

# The Bridges of Königsberg

Karola Kirsanow

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## Abstract

*This is a piece of short fiction I wrote for an X-Prize science fiction competition having the prompt: "At 4:58am on June 28th, 2017, the passengers on board ANA Flight 008, en route from Tokyo to San Francisco, are cruising at an altitude of 37,000 feet, approximately 1,500 nautical miles off the West Coast of the United States. A small bump, otherwise noted as a barely perceptible bout of turbulence, passes Flight 008 through a temporary wrinkle in the local region of space-time. What these passengers will soon find out as they descend into SFO is that the wrinkle has transported them 20 years in the future, and the year is now 2037."*

As the cabin lights dimmed, Vera Spektor pressed her thumb to the base of each nailbed on her left hand, gently massaging the cuticle in the direction of the knuckle, and then moved on to her right, cycling through both hands in an endless loop as she traversed The Problem.

Vera, a graph theorist, was inordinately interested in networks. Of late, she had turned her attention to social networks, seizing upon one of the few occasions on which her own obscure interests intersected with those of the general public; a rare chance to connect.

From an initial focus on the mechanics of the networks - their structure and spread - Vera began to consider their broader implications, and the particular ways in which their form dictated their function. The graphs of these networks, with large and inescapable central hubs, seemed to promise a future wherein more and more people were relegated to the periphery. Always attuned to the exponential, Vera saw this curve stretching forward in a grim arc. These networks, and their huge data stores, would probably be the kindergarten of the first AIs, and she did not harbor much hope that they would be friendly. She became convinced that the best approach was to create a fast-proliferating network with a structure and composition that encouraged human-friendly interaction.

Vera solved the question of her network's ideal structure quickly, but the graph she sketched on her whiteboard revealed a deeper mystery: Vera knew almost immediately that this network would be very difficult to build. She was confronted with the basic quandary of graph theory: you can't get there from here.

Possessed by the problem, she moved on autopilot through her professional life, and spent her rare hours at home absenting herself from the demands of her personal life even more than usual. Her hands sketched out the famous diagram of the Seven Bridges of Königsberg, the founding problem in graph theory, whenever they encountered a pencil-friendly surface. Her girlfriend began to teasingly refer to these drawings, sometimes folded along the vertices like origami, as "replicant guerrilla art". Vera shared her ruminations about the network only at night, spooling out the logfiles of her meticulous mathematical subconscious to the ceiling as her girlfriend listened in. Helen, an evolutionary biologist, knew exactly which expressions to mirror and when to interpose a question, gently encouraging Vera to enlist her closest colleagues and cleverest graduate students in her quest to create her idealized network. But Vera's compulsion toward secrecy led to the gradual construction of a hermetic chamber that even Helen could not penetrate, and their relationship devolved into the occasional friendly wellness check. Vera, emotionally desolated, finally took a long-deferred sabbatical.

And so Vera, now divested of lover and routine, was returning to her hometown from a research trip to Japan, ostensibly made to attend a conference, but actually to observe a coven of hackers implement a new mesh network. Disappointed by the unveiling, Vera composed a rather disjointed email to Helen, her only confidant.

A light cough from a few rows back caused her to exit her manual loop and turn her attention to the landing. Disembarking the aircraft, she peered out of the window ports to discover that SFO's torch-like air traffic control tower was now clad in a pulsating green trellis, and the aircraft parked next to hers resembled the sleek and sinuous airfoils she had seen in science fiction films. Gasps from her fellow passengers and the expressions of the flight crew assembled at the front of the craft assured her that she was not alone in her astonishment. Vera began transiting her nailbeds again.

The startled passengers were hurried through a debarkation tunnel that appeared to be constructed of a lattice of dense foliage, and into what Vera assumed was some sort of quarantine room. A man dressed in a remarkably asymmetrical suit addressed the group and explained their predicament in simple terms: there was a wrinkle in time; ANA 008 had flown through it and emerged 20 years in the future; the appropriate agencies had been monitoring their flight since it appeared on the radar and were already compiling the necessary resources to alert families and re-integrate the passengers; this was not a hoax or a particularly tasteless reality show pilot. Vera noted the way he pronounced "reality show" as if it was surrounded by quotation marks. His words were occasionally punctuated by groans, gasps, or sobs from the assembly, but Vera took them in with relative equanimity. She had been living in crisis mode for the better part of the last year.

