LGM

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AUTHOR'S FORWARD

LGM is a novel set in the present. The year is not explicitly stated, but the time period could be any time at the start of the twenty-first century.

The detection of an intelligent extraterrestrial signal sidetracks the routine existence of a radio astronomer, a reclusive mathematician and two computer entrepreneurs.

The discovery and analysis of this intelligent signal from the extraterrestrials, affectionately called the "Little Green Men," proceeds as it might in real life.

This is a work of fiction. All characters appearing in this work are fictitious. Any resemblance to real persons, living or dead, is purely coincidental.

ACKNOWLEDGEMENTS

Special thanks to my son, daughter, and son-in-law for their careful reading of the manuscript. They discovered quite a few typographical errors, and they also suggested improvements to the structure and content of this book.

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PROLOGUE – GREECE, 450 BC

It was a fine morning, the beginning of a fine day, so I was not surprised when a messenger summoned me to dine, mid-day, with Leucippus. I immediately assented, since the Old Boy always had something to capture my attention. Most men live in the world without thinking at all about it, living from hand to mouth without questioning why things are as they are, and not otherwise. Leucippus was not one of them.

Leucippus had lectured me and our small circle about how different things might arise from more fundamental substances. While one can hack away at a thing, cutting it into smaller and smaller pieces, might there not be a limit? There may be something that describes the essence of a thing, something that cannot be cut without a loss of that essence. This idea of the a-tom, the thing that cannot be cut, was his most interesting idea, yet. Whatever was on his mind, now, might be more interesting, still.

I passed the morning in the usual manner, tending to the garden, and leaving a small devotion to Athena, who had guided me well in her arts. She inspired me in the design of the garden cistern that held water between the rains and allowed a greater harvest from that small plot than I had ever had.

My shortened shadow marked the time for my walk to the house of Leucippus, a mere ten stadia from my own. Although the Sun was at mid-day, the heat was not at all oppressive, and it was a welcome change from the typical chill of the season. Leucippus and two other friends were there to greet me upon my arrival, all sitting on stools near the walkway. I was immediately offered water, and Leucippus, my host, was the first to speak.

"Peleus, old friend, have the gods been good?"

"Yes, they have, but it's strange to hear your talking about the gods. We were led to believe that the gods are not a part of your world."

"You misunderstand. I'm the first to admit that there are forces, above and about, that control our destiny. It's how we name them that makes us different. But, it's much better to eat and talk, than to just talk."

At that, he signaled the servants to bring us food. When my beverage was at hand, I poured a libation to the gods, as did all those seated. Leucippus offered a libation also, perhaps from habit. As senior in the company, next to our host, it fell to me to begin the conversation.

"Leucippus, will you once again regale us with more details of the structure of the world about us, as defined in your philosophy; or, have other things been on your mind?"

"Peleus how nice it is for you to ask, for what would I be if not for my ideas. I am certainly no good in the vineyard, and I have no crafts to match your own. What concerns me now is neither the composition of matter, nor the nature of the gods, but the nature of people."

Theodoros, another from the group, spoke.

"Do you mean the customs of men, which differ widely as we travel from place to place?"

Leucippus smiled broadly in that way he had to indicate he meant something far more fundamental.

"As you say, we travel, and we find strange people in the distant lands. We hear also the tales of those who have traveled farther still, and the people they have met. Do you wonder how there are always people wherever we go?"

I made answer for the group.

"Why would you not expect there to be people everywhere? If a man lives at one place, he can just as well pack his household and move a few hundred stadia farther still. I see no problem with that."

Leucippus smiled broadly, again, as if I had fallen into his trap.

"If he moves, say, to a place where there grows less barley, but more spelt, he would survive, would he not? Or, if he finds a place high atop a mountain, would he not just wear furs to keep himself warm?"

"Yes, that is all logical. Men will adapt to their environment in order to survive, just as an old man will use a stick to help him to walk."

"And what of the other worlds?"

"Other worlds?"

"Earth is just one of many worlds. It has its Sun to provide heat and light. The stars in the sky are other suns providing heat and light to their worlds."

I felt a need to object.

"There is no evidence for these other worlds! Things on Earth we can see, but things beyond the Earth will always be unknown."

”You do not see the gods, but yet you believe. Believe with me, for the moment, that there are other worlds. Is it not logical that therein live men who are adapted to their worlds?”

This was just like Leucippus, to state the ridiculous and render it logical.

“Yes, I agree that there may be men on other worlds. However, you must admit that, since there would be no means to discover their existence, it might as well be that they are not really there.”

1 NOISE

Although their offices were on opposite sides of the building, the trip from Brian's office to Tukey's office generally took just a minute. Brian, however, was extending the trip to a much longer period. He stopped to read some of the bulletin board notices, which was something he rarely did. All useful information came from personal encounters, email, and the Internet. What he may have missed beyond those was likely not important. Still, someone had taken the time to post these items, so one or another might prove to be important. This time, that wasn't the case.

Brian paused to stare through the corridor skylight and admire the huge radio telescope dish responsible for the signal traces he carried in his hands. Such a huge structure would be a marvel even to someone who didn't understand its purpose. It was a megalith of the modern age. He felt privileged to be a part of such a venture. Somehow, civilization had advanced to the stage at which humans could afford to build such “useless” devices, and even pay people like him to operate them.

Arriving at Tukey's office, Brian stood at the closed office door for a few seconds. He really hated to disturb the Old Man; but, that's why the Old Man was there, wasn't it? Brian had spent the last few minutes convincing himself that what he found demanded Tukey's attention. All he needed to do was to follow through. He knocked and opened the door in response to the grunt from the other side. Tukey was in his usual repose, leaning back in his office chair with a journal in hand.

“Professor, do you have time to look at a signal trace?”

Tukey looked up from his journal to see Brian, one of his post-docs, peering through the doorway. The journal he was reading was the traditional paper type. Tukey had never made the transition to reading research papers on a computer screen or tablet. Some of his colleagues extolled one feature of tablets, the ability to enlarge the type font to make for easier reading. Tukey didn't think he had reached the point at which that was necessary, and it would be somewhat strange reading an astrophysics paper in type as large as that in a child's storybook.

Digital publication did have another advantage − faster distribution. Although the journal he held was the current number, it contained research that must be many months, if not years, old. It didn’t matter. In his field, if anything important did happen, he would hear about it from a television newscast, not from a journal.

“Sure, let’s see what you’ve got.”

Brian, a recently minted PhD from the University of Wisconsin, Madison, spread a meter-long chart trace over several stacks of books and papers on the table behind Tukey’s desk. Old scientists always had a lot of paper in their offices. Brian's office was nearly bare. He had used the large format printer to allow a closer examination of the raw data, and he had carefully trimmed the excess borders to make the graph easier to handle and read. It didn't occur to young Brian that the data looked like a traditional strip-chart recorder pen trace from Tukey's own student days.

Tukey immediately saw why the chart was interesting, but he waited for Brian to point it out. The aged professor was acting paternally. Scientist and apprentice, father and son, this type of relationship always seemed to work, both to the benefit of the individuals, and society as a whole. Society had signed onto this particular scientist-apprentice team wholeheartedly, funding Tukey, his post-doc, Brian, and their associated overhead, at a million dollars a year.

"This is one channel from the channelizer. It doesn't matter which one – they all look about the same. If you compare this segment with what comes before and after, you see that the character of the noise changes slightly in sort of a bell curve. The power level doesn't seem to change, but if you do an FFT of the raw data, there's a definite excess of high frequency noise."

