a simplistic way of deciding whether or not to clean the kitchen floor, most algorithms are infinitely more complex, and most commonly used in computer programing. Computers perform functions using detailed algorithms that tell them what operations they should perform and under what circumstances. If a specific condition exists, then perform the specific action. The average home computer today can execute up to 100 million instructions per second, which is exponentially faster than even the most brilliant human mind. But it's important to remember that the computer doesn't think for itself. It's told exactly what to do by the programmer and then it blindly follows the exact instructions in the algorithm.

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By the 1990's, stock traders realized they could harness the speed of computers and began experimenting with algorithms for executing trades. Because the computer could execute trades so much faster than any human trader, investors began using computers to program how their orders would be filled in the market. And because the computer did exactly what it was told it to do, those orders were filled precisely the way they wanted. In other words, the human became the brains while the computer was the speed. If the trade didn't pan out the way the trader had hoped, and that often happened, it wasn't because the computer did something wrong.

Algorithmic stock trading is essentially the same idea as the kitchen floor algorithm - it uses a set of rules to determine a specific action. In the case of stocks, the rules are set up to finesse trade execution. Rather than making the decision about which security to buy or sell, the algorithm decides how and when to place the order. Often, that decision involves splitting large stock order into multiple smaller orders to reduce visibility in the market. In other words, executing smaller trades so that other traders can't see what a large investor is trying to do. In its simplest form, algorithmic stock trading involves the typical if-then statement: IF the stock price hits $50.00 a share, THEN sell 1,000 shares every five minutes for a total of two hours.

As the size of institutional investor's orders grew in size and electronic stock trading exploded, so, too, did the use of algorithmic trading. But it all goes back to the one firm which pioneered the algorithmic trading bandwagon - Knight Capital Group.

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In an industry littered with generations of old-line firms, Knight Capital Group was the new kid on the block. Founded in 1995 by Kenneth Pasternak and Walter Raquet, Knight was not headquartered on fabled Wall Street, but across the river in Jersey City. It owed both its inception and rapid growth to the NASDAQ stock market, a growth that was spurred by the technological advancements of the 1990s.

In 1992, Raquet and Pasternak were both working at a firm called Spear, Leeds & Kellogg. As Raquet looked around the trading floor, he was struck by the fact so much of the buying and selling was dependent on traders and salespeople quoting markets over the phone, despite recent advancements in technology. With the Internet suddenly shifting into reality, information on stock prices was available in real-time and available to anyone who cared to access it. Raquet knew there was a better way for the market-makers at Spear to operate.

Market-makers are the traders who provide liquidity in the stock market. When a customer is trying to either buy or sell, the market-maker will show them a bid or an offer and take the opposite side of the trade, regardless of whether the market-maker is an actual buyer or seller. In the days when floor traders ruled the New York Stock Exchange, the market-makers were referred to as "specialists," and they were charged with matching buy and sell orders, while taking out the spread in the middle for themselves. With the advent of the computer and its impact on the financial markets, technology was beginning to rule the day. It was no longer necessary for brokers and traders to meet face-to-face in order to execute a stock, and they certainly didn't need to be standing on a stock exchange trading floor.

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Raquet had the technological insight to see that the old exchange model was outdated and it would inevitably be replaced by computerized trading. It was a revolutionary way to think at the time, given that stock traders had been meeting in person since the days of the Buttonwood tree in 1792, when they originally formed the New York Stock Exchange. Racquet wanted to be at the forefront of the movement, and in 1992, he approached his colleague Pasternak, one of the top traders at Spear, and pitched the idea. Both men immediately agreed to work together to create the next-generation stock market-making firm.

They reasoned that once the general public had access to real-time stock quotes via the Internet, individuals would begin self-directing their own stock transactions. Stock buyers wouldn't need the services of a massive investment bank, and, with all of the discount brokers popping up, individuals finally had the ability to gain low-cost market access. Today, there are countless online discount brokers who offer investment services, but in 1992, people didn't consider the idea very realistic. The pair submitted a business plan to Spear, Leeds & Kellogg and it was summarily rejected.

The following year, they approached Lawrence Waterhouse, the Chairman of the discount brokerage firm called Waterhouse Securities, and proposed the idea. This time the idea struck a chord. However, Waterhouse knew his firm was too small to support a market-making firm on their own. Rather than rejecting the idea outright, Waterhouse suggested that the team bring together five other discount brokers and create a stand-alone firm owned by the discount brokers.

Raquet and Pasternak took the idea and ran with it. They called their new firm Roundtable Partners, a reference to King Arthur and his fabled Knights of the Round Table,

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where each knight sharing an equal seat around the table with the king. The new business model would have that same egalitarian concept, with each brokerage firm sharing equally in the ownership. In March 1995, Roundtable Partners was launched with a consortium of 20 different discount brokers, far more than the original five had hoped for.

They created a subsidiary called Knight Securities in July of that year, which became the market-making arm of Roundtable Partners for both the NASDAQ and the Over-the-Counter (OTC) stocks. With 75 employees and $17 million in capital, Knight Securities was launched making-markets in 2,000 individual stocks, putting them squarely in the trailing position of the 88th largest market-maker on the NASDAQ exchange. By the end of the year, they had acquired a firm named Trimark Securities, which operated on both the New York Stock Exchange and the American Stock Exchange. That acquisition, paired with their existing presence in NASDAQ and OTC, positioned Knight in all of the major U.S. stock exchanges.

The real beauty of the business, at least from Knight's perspective, was that they often got paid on both sides of the transaction. Whereas TD Ameritrade might be sending a buy order for a particular stock, Charles Schwab might be sending a sell order for the same stock at the same time. Knight, being the market-maker, filled the orders themselves - buying on the bid-side and selling on the offered-side and thus, capturing the bid/offer spread. With the sheer volume of all the discount broker trades going thorough their system, Knight was often buying and selling the same stock at the same time, making the bid-offer spread and essentially taking no risk. The business of electronic stock market-making became pretty simple; it was all about numbers and volume. The more volume a firm could run through their books, the more money they would make with the computers

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were doing the majority of the work. And, even better, those computers never asked for raises or took coffee breaks. Racquet and Pasternak clearly had a winner.