As he finished, a large group of personnel dressed in comfortable-looking

draped garments dispersed among the passengers - the reintegration specialists. A young woman with aubergine hair approached Vera. Vera glanced at the electronic FEMA badge integrated into the folds of her scarf and admired the advance in circuitry they represented.

"Dr. Spektor, welcome home. My name is Ximena, and I'm here to assist you in your transition." She produced a small jewel-like object. Waving her hand over the device to generate a holographic visual display, Ximena began to perform an informational triage, starting with the most urgent topics first.

"Your parents (a 3D image appeared of Irving and Sarah, looking healthy and comfortably attired) are well, and still living in the Outer Richmond district here in San Francisco. They have been contacted and are on their way home from a trip to New York."

Vera breathed a deep sigh of relief, releasing the tension in her legs to settle deeper onto her heels. She thought of her parents the last time she saw them - just a few weeks ago for her - having dinner at the Palo Alto apartment she shared with Helen. They were so happy that their oddball daughter - the one who sometimes forgot to talk and blinked off-tempo - had found such a lovely lady, such a great cook, and a professor just like her! She could see how a weight had been lifted from their shoulders as they enjoyed the brisket, collards, and sweet potatoes, and the sight of their daughter smiling and well cared-for.

Vera looked up at the thought of Helen. Ximena smiled gently and continued, as if sensing her thoughts. "The closest contact of yours from that period, Dr. Helen Robichaux (another 3D image, Helen looking breathtaking in jewel tones and salt-and-curry hair), is on her way in from Berkeley." Vera's head snapped up and her widened eyes met Ximena's. "It will take her a while to be cleared and debriefed. Let me tell you more about 2037 while we wait for her to arrive."

Vera nodded distractedly. She had so seamlessly adjusted to the fact of the time distortion that the thought of an ex-girlfriend from 20 years ago rushing to her side seemed fantastic. Her consciousness divided itself into two parallel threads, one focused on the easy-listening datastream emanating from Ximena, the other mulling the implications of Helen's imminent arrival.

Ximena summarized 20 years of geopolitical and cultural history, and Vera was satisfied that the governmental frameworks she was familiar with were largely intact, the number of existential crises was within acceptable tolerances, and that disasters had occurred at roughly the historical rate. Interestingly, no mention of an internet-enabled social or technological meltdown was made. Vera thought of Helen, and the now-outdated news she had to share with her, and the burning urgency she felt to convey it to her anyway.

A change in Ximena's tone indicated that she was approaching the end of her summary, and Vera's thoughts converged into a single track, giving Ximena her full attention.

"We've embargoed news of your arrival as far as possible to protect your privacy. If I can be of any further assistance, please contact me immediately. I'm available to handle even the smallest matters." She pressed a small piece of diaphanous cloth into Vera's hand, and Vera understood that it somehow contained her contact details. She felt a strange anticipatory pleasure in fig-

uring out how to extract them from the cloth, and realized that Ximena must have foreseen how she would relish this puzzle. Ximena, smiling, led her to a section of the arrivals hall reserved for private jet deplanings, and out to a ground transport bay where she was immediately greeted by the welcome sight of Dr. Helen Robichaux.

Ximena retreated quietly into the building as Helen advanced toward Vera, enveloping her in a hug. "Vera," she said in a voice that sounded almost breathless. "Welcome home." "I'm so relieved to see you. This is all...very unsettling." She pulled her head back a bit to look into Helen's warm eyes. "I'm actually rather surprised you came." She let the question settle between them. Helen smiled more with her eyes than her mouth, and released Vera to hail a partially translucent vehicle shaped like a muscular watersock.