There was a qualitative difference, just barely visible to the eye, but Brian must have been alerted to it by the automated signal analysis programs. The programs must have been well crafted to pluck this little patch of scruff from a sea of debris. Tukey looked sideways along the paper as a way to accentuate the profile of the signal trace, looking for any sort of bump. There wasn't any, but the signal was different in the way that Brian described.

"You checked the Omni."

Tukey was referring to a second receiver designed to record local radio interference.

“None of this is in the Omni data. I do see some of that motorcycle that passes a few miles to the North every night about this time, but that noise isn’t mirrored in the data from Main. And, most interestingly, the width of the blip is what you would expect for a point source convoluted with the beam width.”

Brian was thorough, as usual, and that’s why Tukey had recruited him.

“Well, it does look different, but can we afford an immediate recheck? How’s the Crummy survey going?

Hearing a professor refer to the Kumhansl Milliarcsecond Survey in the same slang as the students and staff prompted a quick smile from Brian.

“We’re at least a month ahead on the data collection, and three weeks ahead on the offline analysis. The monthly report won’t be a problem, barring any equipment troubles.”

“So, we eat for another day. Do a recheck, this time at a slower scan rate, and open up the bandwidth.”

Brian nodded assent. On his walk to Tukey's office, he had predicted the exact outcome of the discussion. That’s one nice thing about science. It’s so objective that consensus is rarely a problem. There is typically only one path to Truth.

“… And charge everything to Crummy.”

“Crummy? How can I justify that on my time report?”

“That reminds me, I’m about six weeks behind on my own time reports.”

“What?”

“Just kidding. Do you think the Bean Counters would let me get even one week behind? They like to close their books, neat and complete, at the end of every week, and then send out invoices that are ignored for ninety days. All in all, I don't think scientists should spend any time at all on this finance stuff; but, since we're forced to do it, we need to work the system."

Tukey paused, as if for emphasis.

"Brian, what makes your data look any different from some instrumental noise?"

"Well, at this point it could be anything, even a bad amplifier on the front-end. But I'm pretty sure that's not the case."

"Well, just-to-be-sure-wink-wink, we'll need to do some more measurements. After all, we want the data from the Krumhansl Survey to be beyond reproach... So, charge this to Crummy."

Brian smiled. He was learning much more on this apprenticeship than any textbook could teach. He left the office and headed towards the control room. Tukey retrieved the journal, but his gaze was still on the data trace that Brian had courteously left behind.

"Are we grasping at straws?" he thought. "Then again, that's what we're paid to do."

He read for another few minutes, and then dozed off.

Tukey rarely dreamed. There was the occasional nightmare, typically caused by too heavy a restaurant meal, but not much more. There must have been something about Brian's data trace that triggered a rare, recurrent dream. Sitting late at night, alone in the telescope control room, he detected a genuine interstellar transmission. The senders had been kind enough to send the message in English. As always, just as he started to read the message, he awoke. Maybe he should call that dream a nightmare, too.

2 VENTURE CAPITAL

Rick stared blankly out the limousine window. He should have been feeling dread, or exhilaration, or a mixture of both. Instead, he was just numb. It didn't help that traffic seemed to be at a standstill. Everyone seemed to have the need to be somewhere else at all times, and they all tried to get there in automobiles. Modern life seemed to balance every advance in the human condition with some step backwards.

“How did it come down to this, Tom?”

Tom, who was to be their point man at the meeting, was reviewing his notes for possibly the hundredth time. Tom left nothing to chance, so he made a very good business partner. Rick hoped that his own creativity added enough to the package to make it a balanced partnership.

“What do you mean?”

“You know. Here we are, on our way to stake our future on a handful of presentation slides. There’s not a single equation in the bunch, and our idea is so buried in financial gobbledygook that even I can't find it. Then there's the audience, a bunch of white-haired suits who couldn't take the square root of four. The only reason they want to see us is that they have twenty million dollars in loose change and they don't know how to spend it."

"We have a good business plan. We paid the consultant to help us write a winner. He knows what they want, what they really look for. Hey, techno-geeks are only good for entertainment value in Suit Culture. The Suits value money, not science."

The limo was Tom's idea. To woo Big Money, you needed to look the part. Tom went back to his notes, and Rick continued to stare out the window. He thought back to their college days when getting to class was an adventure. They fled the dorms as soon as they could, right after freshman year, and got an apartment a few miles from campus. The distance meant they needed a car, and on their budget they needed a very inexpensive car. In the winter they had to pull the battery out every evening and keep it warm in the apartment overnight, or the car wouldn't start the next morning. Now, here they were, eight years later, in a limo.

Tom and Rick had been roommates from the first day of college. Rick majored in Physics, and Tom was in Economics. Despite their different interests, they were matched well in intelligence and were able to feed off the fringes of each other's field. Like most students, they both had mastered the family computer at an early age, and they each were able to write simple programs while still in elementary school. But they really weren't that interested in computers, or they would have studied Computer

Science. Instead, they used their mastery of computers to advance themselves in their respective fields.

Rick had an early interest in particle physics and spent his graduate school days attached to a very large team in charge of a very large detector doing a very large experiment. The data stream was tremendous, and it was his job to reduce it to human proportions, at the same time trying not to lose anything important. The experiment was exciting, but the work was almost routine. Sure, there was a lot of his intellectual input in the pattern matching algorithms (Rick couldn't have been assured of an eventual PhD without that), but he quickly tired of being just a small part of a huge team.

When there was a publication, the team members were not even individually listed as authors. Decades prior, the major Physics journals started to object to papers in which the authors' names took more page area than the actual article. They were the “Blue Ball Consortium,” a not so inside joke based on the appearance of their detector.

Rick was imagining a monotonous, but comfortable life after graduation when he met his first “Rocket Scientist.” “Rocket Scientists,” or “Quants,” are a special breed of Physicist who try to model financial markets with the same tools they use to model nature. Better knowledge of the market wasn't the only goal. That knowledge would be used to make money; and, often, a lot of money, very fast.

Rick saw a posting of a seminar with the strange title, “Random Matrix Theory as Applied to Sampling in the Analysis of Financial Derivatives.” At first he thought it was a joke. By chance, the seminar was scheduled for April first, and Physicists, as Feynman proved, are very creative jokers. Maybe the professors wanted to see which of their students were dim-witted enough to show up. Well, Rick was one of the dim-witted, and he was amazed. Here was a PhD Physicist doing the same sorts of math and computer analysis Rick was doing, but he was happy in his job and making a ton of money. Sure, after the talk, some of the audience thought the guy had sold out, but Rick was hooked. After the typical span of time, Rick was granted his degree, and he was free to pursue this unusual career path.

Rick was ready, but the world was not. He wasn't the only Physicist who had discovered “Rocket Science,” and the ground floor of the field was fully filled. Many of the other scientists had pursued an MBA while taking their PhD, looking for any edge to advance into the field. Many of them came from backgrounds in statistical mechanics and thermodynamics that were more relevant disciplines to financial analysis than particle physics. Rick was depressed, and he had resigned himself to a future of staring at spark chamber photographs, but a trip to the dentist changed all that.

It's not that the dentist himself, a wise old professional, had offered just the right advice, like a bartender, while performing his usual services. The inspiration came from a throw-away magazine he flipped through in the waiting room. There, in the back pages, was an ad that reminded him of the ads he saw in comic books as a child. There was a line drawing of a smiling man with a fistful of dollars radiating dollar signs from his head. In bold type were the words, “BE YOUR OWN BOSS.” The ad had nothing to do with any profession that would have interested him, but it got him thinking. Soon thereafter, Tom, who was plugging away at his advanced degree at another school, and Rick hatched their plan to join forces and take finance by storm. Their first hurdle was convincing the wives.