By 1997, Knight had grown to become the single largest market-maker of NASDAQ stocks, benefitting directly from individuals executing their own trades online without having to call their broker. And just as the founders hoped, Knight was the innovator in low-cost stock market execution, positioned right at the epicenter of the Internet explosion. The firm became the trusted intermediary for America's retail stock brokers and perhaps most importantly, the customers loved Knight. 99.3% of all client orders were executed in under a second, which meant that investors were almost guaranteed the market price when they wanted to buy or sell. No waiting. It might seem like second nature these days, but back then, it was revolutionary. And Knight became very popular - they were executing between 40% and 50% of all U.S. retail stock order flow – that is, almost half of all mom and pop stock trades were going through Knight.

With that kind of volume also came money. Lots and lots of money. The firm was a money-making machine sprouting out cash. Forget about the traders at Solomon Brothers and Drexel Burnham in the 1980s or even a Goldman Sachs partner in the 1990s, they made a pittance compared to the money being made by Knight's traders. Senior trading managers were making as much as $175 million a year. That's in one year! And it was because they took home at least 5% of their group's net revenue as their compensation. The top individual traders were making upwards of $25 million annually, and even trading assistants, the newbies on the trading desks, were pocketing close to a cool million each year.

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Then in July of 1998, Knight used those three little words that investors love to hear – Initial Public Offering – and raised an immediate $145 million more in capital. Within six months after the firm went public, its market capitalization soared from $725 million to $2 billion; by the end of 1999 – a timeframe of just eighteen months – that value ballooned to a staggering $8 billion. The massive growth was fueled by the stock trading business, and with it, most of the credit going to Pasternak as a stock trading genius. As Pasternak became the public face of the company, it fostered deep tension between himself and Raquet, who still considered himself the brains behind the operation. After all, it was his idea in the beginning. But money talks on Wall Street and good ideas come a dime a dozen. Accolades are often reserved for those who are making money today, not the ones who had good ideas yesterday.

That's not to say that Knight didn't have some problems too. Anytime money is involved in the exchange of goods or services, there's almost always someone who finds a way to exploit the loopholes. When you're talking about the opportunity to make millions of dollars – with smart people overseeing money going back and forth – it's not too surprising that some people were looking to skim some off the top. There were more than a few scandals that rocked Knight over the years.

For starters, there were plenty of rumors at other firms that their colleagues at Knight were engaged in front-running. Front-running is when a trader jumps in front of a customer order to buy or sell a stock. In other words, the trader sees an order come in from an investor and immediately submits the same order before putting through the client's order. It's illegal, but it doesn't mean some smart minds can't find a way around those regulations.

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First, because there was such massive volume going through their trading books, the guys at Knight were in a perfect position to make money from front-running - they saw almost everything going on in the market. Knight traders not only saw when the big customers were buying and selling, but they saw the size of the trades and at what price the client wanted to buy or sell. It doesn't take a good trader to capitalize on that kind of insider information; and make a financial killing in the process. Many top executives and traders were well aware of the front-running at Knight and referred to it as "a racket."

There were plenty of ways to front-run, you just had to know how to do it, especially in a way that didn't outwardly violate NASD rules. First, Knight traders routinely drove up the opening prices of IPO stocks on their first day of trading. Before a new IPO stock opened for trading, traders saw the pre-market buy orders coming into their books - customer orders like "buy on the open." Now, if the IPO stock price was set at $25.00 a share and a trader sees millions of shares trying to buy on the open, they clearly didn't want to sell their customers at $25.00 a share. Instead, they made sure the stock price opened at higher levels. Traders bid up IPO stock prices in the pre-market until the price reached a point where it seemed like a good level to sell, say $40.00 a share. When the stock opened at $40.00, Knight traders would sell the stock on the opening to their unwary customers. Then, at the artificially inflated opening price, they oversold the stock and short-sold it. As the opening buyers disappeared and the stock price drifted lower, they'd buy back their shorts at wildly deflated prices. Laughing all the way to the bank. It's nothing too complicated – the same "pump and dump" scams have been used in the past – but who would have thought making money from opening IPO orders would be so easy?

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Another front-running scam was equally simple and equally effective for making money. It involved *not filling* a customer's order unless the trader was guaranteed to make a profit. Regulations at the time allowed market-makers to delay filling customer orders, even if the stock was trading at the level the customer wanted. Traders would routinely place orders in a "hold" status and waited. Any stock order that was placed on "hold" had no obligation of being filled. When the stock price moved past the order price and the trader was assured of a profit, he'd fill the order and send a trade confirmation. Again, it's nothing fancy or complex. It made money for the traders, and that was the name of the game.

John Hewitt, an executive brought in from Goldman Sachs to become President of Knight Capital Group, caught wind of the front-running rumors and discovered there were plenty of less-than-moral activities going on. He called Pasternak and said, "We have a problem. Let's fire these guys immediately."

It was a little too late. The National Association of Securities Dealers (NASD), the regulatory authority at the time, had already been looking into the rumors. Ken Pasternak, together with the head of Knight's Institutional Sales Desk John Leighton, were under investigation for failure to supervise the trading activities of Joseph Leighton, who happened to be John's brother and one of four Leighton brothers who worked at Knight. Though front-running was pretty widespread at Knight, the NASD only went after the worst offenders, and Joseph was found to be involved in all kinds of fraudulent trading activities during his days at Knight.

In 2005, Pasternak, together with John Leighton, would receive fines of $100,000 each for failure to supervise the trading activities of Joseph Leighton. Joseph was forced to

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pay more than $4 million in fines and received perhaps the harshest punishment the NASD could hand down: He was barred from the securities industry. Pasternak, however, was later cleared of any wrongdoing. When the final numbers were tallied, as a firm, Knight paid in excess of $79 million in fines resulting from the front-running charges.

* * *

In the end, the practice of front-running by individual traders was not eradicated by either new rules or new regulations. Instead, it was done by taking the human trader out of the equation. Around this time, technology had eliminated much of the ability of the human trader to front-run investor orders. Putting together buyer and seller was no longer being done by human market-markers. Rather, it was being done by matching engines inside computer black boxes.

With the advent of computerized order placing systems, institutional investors had new ways to disguise their market intentions when submitting large orders. All of a sudden, the electronic trading facilities had created new ways of placing orders, and as a result, the major stock exchanges were beginning to lose favor with big investors. Investor orders were migrating to the new electronic exchanges.