"Let's take a drive around the Bay to my place in Berkeley. We can talk in the car." Vera nodded assent, and the two sat facing each other in the vehicle's single large compartment. A traffic and route display appeared, and Vera was pleasantly surprised as car navigated itself to a dedicated elevated lane parallel to the 101.

Vera looked out the wraparound windows at the elevated roadway, trelised with the same mineral/vegetal latticework she had noticed in the airport. The air coming in from the vents was cool and slightly humid, but her overheated mind was percolating questions at a furious rate. "Helen, it's been so long...I guess. How are you? How have you been?" She did her best to imbue the question with as much meaning as she could.

"I'm doing very well, Vera. Today is a blessing for me, and of course for your parents. I would contact them now, but I was told they are still receiving counseling on the plane. We'll see them in Berkeley."

Vera nodded, understanding. Helen looked at her with a mixture of seriousness and trepidation.

"When your plane disappeared I never told them we were no longer together. It didn't even seem to me that we had broken up - just that we had temporarily fissioned, and would fusion again. I forgot that sustained fusion is still an unsolved problem," she said jokingly.

Vera's chest warmed with gratitude. She flashed to the vision of her parents at dinner, floating, happy, their daughter's future secure. Helen always knew exactly what to say.

"They're an important part of my life now, still. I play mah-jongg and drink plum schnapps with your mother and her friends on Tuesdays, but not too much or she starts palming tiles."

Vera laughed.

"They were at my wedding," Helen said, answering the next question lurking in Vera's stack. "I've been married 17 years. We have two boys, one's almost grown, one thinks he's grown." Helen smiled softly, and Vera smiled back, searching her heart for disappointment but unable to find any. A family picture appeared on the display: Helen holding a steel mug and feigning displeasure in front of a tent with two tall grinning boys and a one tall grinning woman. "Grace is an ecologist, hence the camping. I've made peace with it."

Helen looked directly at Vera, resting her hand over Vera's knuckles. "So, we're still family. Just...differently." Vera felt her equilibrium returning. As

she looked out the window at the formerly sterile office-park-and-conference center corridor from the airport to the city center, she saw that nearly every structure was limned with green. The pattern continued through the lightly industrialized landscape of South San Francisco, with the addition of lattice-work terraces on the low-slung warehouses lining the highway. Vera noticed that the sign on a distant hill welcoming her to "The Industrial City" had the same luminescent qualities as Ximena's ID badge.

Following her gaze, Helen explained, "There's been a good deal of progress in biomaterials in the past two decades. The sign you see on the hill is made of a bioluminescent material - a lot of our embedded display technology uses it. Grace works on symbiotic microecosystems - we've been able to adapt the fungal networks that plants use to exchange information and nutrients to regulate some of our agricultural and climate control systems." She pointed to the latticework terraces. "It's made urban agriculture much more viable. I try not to think about the fact that a lot of the green conduits I see every day are above-ground waste management systems, but an open sewer never smelled so sweet."

The highway bent out into the bay, running next to a series of faintly glowing spiral towers. "Biosynthesis towers," Helen explained. "At the top, cyanobacteria studded with nanocrystals produce energy and useful compounds; under the water chemosynth/algal symbionts produce biomaterials and trap carbon."

Vera marveled at the towers for a moment, and then returned to the topic at the forefront of her mind: "Helen, twenty years ago I was obsessed with the future of networking. You must remember - it was the only thing that mattered to me...that mattered about me, at the end. I was so sure we were headed for disaster was I wrong? What happened?"

Helen leaned toward Vera, immediately serious. "I remember. And you weren't wrong. The first few years after your plane disappeared were very difficult for anyone trading in ideas - I changed universities three times in 5 years. Then we managed to train a generation of artificial intelligence systems to replicate our worst cognitive biases, and even expand on our repertoire. They failed in ways that were nearly impossible for humans to predict." Helen shrugged her eyebrows and shook her head. "For a while, complexity ran ahead of our ability to understand and replicate errors. Then a series of cloud leaks fatally compromised most of our major data silos."

