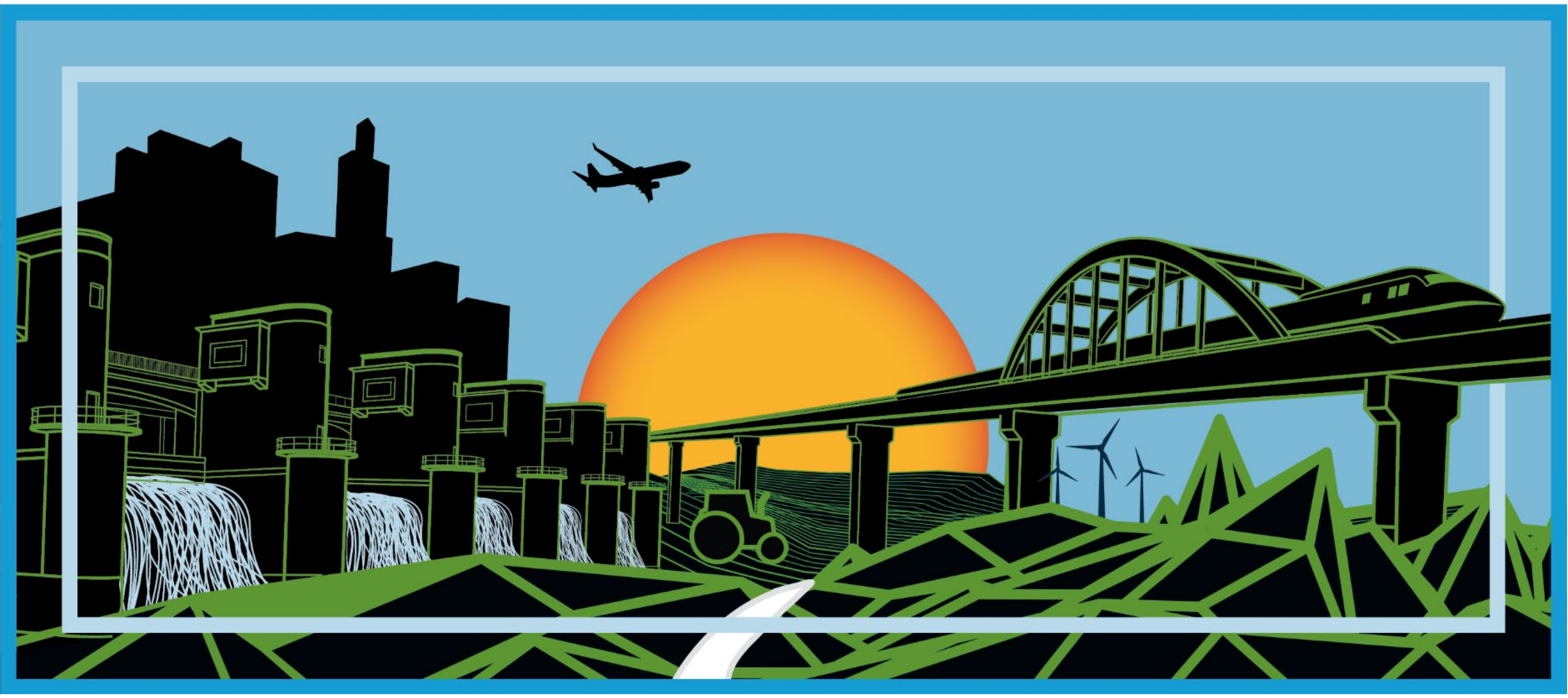

Secure Tomorrow Series

Scenario Narrative #1: Technology Doldrums

Publication: August 2023
Cybersecurity and Infrastructure Security Agency

The Cybersecurity and Infrastructure Security Agency has produced these scenarios to initiate and facilitate discussion. The situations described here are hypothetical and speculative and should not be considered the position of the U.S. Government. Aside from historical references, all names, characters, organizations, and incidents portrayed in these scenarios are fictitious.

RIDING THE SLOPE OF ENLIGHTENMENT

I'm a Ph.D. engineer from the illustrious Whyttz Institute of Technology who became a financial modeler, but then realized I'd rather work slow-paced than fast when it comes to investing. Going back to my roots, I decided to translate my love of science and technology into a long-term investing approach surrounding emerging technologies and technology ecosystems. Riding the Slope of Enlightenment *reflects my efforts to separate hype from practical potential, and search for signals as to when technologies may be ready for investment.*

Playing The Long Game With Technology

May 31, 2035 36 Comments

My friend Ricky can't understand why he's still stuck at work, 3 years after he meant to retire. In the 2020s, he invested in the technologies of the future, companies so essential to scientific progress that their share prices were guaranteed to support a life of leisure and comfort—until they weren't. Brain-computer interface stocks: down 65 percent from 2025 to 2030. The SSY&S Synthetic Biology Index: down 78 percent since 2028. Three sure-fire quantum technology initial public offerings on the BASDSI Market in the mid-2020s: bankrupt by 2032.

As someone who unfortunately gets looped in with the tech proclaimer crowd, I'm often the target of the vitriol from people such as Ricky. I hear from lots of them. They want to know why today's tech reality is so far from yesterday's tech hype. So, I'd like to explain here why three technologies that were supposed to be societal "game changers"—brain-computer interfaces, quantum technologies, and synthetic biology—haven't quite left the sidelines (at least not here in the United States). Those technologies make good case studies for five lessons I'd like to offer about why technologies hit speed bumps—and why things don't have to stay that way.