The average investor has probably heard of the big name U.S. stock exchanges – the NYSE, the AMEX, and the NASDAQ – and might have a passing knowledge of an international exchange or two. If they dabble in penny stocks, then OTC and the Pink Sheets are something they're familiar with. But back ten years ago, 85% of all U.S. stock trading still occurred on the NYSE. Today, there are 13 different public stock exchanges, and that's

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just the tip of the stock trading iceberg. Exchange names include: BATS, Direct Edge, International Securities Exchange (ISE), and the National Stock Exchange (NSX), and even the recently publicized Investors Exchange (IEX). These days, the ubiquitous Wall Street of the stock market isn't in downtown Manhattan anymore. It's in New Jersey. The ISE and the NSX are located, of all places, in Jersey City, New Jersy. BATS is located right next door in Weehawken, New Jersey. When you buy or sell a stock on the NYSE, the trade doesn't actually occur in the old NYSE building. The computer matching engine is located further up Route 17, in Mahwah, New Jersey. And the exchanges are all, more or less, computer-driven. No floor traders need apply.

Outside of trading on an exchange, there are numerous banks which have in-house trade matching in ominous sounding "dark pools," of which there are 50 around the world. Dark pools aren't quite as secret as their name suggests. The dark in their name is, on one level, because no one is supposed to know what's happening inside of them. That is, the details of those markets aren't available to the general public. They are actually a hold-over from the old concept known as "upstairs trading," which was nothing more than a method of hiding large trades from the prying eyes of the specialists on the floor of the exchange.

Suppose a large institutional investor didn't want to send their order down to the exchange floor and risk someone front-running it. They knew their order was large enough that if the size got out, it would move the market. Upstairs trading was a way of keeping those orders insulated from the trading floor; an institutional investor or a major client negotiated a purchase or sale directly with a securities dealer. These days it's called trading in a dark pool.

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It's important to note, that there's nothing illegal about dark pools, despite the connotations implied by their name. Plenty of banks run these quasi-secret sales outlets. There are approximately 45 dark pools around the country that compete with the 13 public exchanges; Crossfinder, the Credit Suisse dark pool, is the largest and it trades somewhere north of 132 million shares a day. Goldman Sachs would dispute Crossfinder's dominance by claiming that their Sigma X dark pool is really the largest. Barclay's dark pool trading venue is called LX and claims to trade 110 million shares a day. All in all, there's no way to be sure who's the largest since the banks publish their own volume numbers in their own way, however, it's estimated that dark pools account for anywhere from 14% to 40% of all U.S. stock trading on any given day.

Many of the same problems which plagued Knight in the late 1990s ended up resurfacing again in the early 2000s. At first, with electronic trading, there was no way to finesse large orders in and out of the market. The risk of a human trader front-running the order just resurfaced in electronic front-running. Instead of humans doing it, HFT (High Frequency Trading) firms were teaching computers to do it. Institutional investors were once again not happy; they were being outgunned by computerized traders and they needed a solution to hide their orders from the prying eyes of HFT traders. Once again, they needed a way to execute large trades without simultaneously moving the market against them. To solve this dilemma, the folks at Knight turned to a Persian mathematician who had written a treatise centuries ago about repetitive calculations - the algorithm.

Algorithmic order execution was designed for the most part to help large-volume traders spread a single transaction out over an extended period of time and across multiple exchanges. One of the more popular algorithmic executions is called the parent-and-child

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order. Say an institutional customer wants to buy 1 million shares of a particular stock and sends that order through an algorithmic execution system. The entire order – the full million shares – becomes the parent order.

From that point, the algorithm's parameters are programmed by the investor. The algorithm will search all of the possible markets – exchanges, dark pools, any possible outlet for trading the stock – and send out smaller buy orders at the best price it can locate. These are the child orders, and there's no trail that leads back to the investor – and the single parent order.

The size of individual child orders and the pricing details are determined by the investor, as is the length of time to keep the algorithm active. The algorithm executes the order within the customer's parameters until it's filled or the time limit expires, whichever comes first.

It didn't take long for smaller-scale investors to catch on to the benefits of algorithmic trading, and the new order-placing strategy became very popular with them too. Other types of algorithmic orders that were created were called peg orders. In one type of peg order, the customer dictates a price above or below the best bid or offer in the market and "pegs" his order to that price. For example, a 1/8 peg order to buy places the order 1/8 of a point below the bid price. If the bid was $25.375, then the peg buy order would be $25.25.

Modifications included a "mid-price peg," in which the peg price is the average of the best bid and the best offer. Alternatively, a "peg best" places the bid or offer as always the best in the market. If a better bid or offer comes in, then the algorithm is programmed to automatically beat that price by a set increment.

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At Knight, the first algorithmic peg order routing system was called Power Peg, a system that was originally developed in-house to execute parent-and-child orders. Technology at the time allowed Power Peg to send thousands of buy and sell orders to the exchanges every second. At the time, Power Peg was placing orders in ways that no human trader could ever hope to.

The system was keyed by a flag in Knight's computer system. When the flag was up, it meant that there was an active parent order in effect and Power Peg kept sending the child orders to the various trading outlets. As orders were filled, a tracking function counted the number of child executions. Once the size of the individual child orders equaled the size of the parent order, the parent order was filled and the flag went down. When the flag was down, Power Peg stopped sending orders. That fact would become very important in its infamous reign as a rogue trader.

Today, algorithmic trading systems are even more advanced. Many are programed with a fail-safe provisions: including automatic shutdowns that stop the process if the price moves outside its normal trading range. It's a way to prevent unintended trade executions at prices the customer never intended, but in the late 1990s and early 2000s, firms had not yet developed this technology. It was something that no one considered important at the time. As such, Power Peg was not designed with an automatic shutdown feature. And that would later become a very costly design flaw.

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Computerized stock trading wasn't the only change in the stock market at this time. On April 9, 2001, a new rule was passed by the Securities and Exchange Commission (SEC) called NMS Rule 612. The SEC had concluded that tick sizes in 1/8 of a point were artificially widening the spread between the bid and offer prices. They determined that it led to excessive profit-taking by market-makers like Knight (no kidding!). As a result, the SEC mandated that the stock market move to decimal pricing.

Foreign markets had long been using the decimal system, with tick sizes of 1/100 of a point or 0.01. Overnight, U.S. stocks went from a system of a 20 1/8 bid and 20 1/4 offer, to quoted with a 20.13 bid and 20.15 offer. Studies showed that investors could save more than $1 billion annually from narrower spreads; and they did. Market-makers, however, saw their profits collapse. And because Knight was at the top of the market-maker food chain, they were the hardest hit from the rule change. The new rule even required market-makers to execute some orders for no profit at all. Essentially, it meant they were forced to do some trades out of the goodness of their hearts. Not the typical creed on Wall Street.