Graduate student wives, at least the wives of technologists, are a complex breed. On the one hand, they are accustomed to a poverty lifestyle, as all student wives must be; on the other hand, they are gamblers. In their minds, this early phase of marriage is like a lottery – they're betting their husbands will get rich. Not only that, but they will get rich rather quickly.

There is, of course, the other species, the wives of non-technology graduate students. These are either masochists, or they enjoy a Bohemian lifestyle. Their husbands would most likely avoid slinging burgers, and they might even aspire to some middle-management position (probably in an amorphous field like human resources), but they've resigned themselves to the fact that there would be no Mercedes SUV in the driveway. It must be true love.

Tom's wife and Rick's wife were fully supportive and rather enjoyed the idea that they would live within a short automobile ride from each other. They would each have a shoulder to cry on, and the dinner parties would be nice.

So, there they were, Tom and Rick, in a limo, building up enough courage to ask for just a few million dollars – small bills, please. Almost as an omen, the clouds had parted ahead, letting a few rays of light into the city canyons. At the same time, traffic began to move. Rick, ever analytical, started to wonder whether there was a causal relationship at play. Perhaps the rays of the Sun had subconsciously triggered the slightest bit of optimism in the drivers, and that was enough to get the line of cars moving.

Such things were common in nature, where a small grain of sand would cause an avalanche, or a bit of dust landing in a cool pond will cause it to freeze, instantly. Just a single driver's stopping properly at a traffic signal and not rushing ahead to block cross traffic might just have this same affect. People pride themselves on their individuality, but when they're in large groups, their fate is generally governed by statistical laws they don't understand.

Rick and Tom's business plan was based on essentially that idea, that large quantities of things, when examined in the aggregate, will perform predictably. They were going to game the stock market using computer algorithms.

3 CHICKENS, CHICKENS, EVERYWHERE

Roos stared out at the expansive plain before him.

"Chickens, chickens, everywhere, nor any egg to eat…"

He remembered some of the real verses to the poem.

Water, water, everywhere,
And all the boards did shrink;
Water, water, everywhere,
Nor any drop to drink.

The notion of shrinking boards set off an uncontrollable flurry of differential equations and tensors in his head, as he subconsciously starting building a model of how boards really do shrink. He shuddered at this unwelcome onslaught and tried to block the thoughts from his consciousness. He succeeded only partially. Mathematics always operated as a background process in his brain.

"You can take the man out of mathematics, but you can never take mathematics out of the man."

Martin Roos had been a Wunderkind of mathematics. His parents had noticed his facility with numbers before he attended preschool. Since he enjoyed arranging things in groups, his parents were worried at first that he might have Asperger syndrome. From the magazine articles that they had read, what he was doing was a sure sign. Their doctor advised them, however, that all other symptoms were absent. Perhaps their son was a budding artist who enjoyed changing the juxtaposition of colored objects. They shouldn't even attempt to ween him from such activities, since that might do more harm than good.

When he had learned to read at the age of four, he was permitted to browse the lower shelves of the household bookshelf. Soon after, he was found immersed in a top shelf book, his father’s Analytical Geometry text from college. His parents thought he was just admiring the pretty pictures, another sign of a potential artist, but then the questions started.

“What are these words?”

“Right triangle.”

“Why is a right triangle special?”

By sixth grade, Martin had developed a strange fascination with the number pi, and he programmed the family computer to print pages and pages of the number. His science fair project in his freshman year of high school was so far outside the realm of his teachers’ understanding that they called in a professor from the local college to offer an opinion. Martin and the professor talked about the equations for nearly an hour. By the end of the week, Martin and his parents received a luncheon invitation from the college, and it was decided that Martin would continue with the usual high school courses, but take math courses at the college, full expenses paid.

Some other high school students might have been uncomfortable with the idea of leaving their classmates and mixing with students quite a bit older than themselves. Martin was a solitary individual, so it didn't really matter what crowd he was in at any moment. Fortunately, the practice of mathematics is easier for solitary individuals.

After high school graduation, he began at Berkeley. It was as an undergraduate at Berkeley that he gained his initial fame. Using his programming skill, some deep knowledge of an obscure lemma of Galois, and idle computing cycles on as many computers he could reach on the campus network, he found an optimum Golomb Ruler of length twenty seven.

In graduate school, he combined his dual interests in pure mathematics and computer science with a thesis on cryptography. It was not unexpected that Roos would earn his PhD in mathematics in record time, and that he would win the Fields Medal, the mathematics equivalent of the Nobel Prize. What was unexpected was his burn-out at the early age of twenty eight. He renounced all interest in mathematics and retired to a free-range chicken farm.

Since his worldly wants had always been small, he had saved a considerable amount of money, so the down payment on the chicken ranch hadn't been a problem. Tom, a college acquaintance, had helped him write a business plan to secure a business loan. The depth of the business plan was likely overkill for the rural bank with which he dealt. For Roos, the business plan served as more than just a means to extract money from a bank. It was an algorithm for an assured income, and he believed that strict execution of this algorithm would be essential for survival.

Roos had chosen chicken farming by an algorithm, also. He needed to get away from it all, so living at a rural location popped up as one logical consequence. Cranking through the numbers of the profitability and administrative demands of different types of small farms, Roos was left with a choice of organic produce or free-range chickens. Organic vegetables were seasonal, so they demanded too much work at certain times of the year. Chickens, however, were steady, year-round work, so he chose the chickens.

As he entered this new profession, Roos couldn't help but make the analogy between what he was doing and the plot of the 1960s television series, Green Acres, in which a New York City attorney moves to a farm to get away from it all. In that case, the man had a wife in tow, and the wife missed her former luxury lifestyle. The attorney knew little about farming, so his rural life was a mess. Roos hoped that the problems were just exaggerated to make for a good show, but he wasn't taking any chances.

Just as he had absorbed so much mathematics in his day, Roos did a careful study of chicken farming, and of the chickens, themselves. He knew that a small operation such as his must operate in a niche, so that's why he decided on a free range farm. He would produce not just free range chickens, but organic chickens. This meant that the chicken feed must be a hundred percent organic; that is, the grain must not have been genetically-modified, and it must have been grown without chemicals such as fertilizers or weed killers. In short, his chickens were luxury fare, so he could demand high prices in specialty store distribution.

Fortunately, free range chickens needed little tending, and an operation such as his could get by with just a couple of hired hands. They were always busy, fixing fences, spreading feed, hatching chicks, and doing weekly harvesting from the flock. Roos was happy that the harvesting just involved putting the chickens into cages for slaughter elsewhere. He was happy, also, that the rural men he hired had a very good work ethic, so the farm ran on automatic. The first year was an adventure, but after that it became more like a routine.

So here he was, paternally gazing at his chickens, oblivious to the forces that would thrust him into the greatest mathematical puzzle since Fermat's Last Theorem.

4 START-UP

Four weeks had passed since Tom and Rick's milestone meeting with the venture capitalists. The consultant had done his homework, and their two-man company was now twenty million dollars richer. The wire transfer came just days after the meeting, but along with the money they got another employee – an interim Chief Financial Officer “recommended” by their sponsors. They could hardly refuse. Besides, they had no idea how to find a CFO if they needed one.

Dan, the new guy, kept a low profile and seemed easy to deal with. He was clearly of the opinion that you had to spend money to make money, so he was no problem at all. To celebrate, they got new business cards with a logo Rick had developed from his college days. Tom, of course, was President, while Rick became Chief Technology Officer and Chief Architect. Dan decided he didn’t need business cards at this point, and thus exercised his first fiduciary responsibility.