Vera nodded, this was the future that she expected. "I see. Non-proprietary data is hard to sell, and corrupted data trains faulty models." She thought of her experiences in Tokyo - so fresh in her mind, and now rendered irrelevant by the passage of time. An initial twinge of disappointment at being denied the satisfaction of solving the problem was followed by a larger sense of guilt that she was still so focused on her private intellectual puzzles.

"That was the twilight of the old regime, but the new era of networking began when we figured out how to build your graph," Helen replied.

Vera spluttered with shock "What? I'm not even sure I ever gave you a useful description, I just blathered on about The Problem and how it made me feel" Her lips curled in disgust. "I was well and truly useless."

"That is a matter of perspective," Helen replied gently. "You were on

the interior of the problem, trying to solve the maze alone. I was on the outside, and a labyrinth is much more legible from the exterior view. Your last message was fairly cryptic"

"It was three pages of fever dreaming and a diagram done in ASCII art," Vera interjected flatly.

"...but with some help I was able to decipher it," Helen continued. "I know you. I know what's important to you. And you had been sketching that diagram in words for months."

Vera thought of Helen listening intently as she circumnavigated The Problem aloud at night, worried that she was losing her. Then Helen would ask the right question, and Vera would look over at her, at the moonlight tracing the topography of her face, and wonder how she thought she could ever lose her in the dark.

"I enlisted your grad student, Emily Drinkwater, the one you were always so proud of. She found a position in a Boston lab working on protein networks and took this on as a side project. She assembled a team just like that Japanese lion robot figurine you kept on your desk."

"Voltron." Vera interjected automatically.

"Yep - still have him in my office, by the way. Great piece; I get a lot of vintage nerd cred. Let me get *Doctor* Drinkwater on the line. She'll be delighted to see you."

Vera was not as confident in Emily's delighted reaction as Helen was, thinking of how she abandoned her graduate student in the throes of dissertation write-up. Before she could muster an appropriately apologetic expression, Dr. Emily Drinkwater's 3D avatar appeared in the cab of the car. Same wry expression, same unruly hair, same cowboy boots, but with the air of confidence and authority that comes with age and a few very good calls.

"Dr. Spektor - it's amazing to see you. Now I can finally have you sign off on my dissertation!"

Vera's heart constricted momentarily before Helen and Emily erupted in laughter.

"Twenty years and that expression alone is almost worth it. Is Helen filling you in on the grand saga of the Spektor Graph?"

Vera's eyebrows made a break for her hairline. "The what?"

"Oh, the name for a class of graphs whose growth pattern can be described by the Spektor algorithm. Still my most highly-cited paper, and yours as well."

Vera gaped mutely at Emily, eyebrows maintaining an impressive altitude. Emily continued.

"After your now completely superfluous memorial service, I had a four-day panic attack before Helen forwarded me your last email. I immediately grokked why you were obsessed with that graph, but I knew I couldn't solve it on my own without making it my life's work. So I finagled a postdoc in your old colleague Ben Hawthorne's proteomics lab, and after a while I approached him with The Problem. Then he contacted Grace - Dr. Erizawa. Grace found a living model system that was a close fit to the graph and growth algorithm - a fungus."

Vera assimilated this news as their car passed into San Francisco. Gar-

lands of greenery were everywhere, and the urban landscape was unmarked by utility lines. It seemed that every large building contained some sort of rooftop greenspace. Traffic slowed as the freeway ended, and Vera could see pedestrians dressed in well-tailored, seamless clothing of various styles. She thought of her own clothing, and how her wardrobe had come to reflect her belief in the coming of a drizzly black-and-teal cyberpunk dystopia. She felt like a bad prediction.

"How was the fungus model helpful?" she asked.

The answer came from Helen. "You may have noticed that a lot of the newer tech you're seeing focuses on hybridization and symbiosis. We've been using massive computer simulations to mine the natural world for biological substrates, combining them, and augmenting them as necessary with silicon or nanomaterials. We took that same approach with the fungus - in actuality, it was an entire symbiotic community of different species. Emily studied its propagation patterns, Ben worked on interactions between nodes in the community, and I studied how those interactions evolved."