In a desperate attempt to right the sinking ship, Knight switched to a hybrid market-making model in hopes of damming the flood of cash draining from the company. They allowed electronic trading for high-frequency trading customers, while they continued traditional human market-making for other customers. But there was no stopping such a fundamental change in the market, profits continued to decline and Knight's business model basically collapsed. Knight President John Hewitt immediately realized the gravity of the situation: "It took zero time for the economics to fall off the cliff," he said of the new SEC rule, "The traders were unable to make money anymore. The whole compensation model

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fell. We were sitting there losing three million dollars a day." Many former Knight traders still contend that the change to decimalization was the ultimate cause of Knight's demise.

Throughout 2001, Kenny Pasternak was often heard complaining about his job, saying how much he hated the work and wanted to quit. But as he'd been there from the beginning, it wasn't an easy decision to just pack up and leave. He no longer saw Knight as a just a business that he was building, it had become somewhat of a family to him. But the reality was settling in, and one employee observed, "Pasternak had lost all drive to be the CEO."

At the end of that year, the board formally asked Pasternak for his resignation, which he gladly submitted. "I was already looking for an opportunity to retire," he said. His forced retirement left the firm's traders wondering about their future, as well as the future of the firm they worked for.

In an attempt to return to profitability, Knight turned to a business strategy based on high volume. Because the profits they made from each trade were so low, they felt that more trading volume would offset the declining revenues. They began to actually pay money to the online brokerage firms for their business, a practice that became known as "paying for order flow." Large retail brokers – firms like TD Ameritrade and Scottrade, for example – received payments from Knight in exchange for sending more business to the struggling firm. From Knight's perspective, it was worth the cost. After all, they made the bulk of their money as a market-maker - collecting the spread between the bid and the offer, even though that spread had narrowed considerably.

The plan worked, to a degree, and Knight saw an increase in trading volume. But it came at a tangential cost, namely the firm's computer systems and servers were having

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problems keeping up with the trading activity. It got so bad that the computer system was going down almost on a daily basis, and the firm knew they had to change their business model again – and build up their technology. The computer systems would begin doing more of the market-making activity, and with it, they'd be able to cut staff and reduce costs.

The new grand plan at Knight was to cut as much of the trading staff as possible, thereby saving millions of dollars. The firm had, at the time, several hundred full-time traders and they wanted to cut that number to less than 100. The massive decrease in traders would be offset through computer automation of their market-making functions. That way, they could squeeze much more productivity from the traders they retained. The plan was put into action in March of 2002 with the first announcement of an 8% cut in staff.

The next step was hiring a new Chief Executive Officer to replace Pasternak. The board of directors decided on Tom Joyce, a well-known industry veteran from Merrill Lynch. He was a Harvard graduate who excelled in sports as a student and that athletic prowess was so much a part of his persona that he had a reputation for hiring only Ivy League athletes to work for him.

Joyce was a CEO who preferred to look at the big picture and develop relationships with clients, especially during rounds of golf. "He was always out with clients," recalled one former Knight employee. Joyce's plan was to take Knight away from the cowboy culture that existed since its founding and turn it into a corporate environment. His vision was a miniature version of Merrill Lynch, the firm he'd been hired away from.

The first step Joyce took was to change the firm's compensation system. He shifted to the standard big investment bank salary-and-bonus model, with discretionary bonuses decided by the new managers that Joyce himself had hand-picked. Traders who had been

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with the firm for many years were less than pleased and many old-time Knight employees felt that Joyce had sent too many experienced personnel packing; traders who had proven themselves over the years.

Within a year, however, it looked like Joyce's strategy was working. In 2002, whereas the firm lost $42.2 million for the year, in 2003, that loss had been replaced with a $38.5 million profit.

Buoyed by the sudden financial reversal, Joyce's next step was a corporate acquisition spree. He retired many of the old Knight electronic execution systems and bought new firms with new trading technology.

Along with the first round of new technology came a new order routing system called Smart Market Access Routing System (SMARS). Like Power Peg before it, SMARS was set up to receive parent orders and then send out the smaller child orders to external trading platforms. The system was up-to-date, faster, more reliable, and could compare prices between more than 50 different trading venues within fractions of a second. Whereas Power Peg was inconceivably fast in its day, performing several thousand transactions per second, it was now the equivalent to a horse and buggy. SMARS was capable of executing as many as 2 million orders per second. Ultimately, that mind-boggling speed would become the metaphorical straw that broke the camel's back.

Power Peg was decommissioned in 2003. It was turned off, yet remained on Knight's servers. It's a common mistake made by many computer programmers; oftentimes rather than delete old programs, they'll simply disable them. The firm had always intended to delete Power Peg altogether, but for some reason they never got around to it.

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Regardless of why the program was never erased, it's the equivalent of a retired executive who is allowed to keep an office in the building, despite the fact that he doesn't really do anything anymore. And just like that aging figurehead, Power Peg still had its brains intact. It was still functional, all it needed was to be told what to do.

Joyce then acquired Attain, an electronic communications firm, in May 2005, and followed that up with the acquisition of Direct Trading Institutional, a firm that specialized in providing institutional investors with trading executions at a low cost.

The buying continued in 2006, with the acquisition of Hotspot FX in January, which gave Knight's institutional clients electronic access to the foreign exchange markets. In October of that year, Atlanta-based Value Bond was brought under the Knight umbrella to jump-start the firm into electronic trading in the fixed-income markets. In 2007, he purchased EdgeTrade, a stock broker and software developer. Then, he acquired Libertas Holdings in 2008, as well as a company called Oasis, which had algorithms designed to trade stock pairs - allowing clients to trade the spread between two or more related securities in 2009. Three other acquisitions brought in state-of-the-art algorithms for trading, Urban Financial Group, Astor Asset Management, and Kellogg Capital Markets in 2010.

All of this technology – new and old – was housed in Knight's data center, located on the fourth floor of their Jersey City headquarters. Contained in this technology stockpile were eight separate high-speed servers that ran the firm's computer trading and execution programs, and each server was responsible for trading a different group of stocks.

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In what should have been a wake-up call for everyone in the financial markets, the Dow Jones Industrial Average (DJIA) posted its largest single loss in history on May 6, 2010. Oftentimes, the average person defaults to the belief that a drop of that magnitude is caused by some seismic event in the markets. Things like a bank default or a major financial crisis are typical culprits. But not in this case. No, that massive drop was due to an algorithmic high-frequency trading error that occurred within the timespan of minutes.