The first order of business was obtaining the raw computing power they needed. In the old days of computing, which were just a few decades prior, you would order a supercomputer, and then wait two years for it to be built and shipped. Nowadays, you could requisition the appropriate amount of raw computing power from a “cloud” service; or, you could assemble your own supercomputer in-house from readily available components. For security reasons, and because he needed to know precisely how his computer functioned, Rick decided to build his own in-house supercomputer. To that end, he ordered 8,192 off-the-shelf computers with individual computing power a step up from a standard desktop.

These computers, however, were not intended to work with keyboards, displays, mice or monitors. The money you would have spent on those peripherals was spent instead on high-speed optical network connections and extra memory. Some software running on each machine and one supervisory machine was used to “glue” all these computers into one, huge supercomputer. The basic programs for doing this were available free on the Internet, but it took someone with Rick’s skill to make them sing.

Along with the computers would come their largest operating expense next to rent and salaries – electricity. The cost for running all these computers was about $75 an hour. This, coupled with the extra air conditioning needed to remove 500 kilowatts of heat, gave their CFO, Dan, something to fret about for the short term.

Rick had been amassing snippets of computer code for years, and he started gluing all the pieces together on a smaller, desktop computer. The most important piece of code was the one designed for getting the raw market data into a useful form. The raw data was piped in from the same type of service that provides real time quotations to the major brokerage houses. Rick's programs were designed to scan the data for trends based on an ever-changing base of rules derived from his evolutionary kernel program. Soon he was able to run small simulations to verify that they could make more money than they would lose. Eventually, when everything seemed to be working, the code would be ported to the supercomputer, and they would link up with a brokerage to execute actual trades.

One factor that worried both Tom and Rick was the idea that they were analyzing the market without taking into account the affect of their own trades. This sort of self referential idea had been bugging philosophers for at least a hundred years. It seemed to be implicit in quantum mechanics, also. Rick likened it to reentrant code in a computer program where a piece of code calls itself to do a calculation. As long as this happens only a few times, computers can handle it. It's only when the process does not complete, or your calculation doesn't converge within a set limit, that you have problems. Tom's hypothesis was that the market was so huge that their individual trades would be little more than noise in the system, and they would cause no ripples in the pond. Tom even did some simulations that showed his hypothesis was true, as long as they didn't get too greedy. Rick had even programmed a greed factor into his programs, and the factor was set rather low at the start. They would try to optimize performance as a function of greed when everything was running.

One condition of Tom and Rick's funding was a schedule and milestones. Although these were constraining, both admitted that they would keep them on track. It wasn't anything different than school assignments and grading. Rick called it a “chicken and egg problem.” Did life mirror school, or was school designed to mimic life? Whatever the case, it kept them focused on their goal.

Deciding on the schedule had seemed to be as difficult as doing the scheduled work itself. Quite often in the process, Rick repeated a rule he had heard in graduate school, that all software projects took twice as long as expected, even when the rule was taken into account. It was best to create your best estimate, and then multiply by two for a safety factor, hoping that the factor would be less than two for some tasks to balance those greater than two for others. This is why spreadsheets were invented.

Renting a building, specifying the computers and getting them installed were some of the more routine tasks, but they took up a fair chunk of their money. Fortunately, these tasks simultaneously populated a large fraction of check boxes on their master plan. To the outside world, Rick and Tom were successful at this point, but only on paper.

In the weeks that followed, Tom spent most of his time reading some mathematically intense finance papers in an attempt to get further insight into the market forces they were attempting to turn to their advantage. Rick was running some test programs using real market data, but still no real money. He found that it was very rare when he would lose money, but the amount of money he was making was still quite small.

“Time to crank-up the greed,” he thought, reasoning that there would be loses more often, but a lot more gain, a factor called scalability. What he found, instead, was that his system entered a mode in which there were loses for extended periods, followed by gains for other extended periods. His evolutionary algorithm needed tuning, since the ideal response was a continuum of gains and losses in which his program made money for whatever time, short or long, it was operating.

Rick had reached the mode that all computer programmers hate – Debugging. The problem with taking the bugs out of a program is that there are so many places where they could hide, just like bugs in the real world. It might be a case of counting from one instead of zero, or having a subroutine that's never run because it's only called on a condition that doesn't exist. There were software tools to aid in debugging, but Rick's preferred method of debugging involved staring at printed sheets of code with a red pencil in hand, looking for divine inspiration.

While the men were tending the shop, Connie and Mary were growing accustomed to their new lifestyle. Their new lives, so different from their former lives as the wives of struggling students, was like a paradise; but, it was a paradise with limits. Although Tom and Rick were pulling down regular salaries, they were not large by the standard of the day, and they were living in an expensive region. Still, it was nice to bypass the soup aisle while shopping at the local supermarket.

The big attraction to them was a huge shopping mall located very near to where they lived. The mall had a good mix of upscale and discount stores, and nice places for a leisurely lunch. They tried not to go there too often, but at least once each week was a necessity. On those trips there would first be a pass through those stores they couldn't afford, just for entertainment sake. After that, it was lunch and some earnest shopping in the more reasonably priced stores.

It was always good to have an instant critic while trying on clothes, and someone to encourage a purchase when the price seemed a little too high. It was on one of these excursions that Connie and Mary decided to overhaul their spouses' Casual Friday look. This was especially important, since Casual Friday at their operation was every day of the week, unless there was some off-site business meeting. The girl's scheme, which worked as planned, was that a simultaneous assault on two fronts couldn't be rebuffed.

The boys resisted at first, but they were weaned from their blue jeans to some yuppie-wear within a week. The blue jeans were kept safely in a drawer for occasional weekend yard work and home repairs.

As new home owners with modest salaries, Tom and Rick needed to do their own home maintenance and repairs. Visits to the nearest home goods store happened every weekend, and the wives would usually browse the garden shop while the men tried to make sense of the vast variety of tools and supplies.

Not surprisingly, Rick was a whiz at fixing broken door bells and light switches, and he didn't mind lawn mowing. Such mindless work as lawn mowing left his imagination free to explore solutions to the vexing problems of the previous week. Tom wasn't as technically skilled as Rick, but the simple recourse of do-it-yourself videos on the Internet proved sufficient in most cases.

Tom enjoyed his trips to the home goods store for another reason. As an economist, he was a student of the human condition, and it was interesting to observe the wide spectrum of people shopping there. There were professionals, such as Rick and himself, mixing with tradesmen speaking a plethora of languages. In a store such as this, the knowledge base of the tradesmen was far more useful than any training that Rick or he had received.

Tom remembered a humorous story in which visiting space aliens determined that the automobile was the dominant species on Earth. This automobile species was well tended by the slower and weaker symbiotic species that we call humans. He didn't think that space aliens would be that stupid, but they would surely lump everyone in the home goods store into the same category, fancy degrees being irrelevant.

5 BIG EAR

Tukey rounded the corner and got his first-of-the-day glimpse of the giant radio telescope antenna that beckoned him to work each day. It was a hundred meter marvel of engineering with a surface matched to a paraboloid to within a few millimeters. Such high precision was needed. If it were less, the antenna would be inefficient at focusing the short wavelength radio waves used for observation. With a structure of this size, some compromises were necessary. A structure so massive as to keep such a precise shape at any tilt angle and in high winds would not be able to support itself unless constructed from exotic and expensive materials. Instead, the lower surface of the structure was dotted with hundreds of position sensors and magnetic pistons that worked in concert with some complicated computer systems to push or pull the surface to bring it into shape.