Emily nodded. "Our lab was working in an XPrize collaboration with researchers attacking degenerative plaques, like those in Alzheimer's, with nanoparticles. Ben and I thought we could adapt the nanoparticle interference model used in disease treatments into a nanoparticle augmentation model, where silicon nanotech helps to direct the growth of the biological network, and conducts part of the information payload as well."

Vera leaned toward Emily's image in excitement. "How did you use a cyberfungus to connect people?"

Emily grinned. "We took advantage of a laissez-faire regulatory environment in the mid-20s to seed a spore-based mesh network in a group of international volunteers. We flew under the radar while everybody was focused on the problems with the big silicon networks."

"This was not a trivial project," Helen added. "There were beaucoup complications, and for a while each of us was under surveillance by a rotating cast of shady characters. Hell, Ben was followed around Lagos for a week by operators wearing ninja suits. But we managed to assemble a broad, diverse initial cohort. And it spread from there."

Vera was stunned. "I cannot believe that this works, and that people consent to use it. What is the experience like? How do you disconnect from a fungal network that has colonized your nervous system?"

"The network is like an additional layer of consciousness. It does not insist upon itself - logging in' is like summoning a memory from deep storage. It doesn't run very many local background processes. It just connects you to the data pushed to the shared repository by other users, and to verified public silicon repositories. Buffer space is low, so when things aren't attended to for a while, they are just dropped from your local memory back into the public repository. It has the ephemerality of real memory, but the infinite capacity of the internet. Pushing data requires a good bit of effort, so it's difficult to inadvertently compromise your privacy, or to 'spam' the network. And network security is modeled on natural fungal defense mechanisms," Helen said.

"Right now we can only transmit visual and auditory data, in a kind

of AR-overlay,” Emily added. “Anything else would be too overwhelming, and possibly open to malefactors. Most people use it as an adjunct to their daily life - it’s entrancing, even rapturous, but too much work to be addictive. And it can be removed with an over-the-counter antifungal treatment.” Vera leaned back in the seat as she thought about what she had just learned. She imagined how a partially modular hyper-mobile network could be useful in exploring remote areas of the planet, or other planets. She smiled as potential applications flooded her mind.

Emily and Helen seemed relieved at her improved mood. “Well, Dr. Spector, it’s been a pleasure reconnecting, but I’m sure you have a very full day ahead of you. I hope we’ll have a chance to talk again soon, in person,” Emily said, signing off. Her image disappeared and Vera was once again alone with Helen in the car.

“We named the network ‘Mzizi’, after a Swahili word for root,” said Helen, smiling. Vera looked out at the bay, at the muted glow of the symbiont towers surrounding Treasure Island.

“All of this is beautiful, incredible. I have so many ideas I hope I can still be a part of it all.”

“There are still plenty of problems to work on, and there are a lot of people who would like to work with you,” Helen said. “If you’d like, I can connect you to the network when we get to my house.”

“Great, I’ll just take some of your cyber-shrooms and then meet with my parents for the first time in twenty years,” Vera joked.

Helen laughed. “I would probably reverse the order of those two events. But yes, you deserve to see what you’ve helped to create.”

As they sat in comfortable silence, Vera thought about the last, desperate message she sent to Helen before boarding her flight in Tokyo. In a rambling discursion about the Seven Bridges of Königsberg, she laid out the essential dilemma: the rules say that each bridge can be crossed once and only once, but what if you ignored the map, ignored the city limits, and just kept walking all the way to the Kaliningrad oblast, where the river begins - a different graph for the same problem? Where should one focus: on the map or on the territory, with its tributaries and complications?

In Tokyo, Vera realized that she had to cross boundaries to connect, always focused on the underlying problem, not its abstraction. And Helen must have had the same realization as well, reaching out to connect with another graph-walker, who connected with two more, until they created the right graph to solve the problem.

Vera looked forward to seeing her parents again, and exploring the network she had inadvertently helped to found. She thought of the time she had missed, both before and after she boarded that flight from Tokyo; the old puzzles that had been solved, and the new ones that were just opening up. The car curved away from the shoreline toward Berkeley, and Vera looked outward.