By 2010, the algorithms being used in HFT accounted for as much of 70% of all stock trading. They were incredibly sophisticated and computers were now placing orders in the market at incredibly high speeds. The human trader was running on autopilot and it was a bomb just waiting to go off.

On that faithful day of May 6, 2010, investors started the day concerned about the looming European debt crisis, especially what was happening in Greece. At 2:42 PM, the DJIA was down 300 points. Then, within five minutes, the index had plummeted down another 600 points. Seconds later, the market hit the day's nadir and was down a full 1000 points on the day. By the close of trading, it had managed to claw its way back slightly, posting a 600 point drop at 4:00 PM in New York. About $1 trillion in market capitalization had been erased by the day's trading, and it still remains the largest one-day decline in the Dow's history. The event came to be known as the Flash Crash.

The SEC, together with the Commodity Futures Trading Commission, launched an immediate investigation to figure out how the U.S. stock market could possibly lose $1 trillion in the space of a couple of hours. What they found was, in fact, that it had only taken twenty minutes for an algorithm to bring the financial world to its knees. According to the

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agencies' joint report, at 2:32 PM, a mutual fund named Waddell & Reed had begun using an algorithm to execute a standard parent-child sell order for 75,000 E-Minis futures contracts worth approximately $4.1 billion. E-Minis are futures contracts that trade on the Chicago Mercantile Exchange and each individual contract is worth 50 times the value of the S&P 500 stock index. They're often used as a hedge by institutional investors to protect their portfolios from declining markets, without having to sell their individual stocks. On May 6th, the European debt crisis was causing them enough worry enough to want to hedge their holdings.

The traders at Waddell & Reed instructed their algorithm to send sell child orders as large as 9% of the trading volume calculated over the previous minute. In other words, the program was supposed to sell the $4.1 billion parent order piece-meal, not more than 9% of the trading volume posted every minute. However, the traders made a tragic mistake, they forgot to set both a time and price parameter, so the algorithm simply unloaded the shares as quickly as it could, without regard to price. Then, with no pre-determined time for the algorithm to stop selling, it continued executing orders as the market dropped.

Other firms had their own algorithms running to purchase the E-Minis contracts that Waddell & Reed was selling but, as the market dropped, they immediately switched to selling, which sent the market into a free-fall. And because it was all computerized, the trades were taking place at a rapid-fire pace, Waddell & Reed's algorithm interpreted that as a need to sell even faster. Within 14 seconds, a total of 27,000 contracts were traded. With the price of the E-Minis accelerating downward, selling moved to other exchanges as investors started selling their actual stock holdings, and, by then, the panic had spread throughout the entire U.S. stock market.

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In the end, the event was blamed on a computer malfunction, but remember, the algorithm was done exactly what it was told to do, to the letter. There was no minimum price limit and no timeframe set; the algorithm was simply following instructions. For all of the advancements we've made in technology, there is still no computer anywhere that possesses the human survival instinct that tells it to stop selling when it's creating a panic in the market.

Following the Flash Crash, many exchanges allowed trades to be cancelled as a way to helping their members starve off the massive losses they'd sustained. The New York Stock Exchange, for example, cancelled all trades that were 30% or more away from the price at the start of the trading day. As a result, many market participants lived to tell about the Flash Crash and were elated. Just as many, however, were unhappy; those who had benefitted from the free-fall.

Additionally, two new rules were put in place to govern securities trading. Circuit breakers were required to halt trading if the market experienced what were labeled as "significant price fluctuations." Called limit-up/limit-down bands, the rule stated that if a stock moved up or down by 10% or more during a five-minute period, there would be a mandated pause in trading for five minutes. It was something of a time-out for traders, a period for them to collect their thoughts and think about what they were doing before potentially wreaking havoc on the financial markets.

The second new rule which was instituted by the SEC. Rule 15c3-5, also known as the Market Access Rule, dictated that the exchange would have algorithms in place designed to ensure the integrity of their computerized systems. It also required that broker-dealers implement their own risk management controls to block erroneous orders

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from reaching exchanges in the first place. The rule was written to specifically protect the markets from the type of rogue algorithmic computer trading that created the Flash Crash, but as we have seen so many times before, more regulations don't often equal more safety in the financial markets.

* * *

In the year following the Flash Crash, the NYSE began discussing the creation of a new retail stock trading platform for its members. In July of 2012, the exchange finally received approval from the SEC to establish the new Retail Liquidity Program (RLP). The basic idea was that orders from retail investors – average individuals who buy and sell stocks, as opposed to large institutions – would be directed into a single dark pool, run by the NYSE with the new pricing rule that allowed stocks to be quoted with as little as $.001 increments. If market-makers thought the old one cent pricing was bad, the new increment was going to be 1/10 of a penny.

In the RLP dark pool, member firms could bid and offer for the retail orders that were submitted. The result for investors would be, at least in theory, better prices. If retail investors didn't like the one cent bid/offer spread for a stock, they had the ability to transact somewhere in the middle. The promise of a smaller bid/offer spread for individual investors was touted as a huge step forward in the investing world. Market-makers, like Knight, were adamantly opposed. They felt that the creation of this special dark pool would move even more trading away from the exchanges. What's more, because price increments

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were less than a penny, market-making spreads were being gutted even further. Going from 1/8 of a point to one cent was bad enough, now they couldn't even make a penny!

But the decision was made and keeping profits high at market-maker firms wasn't the top priority of anyone else in the industry. This time, the NYSE clearly favored the well-being of individual investors over the profits of its members. The RLP dark pool was set to come into existence on the morning of August 1, 2012.

In anticipation of the new program, the NYSE had been working on the software specifications with its members to handle the orders. There was a new trading location to send orders and new rules for market trading. The software specifications were sent out as far back as December 2011.

Despite their misgivings about the new dark pool, Knight executives were even more wary of losing customers. They didn't want to give their customers any reason whatsoever to trade elsewhere, and if that meant smaller market-making spreads, so be it. Knight's programmers worked on the upgrade code to their SMARS order handling software and updated the execution programs to accommodate RLP orders. Then, when the new program was formally approved, they still had a few weeks to finalize everything.