Radio astronomy antennas had come a long way since 1929, when Karl Jansky quite accidentally built the first radio observatory at a Bell Laboratories testing station in Holmdel, New Jersey. His antenna was a fifteen meter directional wire array that looked more like a clothesline than the parabolic antennas in use today. Jansky was a physicist doing research into noise sources that interfered with radio communications. He found noise from lightning strikes, and another, steady hiss that changed in amplitude in a cycle just four minutes less than 24 hours. This is the period of a sidereal day, the time it takes for the stars to circle the earth, so this steady hiss came from the stars, and not the sun or earth. Jansky published his results, they were front-page news in the New York Times in 1933, and so he became the first radio astronomer.

It was surprising, but no flurry of research in radio astronomy began after Jansky's success. It could have been that astronomers were not interested in radio, and radio engineers were not interested in astronomy. It wasn't until 1937 that an amateur radio enthusiast, Grote Reber, designed a 30-foot parabolic dish antenna and built it in the backyard of his house in Wheaton, Illinois. Reber chose the paraboloid shape and a high radio frequency for the same reasons they are used today, higher angular resolution. Reber's antenna was made from a wood frame and iron sheeting. The weight of the iron sheeting alone was more than a thousand pounds, and the wooden framework brought the total weight to about two tons. The world's first parabolic radio telescope antenna cost Reber about $4,000. In today's terms, that's about $50,000. Reber was a very dedicated amateur astronomer! For all this effort, his first observations were unsuccessful. It was only after migrating to lower frequencies that he was able to produce the first radio maps of the sky. Reber was the only radio astronomer until the end of World War II.

The advent of radar in World War II led to a surplus of radio equipment and a cadre of engineers and scientists who had experience in building and improving the wartime radar systems. Among these was Bernard Lovell, an English physicist who used radar to study meteors. Lovell championed the construction, at Jodrell Bank, of a monstrous 250 foot fully steerable paraboloid antenna that was completed in 1957. It was this observatory that verified the presence of the Russian rocket that launched the first artificial earth satellite, Sputnik I, on October 4, 1957. Sputnik launched the world into the Space Age, and it also caused a surge of interest in radio astronomy.

In the United States, John Kraus designed a radio telescope called the Big Ear. He and a group of students at Ohio State University built this radio telescope in the late 1950's for about $250,000. Comparing this with Reber's $4,000 telescope, you can see a definite trend in the cost of equipment! The government also took notice and established the National Radio Astronomy Observatory in remote Green Bank, West Virginia, where it would be shielded from most man-made interference. Of course, those were the days before cell phones and direct broadcast satellites. The NRAO's premier instrument was a 300 foot parabolic antenna built in 1962. It collapsed in 1988, a victim of metal fatigue, only to be replaced by the more versatile 100 meter Green Bank Telescope. Perhaps because of national pride, the Green Bank Telescope is just slightly larger than another 100 meter telescope at Effelsberg, Germany.

Blaise Tukey was born in 1969, the year of the first moon landing, but by the time he had entered school, the initial glow of man in space had vanished. Seeing man's conquest of the moon as a *fait d'accompli*, the public rarely tuned their TVs to watch the then frequent moon jaunts, despite moon buggies and live color television from the moon. The last man walked on the moon in December, 1972. But the Viking, Mariner, and Pioneer planetary probes returned spectacular photographs of most of the planets shortly thereafter, and Blaise was hooked on astronomy.

He immersed himself in the astronomy section of the local library, first intent on viewing all the pretty pictures, then memorizing the constellations and the names of the planets and their satellites. He built his first optical telescope in the sixth grade, polishing and testing his twelve-inch mirror using techniques that had changed little in hundreds of years. Earning his stripes through many a cold night, he gradually integrated himself into the local amateur astronomy club where he learned even more. Soon he realized that although his club mates had a lot of technical knowledge, they possessed only limited knowledge of real astronomy as practiced in the universities. At that point he stopped attending meetings and went off to do his own thing.

Then he discovered radio astronomy. His local library had just two books on the subject, one of which was an ancient amateur's guide with vacuum tube circuitry. The other was an illustrated history, almost current to the present day, with wonderful photographs of antennas and control rooms full of electronic equipment. He was hooked, but he realized that the pursuit of radio astronomy required as much knowledge of radio electronics as astronomy.

He had noticed that a neighbor down the street had a very large antenna on a tower alongside his house that obviously wasn't used for television. His neighbor was an amateur radio operator, or Ham, as they called themselves, and Blaise built up his courage to knock on the door. He was glad he did! He got a grand tour of his neighbor's radio shack and talked to New Zealand via radio. He got an armful of books to bring home, and a promise that he would be tutored enough to become a licensed radio operator. It appeared that the ham radio hobby propagated in a master-apprentice fashion.

The main hurdle to getting his amateur radio license didn't involve learning electronics and the necessary Rules and Regulations. It was learning Morse Code. This code, an extension of the rudimentary code invented by Samuel F. B. Morse in 1836, was a hundred and fifty years old, but it was a requirement for a radio license since it could be used to transmit messages with primitive equipment in emergencies. Tukey devoted as many hours to learning the code and studying radio electronics as he had making his optical telescope mirror. All this study paid off when he passed the examination for an advanced class of license that allowed him to use nearly every frequency reserved for radio amateurs.

Tukey's father was a carpenter. His family didn't have the money to fund a well equipped radio shack like his neighbor's, but that didn't matter. Tukey was more interested in building radio receivers than transmitters. The small amount of money he earned doing odd electrical jobs and painting houses, amplified by a steady stream of surplus equipment he obtained from other Hams, allowed him to build sensitive receivers spanning all useful frequencies. In high school, he placed first in a science fair with a radio telescope assembled from one of his receivers, an antenna made from copper plumbing pipe, and a chart recorder. Like Jansky, he was able to show charts of the increased radio intensity at the galactic center, a radio source known as Sagittarius A.

After high school, his course was clear. He majored in Physics and Astronomy, and at the same time attended electrical engineering courses most appropriate to his career path. With such an excellent background, he was quickly accepted into graduate school to apprentice under a Professor of Astronomy whose own radio credentials extended back to the early years of the 1950s. His thesis, on fast amplitude fluctuations in pulsars, brought him to the forefront of his profession where he could have happily remained doing the almost routine things that other astronomers did. But there was a Siren call for him to devote himself to SETI, the search for extraterrestrial intelligence.

When Tukey was still more than a mile from the parking lot, he turned off his car radio. He also checked that his cell phone was really off, not just in standby mode, and he stashed it in the map compartment. These were precautions required of all employees to prevent spurious interference. The man on the street didn't realize that radios are also unintentional transmitters, and that cell phones, when not off, are transmitting their presence to the nearest tower. He did keep his PDA in his pocket. Like all other computer equipment in the observatory, it was Tempest rated; in other words, it was certified not to interfere.

The main antenna was casting its long morning shadow across the plain. The shadow didn't quite reach the control center, since the antenna was placed at a suitable distance to isolate it from other sources of interference caused by human presence. Humans themselves emit radio waves, but fortunately the emission only becomes detectable above 100 Ghz, a hundred times cell phone frequency, and almost a factor of ten higher than the highest observation frequency. That there was just one, huge antenna and not many smaller antennas, was significant. Although it was possible to synthesize the equivalent of a large antenna from many small antennas, the synthesis was not ideal. Instead of just concentrating reception in one direction, there was also spurious reception in other directions. Changing reception frequency for one antenna was also much easier.