Ordinarily, when a new computer update is installed, it's tested repeatedly to make sure that there are no bugs. Knight, being a technology oriented firm, constantly updated and modified their systems. The testing process could take weeks or even months; the more important the system upgrade, the longer the testing process. And when you're talking about one of the world's largest financial markets, there's little room for error.

On July 27, 2012, the IT department was convinced they had a working version of the software upgrade, but weren't 100% convinced of its full functionality. The lack of

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absolute certainty, however, didn't keep them from migrating the software into the SMARS system. RLP was going live on August 1, 2012 and Knight had to be open for business regardless. On July 31, the night before RLP went live, Knight's SMARS programmers began loading the new software on to the servers.

I cannot speak from first-hand experience about the intricacies of loading a new trade execution system onto a computer server. It was late at night, so perhaps that had something to do with it. It's a high-stress situation, which was also possibly a factor. Whatever the reason, the updated software was only loaded on to seven of the firm's eight servers. At first glance, it doesn't seem like such a critical error.

In hindsight, it was disastrous. It's common practice in the industry to have a second IT person check the work of the first, just to make sure that everything was installed properly. Knight's IT department was top-notch so perhaps they didn't always see a reason to double-check their work. They were experienced in this sort of thing, that is, they handled over 100 software updates every year and those updates generally worked flawlessly, so there wasn't any apparent need to double-check their work. As one Knight executive later said, "The IT guys were arrogant."

In the ancient Greek tragedy, the concept of hubris is a commonly a contributing factor to the downfall of the tragic hero. It's the hero's hubris – his belief in his own infallibility – that prevents him from seeing what's right in front of him, namely that he is bringing on his own demise through his actions. Where the story of Knight is a tragedy, on some levels, Knight is a tragic hero and the hubris of the IT personnel is a tragic flaw.

At 8:00 the next morning, the pre-market orders began to accumulate on the SMARS system. But something was wrong, and SMARS started sending out an automated error

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message to a group of 97 Knight employees. “Power Peg disabled,” the message read. “Power Peg disabled” over and over again. The market was opening in 90 minutes, though Power Peg was decommissioned nine years earlier, it wasn’t even supposed to be operational. Perhaps those 97 employees had never even heard of Power Peg, but Power Peg had just woken up from its nine year slumber.

At 9:30 AM, the market opened. Normally, it might not matter that new software was not loaded correctly on one server, but this time it did. Back when the Power Peg system was operational, there was a flag that told Power Peg when the parent orders had been filled. When the flag was up, Power Peg kept sending child orders to the various exchanges. When the flag was down, Power Peg stopped sending orders. As it happened, the programmers had recycled the old flag for the new RLP update. As soon as that flag was up, Power Peg miraculously came back to life, it was a signal for Power Peg to start trading again. The orders that went through the other seven servers worked fine, but for the orders assigned to the eighth server, Power Peg took the reins and started doing what it was supposed to do.

As the orders came in, Power Peg began executing them, taking the main order as a parent and sending out child orders across the exchanges. 212 premarket orders came into that eighth server and Power Peg was doing what it was programmed to do: buying on the offer and selling on the bid, then repeating the process endlessly. As long as the flag remained up, Power Peg kept going. And because there was nothing to turn the flag off, Power Peg never stopped. It was buying and selling 140 NYSE stocks and ETFs and executing 2,400 transactions a minute.

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At that frenetic pace, it didn't take long for traders on the floor of the NYSE to notice that something was up. Within the first minutes of trading, volume was 12% higher than normal. After a couple of minutes more, NYSE stocks had traded the equivalent of 30 days' worth of volume. And Power Peg was just getting started.

You might think the new rules established after the Flash Crash – the rules specifically designed to prevent a rogue algorithm from doing exactly what was being done – would have kicked in. But the circuit breakers weren't designed for massive trading volume, they were designed for large price swings. The same was true for the limit up/limit down bands. They weren't triggered either, for the same reason. Those protections only came into play when stock prices were moving up or down by 10% or more and that wasn't happening. Power Peg was massively buying on the offered side and equally selling on the bid side. The stocks really weren't moving outside of their trading ranges.

Then, what about the internal risk controls at Knight? *Nearly* all of the trading accounts at Knight had limits in place to automatically trigger a shut-down if certain thresholds were reached. That is to say, there were risk limits in place for every trading account except for one: the error account.

The error account was the trading account designated for the trading mistakes generated in those other accounts. As such, it never dawned on anyone at Knight that they needed stop-gap measures to shut down the error account. It just didn't seem necessary. Since Power Peg's resurrection wasn't a part of the firm's normal trading protocol, all of the Power Peg trades were automatically sent to the error account.

At 9:34, NYSE computer technicians traced the massive volume spike back to Knight. They found that 20% of the entire NYSE trading volume was being driven by the Electronic

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Trading Group (ETG) at Knight. Duncan Niederauer, the CEO of the NYSE, immediately tried to call Tom Joyce to inform him about it. Joyce, however, wasn't in the office. He was at home recovering from knee surgery.

That information was then routed to Knight's Chief Information Officer who, upon hearing the news, immediately gathered together the firm's top IT people and headed to the fourth-floor data center to figure out what exactly was happening. Ideally, this was the perfect time to flip the kill switch that is *de rigueur* in most trading systems. But again, they didn't have that option, because no one had ever installed one.

After nearly twenty minutes – all the while Power Peg was freely trading – the Knight technicians decided that the problem was most likely something to do with the new code they'd installed - a pretty standard first response for programmers when something goes wrong with a new software update. Because they knew the old version worked fine, it made sense to their algorithmic brains that reinstalling the old system would solve the problem. IF the new system is acting up, THEN go back to the old one. As it turned out, it was the worst thing they could have done.

Within a couple of minutes, the techs had successfully removed all of the new RLP algorithms from the SMARS update. However, that action didn't turn off the flag that was telling Power Peg to buy and sell; Power Peg just kept going. But now, the updates were turned off at all of the other seven servers, and not just server number eight. Power Peg jumped in to fill that void and was now was running on all eight servers simultaneously. Buying on the offer, selling on the bid.

It wasn't until 9:58 that the programmers located the problem. They immediately shut Power Peg down, but not before the algorithm had done an incredible amount of

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damage. For the time-span of a full 28 minutes, it's easy to criticize the group for the delay. But a former Knight executive explained it with the following analogy: Imagine you have a young child who has locked himself in a bathroom. He is inside screaming for help. You have a large ring of keys, all of which look the same and one will unlock the door. As you go through the process trying one key after another, the child continues to cry and scream from the other side, with the shrieks growing in intensity. When you fit the seventh key in the lock, the door opened and lets the child free.