It was now about 10:00 AM. Optical astronomers worked by night and tried to sleep by day, but radio astronomers kept time by whatever objects were visible in their hemisphere, any time of the day or night. Tukey flashed his ID badge at the security desk and clipped it to his open collar. Security had gotten increasingly tight over the years, since there was one lunatic fringe after another knocking on the door without an appointment. The huge antenna, if nothing else, was an icon of UFOs, extraterrestrials, and their ilk. He fetched his mail from the hallway slot and decided to bypass his office to go directly to the control room.

Brian was not in the control room, but that was no real surprise. The technical staff kept things on an even keel, and most things were highly automated. Scientists were needed at the occasional decision points, but impromptu decisions were rare. Most things were carefully planned because of the huge hourly cost of using the instrument. Tukey turned down the skylighted corridor towards the office wing. He found Brian, not in his office, but in the nearby office of Marianne, one of the graduate students. They were studying a computer screen when Tukey knocked on the open door.

"So, what have we got?"

"Well… things aren't exactly clear, yet. We're still crunching the high resolution data from this morning's transit, but we may have missed the source, if there is a source, on the first scan. It's like the Heisenberg Uncertainty Principle for astronomers – The closer you look, the more you need to know where to look. You can resolve the hairs on the head of a fruit fly with a high powered telescope, but the fruit fly had better hold still. We'll just keep stepping until we see a strong signal, or admit we were fooled."

Tukey directed his attention to Marianne.

"It's nice having someone to share our SETI fantasies with, but how's the *real* research program?"

"Well, if you can call the Krumhansl Survey, research, it's going well. I think it's more like stamp collecting, or one of those Victorian bugs-pinned-to-a-board sort of thing. It's the things that I help Brian with that keep me going."

That was one thing Tukey enjoyed about Marianne. She wasn't yet a PhD but she talked like one, speaking her mind and letting the other side interpret as they may. Tukey was like that as a graduate student, and he was certain Brian had been the same. Was this a learned response for scientists, or were scientists selected from a group possessing these traits? Perhaps there was a sort of kin selection effect at work in his group, or at work in the profession in general.

"Well, I'm sure it works both ways. I mean, would Brian be interested in such an unrewarding enterprise if he didn't think other people were interested? What can I say, except keep up the good work, both of you."

His minimal professorial duties of the day completed, Tukey retired to his office to check his e-mails and budget sheets. The next transit sweep wouldn't occur until tomorrow, no matter what timeline was laid into his project plan. The rotation of the earth would stop for no man, research director, MBA, or otherwise. Tukey settled down for another bout with the journals, and maybe a nap after lunch.

6 FINANCIAL MODELS

Electronic calculators had always been central to finance. NCR Corporation, a pioneer in minicomputers and parallel processing supercomputers, had been called National Cash Register. In 1914, an NCR executive, Thomas J. Watson, Sr., joined another company, The Computing-Tabulating-Recording Company, and changed its name to International Business Machines Corporation; or, more commonly, IBM. Until the early sixties, computers and calculators were just number-crunchers and an easy way to print pay checks.

Economics had always been a strange cousin to finance. Economics deals with equations, not just numbers. Finance involves things that can be done on the simplest calculator and maybe the occasional exponentiation for mortgage calculations, whereas economic equations often involve calculus and other higher mathematics. But it's more than math. Its model building and theory forming is more like physics than keeping shop. Scientists who ventured into the financial markets were often called *rocket scientists*, and Rick wore this appellation proudly. He would caution, however, that it's much nicer to ride the rocket on the way up than down.

One of the greatest advances in computation economics was the Black-Scholes derivative pricing equation derived from a model that attempted to equalize the risk and reward aspects of investing. From this beginning, an entire field developed to apply these models to niche market areas. The object of these models was to transform rocket science into money. Tom and Rick were attempting to do the same, but they had staked out an undeveloped area. Natural phenomena based on random events typically followed the Gaussian Distribution, commonly called the Bell Curve. Human individuals think their lives are purposeful, and anything but random; but, in the aggregate, humanity as a whole is a random ensemble. As Rick would say, “People are like gas.” Individual gas molecules in a balloon do their own thing, traveling fast, slow, in between, this way, or that, but in the end they average out to give a constant pressure that keeps the balloon inflated.

Fortunately for Rick and Tom, the gas model is not exactly true when it came to stock trades. Some people choose not to sell, even when their stock dives to a tenth of its value. Others hedge their potential losses by buying more stock in the same company, thereby reducing the average acquisition cost of the stock. Likewise, some people are too suspicious to sign onto the next sure thing. The result of this is that the Bell Curve has fat tails. When the wives, then just girlfriends, had first heard the men discussing “fat tails,” they were insulted. The economic explanation seemed like a coy cover-up, but after a while they became believers, and the men married them, fat tails notwithstanding.

Rick and Tom were attempting to analyze the Bell Curve of stock trades in real time, and to capitalize on human psychology. As Rick would say, they were going to make money in the tails. One advantage of this approach is that timing wasn't that critical. Other computer schemes worked in an arbitrage regime in which every microsecond was important. Rick and Tom were working at the seconds, perhaps minutes, level.

Rick's fat tail analysis was based on a self-improving model, an evolutionary program that would optimize itself in response to its wins and losses. The wins and losses would be just paper wins and paper losses at first, while he got the bugs out of his program. Such programming required the computation power of a supercomputer.

Tom and Rick had many options in specifying their supercomputer. As Rick said repeatedly, when you look beyond a certain threshold, everything was scalable. What that meant, in effect, was that a small computer would make a small amount of money, and a large computer would make a large amount of money. After some mathematical modeling, Rick calculated the minimum computer that would give them a break-even operation, just covering their operating expenses, and they arbitrarily doubled it. The doubling was either a safety factor, or an anticipation of a 100% profitability. It was probably somewhere in between.

There was the business plan, and then there was Rick's plan – All the tasks he needed to complete to get their computer process working. Computing is logical, and so was Rick's plan. The master program was split into many separate and independently operating units. He could program and debug each of these modules separately, and when they were all working, he would glue them together.

There was a module that received the raw stock ticker data, another that filtered it and put it into a convenient format for computations, and several others that handled the computations. The computation programs were different than those of a typical mathematics program. Although their calculations were always precise, the calculations that were being done were not decided by Rick. The computer made its own decisions. When the program was started, it made trades at random. By keeping score of the winners and losers, it was able to train itself to pick winners.

Rick's major occupation after the computer was operational would be to monitor its performance. He had developed a metric, called a fitness function, that told him how well the system was performing. The computer could unload a stock when its value went up a penny – pat itself on the back, or whatever doubles as that body part on a computer, since it was making money – and move on to other things. Rick's fitness function would see that after that penny's profit, the stock zoomed upwards several dollars, and it would caution Rick to suitably chastise the computer. He would do this by analyzing and modifying the code.

But the time for planning was over. Soon the computers would arrive, and Rick would set his programs loose on the real world.

At the same time, Tom was following up on whether there might be a use in their scheme for the latest buzz word in finance, Tsallis entropy. Since their model financial system was like a bag of gas, anything related to thermodynamics might be useful, and entropy was a big part of thermodynamics. Classical entropy was a useful concept, since it set a level playing field for transactions. There were no preferred traders and no certain outcomes.

Classical thermodynamics had the problem that it could only be applied in equilibrium systems in which a trade in one direction was identical to the reverse trade; that is, the process was reversible. In the case where you were always trying to make money in a trade, you were introducing some irreversibility. If the profit taken was small compared to the investment, this wasn't that much of a problem. If you went for higher profits all the while, there might be some catch in the equations that would get you in the end.

Tsallis entropy was a new way of looking at entropy in non-equilibrium systems. Tom saw that its application improved some tasks in the physical sciences, such as signal and image enhancement. Fortunately, the mathematics wasn't that intense, so Tom was enjoying his research. What made it all the nicer is that he was getting paid to do this homework assignment.

7 NUMBER CRUNCHING

“Ah, there’s nothing like the smell of computers in the morning!”

Despite the air-handling equipment, hot computers still emitted a smell not unlike the new car smell of yesteryear. This was the smell of volatile organic chemicals mixed with an equal part of motor oil from the cooling fans. Fortunately, from a respiratory health standpoint, the smell faded after a few months, but it never quite disappeared.

Rick rounded the corner and noticed, as he passed the offices, that, once again, he was the first to arrive at work. Most programmers worked a strange shift schedule of roughly noon to midnight, and perhaps later. Such a schedule had been imprinted on them through long nights of impossible homework assignments. If you asked a programmer to attend a nine AM meeting, he would usually respond that he normally didn’t stay up that late. Rick had somehow outgrown this right of programmer passage and replaced it with the joy of working in seclusion.

Things had gone smoothly in the hardware installation phase. The cabinets that would house the separate computers of their cluster arrived first, and they were wired for power by professional electricians. Since there would be 128 computers in each cabinet, they needed 64 cabinets in all for their 8,192 computer cluster. Rick had hoped to arrange these in an eight-by-eight array (programmers are hung-up about a powers of two thing), but their space wouldn't allow this. They ended up with four rows of fourteen, and a bastard row of eight. Rick still hadn't gotten over his irrational dislike for this configuration, but the short row allowed space for the central operating desk with its four large monitors, multiple keyboards and master computer. This area was isolated as a room-in-a-room to shield the operators from the steady noise of the cooling fans. They had investigated liquid cooled computers, but liquid cooling was too expensive, and they had enough problems without needing to mop floors after the inevitable leaks.

After the cabinets were wired, it was time to install the computers. These were plugged into small boxes just a few inches high that stacked one atop the other in the cabinets. The combined height of thirty-two of these, plus a large space at the bottom for cabinet cooling fans, completely filled each six-foot cabinet. A herd of students from a local college was hired for a weekend to uncrate everything and install the computers in the cabinets. Bolting the computers to the cabinets was the easy part. The hard part was the cabling. Fiber optic cables interconnected computers in each cabinet to a router, and then each router was connected to the master computer by fiber optic cables in overhead trays. The master computer, which was also called the supervisory unit, fed instructions and data to the computer array and received their results.

When all 8,192 computers looked as if they were working, Rick pummeled them with some diagnostic programs he had written in anticipation of that moment. More than eight thousand computers, each with billions of tiny transistors wired to execute his every whim! That's more than a trillion transistors doing billions of operations per second. Rick remembered that ENIAC, the first large scale general purpose computer, had less than 20,000 vacuum tubes. It could do just a few hundred mathematical operations every second.

Computers are generally reliable, once they've been shown to work for the first time. During Rick's debugging phase, a few were flagged for errors, most of which were corrected by tightening the existing fiberoptic connection, or replacing a cable. One computer seemed to be DOA, until Rick noticed that the switch on the power supply was set for a higher voltage they weren't using. Having every computer operational out of the box wasn't as unlikely as you would think. A “Six Sigma” manufacturer ships fewer than four defective pieces of equipment for every million that it sells.

There were two types of “glue” that connected these 8,192 individual computers together to make a single supercomputer. There was the fiberoptic network cabling, but there was also the supervisory software that made certain each unit had enough data to do something useful at all times. Much of the software concerned the communication of intermediary results between units. Such data were routed through near neighbors when possible, but often the supervisory computer needed to handle the transfer. That's why that computer was faster than the others.

In order for software to function as quickly as possible, Rick tried to write many software routines in machine language, a code nearly unreadable by humans, but very easily understood by machine. Other, less time-sensitive programs, were written in high level languages that made coding easier. In the end, these high level programs were automatically converted into machine language, since that was really the only language that a computer understands.

Rick was in his own element, and he was on a roll. Somewhere in the back of his mind was the idea that he was doing this to make some money. In reality, he was doing it because he enjoyed it.

One thing different between Rick and Tom was their preferred working hours. Whereas Rick would arrive very early in the day, thereby avoiding the heaviest rush hour traffic, Tom preferred banker's hours. Tom was able to avoid some traffic during his morning commute, but his hours were set more by the people he needed to interact with during the day than his own preference. Since he handled the business side of things, he needed to keep the same, regular office hours that others kept. Rick's interaction was with his machines, which worked 24/7 and could care less with whom they interacted, and when.

Still, there were quite a few overlap hours between the two; and, when Tom wasn't at some business lunch, they would have lunch together, usually experimenting with different cuisines as an adventure. They had really enjoyed a nearby Afghan restaurant, and they were sorry when it had closed. Even without that, they was no loss of variety as they jumped between Thai, Chinese, Indian, Mexican, the many burger joints, and several other budget options, at the flip of a coin.

That day, Rick and Tom opted for something somewhat different. They went to a vegetarian restaurant. It was not because they felt that their bodies needed a purge, but Tom had heard from a business contact that the food was surprisingly superb. The restaurant was located in a storefront at a strip mall in a marginalized region between a decaying neighborhood and a neighborhood undergoing gentrification. The new money class from Rick and Tom's generation needed places to live, although few like they could afford a suburban home; and, they liked their restaurants nearby.

Fortunately, this was a vegetarian place that didn't think that fried food was poison, and that's likely one reason why most menu items had a great taste. Tom remembered his mother's breaded and fried cauliflower from his childhood, so an obvious first choice from the menu was a fried tofu and cauliflower medley. Rick chose the eggplant, and they ordered a starting salad and buns stuffed with potatoes and assorted vegetables. For drinks they ordered mango milkshakes.

As they dug into their salads, Tom continued their luncheon conversation with a work-related topic.

“Rick, I've been reading about quantum computers, and it's got me a little worried. If these things are so much faster than supercomputers, is some upstart company going to use one of those to do what we're doing, and eat our lunch?”

Rick waited a second to swallow his food, and then he responded.

“Well, unless what you were reading was just a rehash of some press release, you would also have read that many people aren't sure whether quantum computers will be any faster that the usual type; or, maybe, they might just be useful for a very specific task. The ones that I'm familiar with, quantum annealers, would be good for finding the best route to Grandma's house, but not much more.”

“Yeah, that sounds like what I read, but scientists are doing a lot of work on these things. Maybe there will be some breakthroughs.”

“Well, the biggest problem might be a fundamental limitation. The “qubits,” the essential computing elements of quantum computers, need to be in a combined state called a superposition during quantum computation. Right now, the time period for superposition seems to be too short. Maybe longer superpositions are fundamentally impossible.”

“So, the important question is, what's the shortest time you estimate it will take, fundamental questions aside, for quantum computers to become practical?”

“Ten to fifteen years, as a very rosy prediction; namely, long after we've cashed out of our venture.”

“That's a relief.”

“As if that was our only worry...”

Tom laughed, and then it was back to his salad.