That's precisely what happened with Knight's IT staff. They tried all of the typical fixes to solve the problem, methodically one after the other, all of the fixes that had worked in the past. It took six attempts at choosing the wrong fix before they found the right one. Just like the algorithm they were trying to shut down. IF this fix doesn't work, THEN try the next most likely solution. Repeat as needed.

At 9:59, the head of the IT department called Joyce at his home to alert him as to what had happened and reassures him that they'd solved the problem. The bleeding had stopped. Power Peg's career as a stock trading algorithm had officially ended – never to be allowed on the trading floor again. But they'd lost a lot of blood in the process. Trading volume on the NYSE was 364 million shares during the first half-hour that morning. The typical volume for that timeframe was only 100 million shares. And that was just the NYSE!

The financial news outlets immediately picked up on the story, and reports began to fly around on television and on the Internet. At 10:15, the damage assessment was finalized. During its brief liberation in the market, Power Peg had routed approximately 4 million trade executions in 154 stocks, trading more than 397 million shares. Knight had a

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net long position in 80 different stocks worth $3.5 billion, and a net short position in 74 different stocks worth $3.15 billion.

By 10:30, Knight's own stock began to plummet. Executives at Knight – with their CEO on the way to the office – began having conversations with regulators and the individual exchanges about cancelling the trades executed by Power Peg. Joyce made it into the office on crutches by noon, and at 12:30 he was officially informed by Niederauer of the NYSE that that Power Peg's trades, although unintended, would stand. Under NYSE rules, they could not be cancelled.

Different exchanges have different rules for allowing trade cancelations. At the NYSE, the trading range must be between 20% and 30% off the opening market price. In Knight's case, the issue was volume, not price. With very few exceptions, none of Power Peg's transactions had moved the stocks more than 10% away from the opening price, which meant that the cancellation rules did not apply. After further review, six of the 140 NYSE-traded securities that Power Peg had traded met the criteria, and those six were cancelled.

It wasn't the news that Joyce was hoping for, to be sure, so he called Mary Schapiro, the Chairman of the SEC. He pleaded his case, explaining that it had been a computer malfunction and that Knight should not be responsible. Sympathetic as she might have been, Schapiro informed Joyce that it was between Knight and the New York Stock Exchange. The SEC had no authority to overrule the NYSE and she was unable to help.

When that Hail Mary (literally) didn't work, another truth came to light. Knight had a $7 billion position in various stocks. Other market participants knew that too, and at some point, Knight had to unload their holdings. Given the massive position, when the time

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came for them to buy and sell, prices would start moving all around. Wall Street smelled blood in the water, and it was coming from Jersey City.

By the time the market closed on August 1, Knight traders had managed to sell off a big chunk of their stocks. The total position was whittled down to $4.6 billion, which meant that they'd successfully sold off more than $2 billion of their holdings. But another problem still remained - the firm lacked the regulatory capital to hold such a large position, and the clock was ticking. Stocks settled three days after the trade date, which meant that Joyce had three days to either find a buyer for the absurdly large position or figure a way borrowing money to finance the stocks. He started working his Rolodex, calling the large investment banks, knowing that he needed help if Knight was going to stay alive.

In the same way that a buyer of a large block of stock wants a discount for buying the full amount, so, too, would a potential buyer of Knight's massive position. Bids filtered in from market participants and hovered around an 8% to 9% discount from the market's closing prices, far more than the discount Joyce expected. On that $4.6 billion block of stock, a 9% discount amount to $414 million.

Knight then approached Goldman Sachs to buy the portfolio and was shown a bid at a 5% discount. The price from Goldman was better, but it was still going to cost Knight $230 million. It was still a massive commission to pay on the sale, but Knight was up against a wall and they didn't have time to shop around for a better deal.

Meanwhile, Knight arranged emergency funding from JP Morgan to help keep them afloat, but even with a new credit line in place, they were still short about $440 million. Joyce made a desperate call to Richard Handler, the CEO of Jeffries, who told the embattled

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Joyce that he'd be able to help him out. Handler arranged, through the Jeffries' stock loan desk, the additional funding that Knight needed.

Before the start of the trading day on Thursday, August 2nd, Knight sold off its positions and took the massive loss. While they had about $365 million in cash and liquidity on hand at the time, the losses were still well in excess of that amount. The $200 million they'd lost on cutting their position from $7 billion down to $4.6 billion was just the tip of that iceberg, Power Peg lost money buying on the offered side and selling on the bid side, and they took a hit selling their remaining positions. All told, the firm was looking at a shortfall of approximately $440 million. That was money that they did not have. Taking the losses was a foregone conclusion; there was no way around it. The other foregone conclusion was that they needed a massive capital infusion if they had any hope of staying in business.

On that Thursday, Knight issued a press release as a way of explaining what had happened. They hoped that by coming out immediately it would quell investor fears and cauterize the gash that was bleeding. "Knight experienced a technology issue at the open of trading at the NYSE yesterday," the press release stated. "This issue was related to Knight's installation of trading software and resulted in Knight sending numerous erroneous orders in NYSE-listed securities into the market." It wasn't really a story at that point, as every major financial media outlet had already told and re-told the story countless times.

What it did do, however, was suggest to the Street that the blood they smelled in the water was getting closer. Citadel, a vulture hedge fund with a reputation for swooping in to feast on dying companies, put an offer on the table to buy Knight. They were willing to pay

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between $0.50 and $0.61 a share for the company, when the stock was trading at $4.00 a share. It was, quite frankly, an insult to Knight. Thank you, but no thank you.

The insults, however, weren't limited to low-ball offers. Many of Knight's most important clients – including TD Ameritrade, Vanguard, Fidelity Investments, Scottrade, E-Trade, and Pershing, among others – stopped routing orders through Knight. Many of the original roundtable partners weren't so happy anymore with their seat at the table anymore. Without the order flow from their major customers, Knight's money problems only worsened.

Virtu Financial, an electronic trading firm that specialized in high-frequency trading, approached Joyce with the equivalent of a life ring being thrown to a drowning man. They were interested in merging, or some type of partnership with Knight. Details of the proposal weren't terribly specific, but given their situation, it seemed like a pretty good offer. It would allow Knight to stay solvent, if nothing else. Buy Joyce was adamantly opposed to a partnership with one of Knight's competitors, and he declined the offer.