8 SETI

Tukey arrived home at about eight. He always left work at a late hour, since traffic was too heavy around the 3-7 rush. When his observations ended in the rush hour time frame, he would often work late just to keep his sanity. He instinctively flicked on the television to no particular channel and walk into the kitchen for some food. He didn't really care what was on (a thousand channels, and nothing to watch, as the saying goes), and since he got all his news from the Internet, he was sure he wasn't missing anything. He zipped open a bag of tuna, plopped a fork into it, and retreated to his favorite chair. The tuna went down quickly. He eased back into the chair, and he succumbed to his usual post-dinner stupor. In his half waking state, he reflected on the events of the day and reflected on his profession.

There were always those who would push the technology of their day to contact extraterrestrials. It all started with Mars, and Giovanni Schiaparelli, the Italian astronomer who found the "canals" of Mars in 1877.

Schiaparelli thought that these were just geological features, but others believed that they were waterways. Soon, there were maps with many canals criss-crossing Mars, and the land around these even seemed to change with the season, as if vegetation were blooming. An American, Percival Lowell, was fascinated with the idea that these markings could be a sign of a Martian civilization. Suddenly the Martian canals were a feature of a desert landscape, designed by the possibly extinct Martians to bring water from the poles to equatorial oases of vegetation. He wrote a popular book, *Mars as the Abode of Life*, expressing his vision.

SETI had become a true scientific discipline in 1960 when Frank Drake pointed the Green Bank, West Virginia, telescope at two nearby stars, Tau-Ceti and Epsilon-Eridani, and listened. It would have been embarrassing for the human race if someone were talking, we had the capability to listen, but didn't. Drake listened for two weeks, and then the telescope was relinquished for more important things. As if hearing from beings from another planet wasn't important!

SETI seemed to languish for many years thereafter, although a young graduate student, Jocelyn Bell, made an accidental discovery at Cambridge University in England that reminded everyone about the possibility of detection. Her faculty adviser, Anthony Hewish, had encouraged her to make measurements at a rapid rate as a way to find quasars. Bell's radio telescope looked nothing like Tukey's instrument. It was composed of thousands of wires connected by miles of cables in a way to boost reception. The frequency was low by today's standards, more like an FM radio station than a broadcast satellite. In 1967, Bell found a signal she couldn't explain that she described as a bit of “scruff” on her chart traces. The radio signal was periodic, a feature never before seen in radio observations. There was, of course, the obvious search to pin it down to something terrestrial, such as satellites, or radar waves bounced off the moon. But the signal kept sidereal time, star time, and not earth time, and it had features that identified it as coming from outside the solar system.

The Cambridge team jokingly referred to the signal as “LGM,” an abbreviation for Little Green Men. There was the possibility that they had discovered signals from an alien civilization, but they had actually discovered pulsars, rapidly spinning neutron stars that give periodic signals because of their rapid spin rate. Hewish eventually received the Nobel prize for this discovery. Bell didn't, a fact that raised the hackles of many a feminist. There has always been the tradition that the student works under the direction of the professor, the professor gets the glory, and the student is blamed for the mistakes.

Ten years passed before the next potential SETI event, the “WOW” signal at Ohio State University in Columbus, Ohio. Astronomers commissioned a radio telescope called the “Big Ear” there in 1973. On August 15, 1977, when the “Big Ear” was pointed at the constellation Sagittarius, there was a signal that jumped off the charts. It was thirty times stronger than the background noise, and it had a characteristic that indicated that it came from a source outside the solar system that was scanned by the antenna beam. The operator on that night circled the reading, labeled it “WOW,” and a SETI legend was born. Follow-up studies, including one with the sensitive Very Large Array telescope in New Mexico in the mid-1990s, did not recover the WOW signal.

SETI research faced some fundamental problems. There was the chicken and egg problem: what if everyone was listening but no one was talking? The cost of listening was small. All you needed was a radio telescope, already in place because of conventional observation programs, and a little electronics. Talking, however, required power, and lots of it. Megawatts of power.

There was also the problem of choosing the right frequency, although arguments for the “water hole,” a frequency region near a prominent hydrogen marker signal, were persuasive. Hydrogen is the most abundant element in the universe, and this frequency region is also a minimum in the galactic noise spectrum. But a further problem was whether radio was the proper medium at all. A hundred years ago, Earthlings would have been looking for smoke signals. There was even a proposal at the turn of the last century to set fire to large swaths of forest, in the shape of geometrical objects, to signal Mars of our existence. Even now, there was talk that optical signaling, using lasers, was the proper medium. A hundred years from now it might be obvious to use positron beams, or something like that. Perhaps the alien technologies are so far advanced that we would have no idea how to communicate with them.

Then there was the problem of what to do if a SETI signal were actually discovered, although this was a problem Tukey would gladly face. There was a set of SETI protocols, endorsed by all astronomers, that governed what should happen if a candidate signal were received. The first, and most obvious, requirement was a verification that your signal was actually a candidate, and not some natural or man-made interference. If a true candidate still existed, the next step was to have it confirmed by your colleagues through independent observations and ensure that a continuous reception is obtained. It is only at that point that the discoverer informs his government, the United Nations, relevant organizations, and the general public. The discoverer has the privilege of making the public announcement. After that, the usual rules of science apply; namely, get the data and share the data, usually through conferences and publications. There are also some technical issues, like protecting the frequencies from interference. Lastly, no response would be sent before much consultation.

As in other scientific disciplines, colleagues exchanged their most recent results and theories at conferences. Technology may have given us email, teleconferencing, Internet message boards, and cellphones, but there was still nothing like meeting and talking face-to-face. Although the attendees were supposedly there to hear the formal presentations, the real action happened in the back corridor and coffee room discussions. There, preliminary data were divulged and collaborations hatched.

That year's International SETI Conference was conveniently scheduled for San Diego. Its proximity made travel very convenient for Tukey and Brian, and their budget had an ample allocation for travel. They prepared an abstract on a signal processing technique Brian was developing, and Tukey submitted the abstract to the conference committee. As Brian freely admitted, Tukey's name as an author assured acceptance. There was the Old Man's reputation, but there was also the careful oversight that Tukey brought to each research project. Eventually, the results of the Kumhansl Milliarcsecond Survey would be presented at a conference, but not at the SETI Conference, followed by a publication in which Brian's name would be just one of many.

Brian's computer skills had been a definite asset to Tukey's SETI project. Their main piece of hardware, the channelizer, was state-of-the-art, but it was useless without proper software control. The radio telescope grabbed a huge chunk of the frequency spectrum at one time, but any faint signals would be lost in the background noise of radio wave photons at each little frequency talking at the same time.

The channelizer sliced the broadband signal into tiny pieces, and it was able to see whether anything interesting was happening in any particular piece. Conceptually, this was easy; but, practically, there were some details that needed to be handled. The most important of these was the fact that the Earth was a moving platform. Earth's rotation on its axis and its revolution around the Sun caused frequencies to shift slightly. Since the radio signals passed through Earth's ionosphere, there was a scintillation, like the twinkling of a star. Correction was needed for all this, and also some corrections for subtle flaws in the telescope's electronics.

Brian had become an expert on these corrections as they applied to their telescope; and, as a good programmer, he had written his codes in a general enough fashion that they could be used at most other telescopes. This was the work that Brian would present at the conference.

About the Author

Dev Gualtieri received his PhD in 1974 and had a thirty-five year research career in physics and materials science.

He is listed as an inventor on more than thirty US patents, and on numerous international patents. His eclectic research interests included superconductivity, chemical thermodynamics, magnetism, electronics and computer science. At one time, he was an internationally recognized expert in crystal growth.

Dr. Gualtieri is now retired, and he resides in Northern New Jersey with his wife, Anne. They have a son and daughter who reside with their spouses in Pennsylvania.