Howard Lutnick, the CEO of Cantor Fitzgerald, called Joyce to see if Cantor could make an investment in Knight, but that offer, like Virtu's, went nowhere. Then Citadel came back again. This time they would loan $500 million to Knight, complete with an interest rate of LIBOR + a whopping 8.5%. In addition to massive interest payments, Citadel would also get a minority stake in Knight, diluting Knight's shares by 10% to 20%. That offer, too, was declined without much discussion.

Then, on Monday, August 4, a deal was struck between Knight and a consortium of banks that included Jeffries, Blackstone, TD Ameritrade, Stephens, Stifel Nicolaus, and GETCO. Knight would get $400 million in cash, and the consortium received preferred

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shares with the option to buy Knight's common shares at $1.50 apiece; shares that could be converted to a 73% ownership in Knight's. In this deal, shareholders would be diluted by about 70%, but Knight would remain independent. It was time for Knight to accept the reality that they were living on borrowed time. The rescue seemed to be complete and the matter was settled. However, Knight would not remain independent for long.

By November, Knight's stock price was hovering around $2.50 a share, which meant the firms who had saved the dying company saw a nice profit – $1.00 a share – if they chose to exercise their options. And they would be happy to do so. It would be quick cash in a relatively short period of time.

So on November 27, Knight was back in play. Virtu Financial once again proposed to buy Knight, this time upping their offer to $3.20 share, all in cash. At the same time, GETCO, a Chicago-based high-frequency trading firm, was contemplating their own bid. They were already a market-maker in 500 different NYSE stocks, and they relied heavily on Knight's algorithms for trade executions. They estimated they could save between $90 and $110 million annually just by combining their operations with those of Knight.

GETCO immediately submitted a bid for Knight following Virtu. The new bid – a combination of cash and stock – started off at $3.50 a share, the climbed up to $3.60 and eventually landed at $3.70 a share. Their plan was to carve up Knight and sell off the individual components to pay off the debt they'd incur. The offers were put to a vote by Knight's shareholders and a majority agreed that GETCO was the better option - Knight Capital Group was officially sold to GETCO. The firm that had ridden the technology wave to the top found themselves a victim of technology in the end.

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* * *

Throughout his tenure as CEO at Knight, Thomas Joyce openly discussed what were deemed to be the most "significant risks," both with board members and with the employees. When one employee once asked what Joyce saw as the biggest risk to the firm's well being, Joyce suggested that a rogue trader was, to his mind, the biggest threat they faced. It never occurred to him that an algorithm running in the computer system would turn out to be the rogue trader he so feared.

As for the IT employee who installed the new software – or who failed to install the software – the firm took precautions to preserve both his privacy and his own personal safety. He was never publicly outed by the company and he was placed on twenty-four-hour-a-day suicide watch. Every evening after work, a Knight employee would accompany him home and stay with him until he returned to the office the next morning.

At its core, though, what happened at Knight was more than just human error. Yes, the human component was a major contributing factor, but it wasn't the only one. The disaster that was wrought in the first five minutes of the trading day on August 1 was a software problem. The ensuing 35 minutes, however, were a catastrophic failure of risk management. It was more an institutional problem than the fault of any individual. Knight as a company didn't have adequate controls in place to prevent the erroneous orders, nor did they have the necessary controls to ensure the proper deployment of new computer code.

Of course, the failure of the firm's risk-management policies is manifested in the fact that they didn't have a kill switch in place to shut down the system. That would have solved

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the problem shortly after it became a problem in the first place. And it could have been a very simple algorithmic expression for a programmer to write: IF the daily volume reaches a certain level, THEN shut it down. Alternatively, substituting any number of factors for "daily volume" would have had equally beneficial results: profit/loss, market exposure, firm's capital. Pick one. Any of those would have substantially eased the pain Knight experienced. Perhaps the IT staff was unfairly singled out for their arrogance.

The SEC began an investigation in Knight's trading practices and their risk management policies just days after the Power Peg incident. They would later say in their final report that the firm was in direct violation of the SEC Market Access Rule and that Knight lacked reasonable risk-management procedures. Tom Joyce resigned his position as CEO on July 3, 2013. Senior technology executives were purged from the firm's employee roster, while others were reassigned to other positions within the company. Knight was then fined $12 million by the SEC.

Walter Raquet, the man who originally conceived of Knight Capital Group, would say of the Power Peg affair, "It couldn't have happened under Kenny's and my watch. We had so many controls that something like that could never have happened." And even though it's easy for him to Monday Morning Quarterback the situation, you have to wonder if his technological insight and forward-thinking would have thought that something could go so drastically wrong with firm's computer systems. After all, they were only as good as the people who programmed them.

On December 23, 2012, the IntercontinentalExchange Group, which now owns the NYSE Euronext, filed a plan to offer all of their member firms a kill switch as a way of preventing another Power Peg incident. Under that plan, member firms would have the

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option of pre-setting trade thresholds that blocked the firms' orders when thresholds were reached. Two other stock trading platforms – BATS and Direct Edge – already had a kill switch function for their members.

Shortly thereafter, Power Peg was officially erased once and for all. The program was completely deleted from all of Knight's servers, prompting a senior executive to announce ceremoniously, "Power Peg is now dead." Never again would it be able to rise up and go rogue. The person who woke Power Peg up from its hibernation was never named, as Thomas Joyce continues to this day his policy of protecting the privacy of the employees involved in the incident.

Because algorithms are nothing more than a set of instructions that a computer follows, traders must still monitor their executions and keep close tabs on what the algorithms are doing. An algorithm is only as good as the person who writes it and there are many possible alternatives to the final outcome of Knight's disastrous flow.

IF Knight's systems administrators had deleted Power Peg in 2003 when they were supposed to, THEN Power Peg would not have created the mess it did. IF Knight had procedures in place to review the deployment of the SMARS update, THEN they would have caught the missing code on the eighth server. IF someone at Knight had paid attention to the error messages they received on August 1st, THEN Power Peg could have been turned off before it started trading. IF the flag that turned Power Peg on hadn't been recycled, THEN Power Peg never would have woken up. IF a kill switch had been installed, THEN the losses would have been minimized.

That's a lot of IF statements to be sure, but perhaps the most pointed IF-THEN came from Larry Tabb of the Tabb Group. His words, expressed as an algorithm, were quite

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damning of the system as a whole: “If this happens to one of the most sophisticated players in the market, then we really need to rethink our overall market structure.”

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