LESSON #1: GAME-CHANGING ≠ FAST-CHANGING

Technology investing and technology development favor the patient. Progress can be so slow you barely see it. Take brain-computer interfaces (or BCIs, as most people call them now). They've been studied since the 1970s, and 60 years later, they're hardly ubiquitous. Maybe you know someone who owns a BCI wearable for virtual reality gaming that responds directly to brain signals. The latest statistics from Sartati, a leading online statistics platform, show that about 12 percent of U.S. households own a BCI device, and in some workplaces they're just starting to become more common. There are lots of reasons why technology might develop slowly, some of which I've covered in previous posts. (See Recognizing the Express Lanes for Tech Development.)

But back in the late 2010s, patience was in short supply during a period of technology exuberance:

- The dominance of tech giants led to widespread investor belief that, with their deep pockets and access to the best minds and big data, they were poised to revolutionize other fields.
- The 2010s had seen a remarkable run of access to venture capital.
- The United States was rebranding itself as an innovation economy.

And here were three technologies that promised to change society as we knew it:

- BCIs enticed us with the potential to control devices with our minds and directly access knowledge from the internet, turning science fiction into reality.
- Synthetic biology would redesign and harness biological organisms to cure diseases.
- Quantum computing would reveal fundamental insights into the inner workings of matter, revolutionizing the design of materials and medicines.

If you haven't noticed these changes, it's because they didn't happen. Yes, it is plausible that BCIs, synthetic biology, and quantum technologies could one day achieve these milestones. But significant technical hurdles have been and continue to be in the way. It reminds me of my grad school days, when the theoreticians and modelers in our lab group would craft papers outlining why something should work, and then talk to us engineers as if they had already figured out the hard part. I hated those folks.

Technologies don't all follow the same path for development. In the 2010s, the blinding speed of digital transformations led by software created the illusion that all technology moves that fast. Hardware is different. Take the transistor: it was developed in the 1940s, but personal computers didn't arrive until 30 years later.

The software/hardware dichotomy led to what I call the "Colprin rejoinder." Back in the 2010s, astronaut Bart Colprin famously expressed his disgruntlement about our inability to reach Mars by stating, "…you sold me on colonizing Mars. Instead, you gave me reality TV." Similar disillusionment happened with the state of our three technologies by the close of the 2020s.

- For BCIs, "write" capabilities never emerged for noninvasive devices. I wanted to download knowledge at will from the internet directly into my brain. Instead, companies spent their time developing stylish, noninvasive wearables. These are great, but even with "read" capabilities, we still haven't reached full BCI control of complex equipment.
- More than 15 years after the first claims of "quantum supremacy" over classical computers, we have yet to produce a general-purpose quantum computer with error correction. There's been some success with quantum sensors, but mostly for military applications. Individuals who bought into the promise of these sensors for mineral wealth discovery are still waiting to see their investments pay off.
- Synthetic biology has not discovered the holy grail of petrochemical synthesis—although, in fairness, the field has had numerous successes. There are good-news stories about advances in gene therapy. Unfortunately, the public seems more focused on questions of trust regarding synthetic biology in food production and vaccines, overshadowing progress.

LESSON #2: INTERMEDIATE CAPABILITY OR INCOMPLETE CAPABILITY?

To many investors, "NISQ" is a four-letter word. The abbreviation for "noisy intermediate-scale quantum" was coined to describe the stage of capability that quantum computing had reached in the late 2010s. At the time, pundits expressed hopes that these systems would begin to address test problems, increase understanding of quantum computing, and stimulate algorithm development, which would accelerate progress in quantum computing. But without error correction, efforts to apply NISQ computers to practical problems—particularly ones that traditional computers can't address—haven't really materialized.

NISQ-stage computing, which many say we're still stuck in, is a typical example of a situation where the desire to provide a value proposition leads to the rollout of an incomplete capability. If you struggle to identify a use case for your technology, it's not "intermediate"—it's incomplete. In the mid-2020s, there was enormous pressure to deliver something that would maintain interest and keep funding flowing, so companies rolled out devices with incomplete capability. And, to some extent, the same is true for BCI devices. Both technologies went through a period in which companies were actively soliciting research communities and the public for ways to apply their technologies, which I always take as a bad sign. Yes, technologies can have early, niche applications that sustain interest in developing them further. Case in point: the early application of transistors in hearing aids. But with the hype surrounding these technologies, the fact that there were no obvious applications should have been a worrisome signal to investors such as Ricky.

LESSON #3: THERE'S NO REVOLUTION WITHOUT SCALE

Scale is difficult for new technologies to achieve, but scale is critical in three ways. Scale in manufacturing is the ultimate determinant of costs and prices. And even after you've managed to create a working product, scaling up manufacturing presents a host of additional challenges. For example, Ben Cartemonne in his article, Rethinking the Bioeconomy, argues that the U.S. transition to a bioeconomy stalled partly because of an inability to foster pilot-scale testing and provide necessary supporting infrastructure. Efforts to set up noncommercial biofoundries faltered in the mid-2020s, providing fewer opportunities for academic researchers to assemble larger fragments of synthesized DNA. Producers of cultured meats are experiencing technical hurdles in scaling up the volume of production while maintaining a sterile operating environment and controlling operating costs.

Scale in marketing launches products from the niche market for early adopters into the "gotta have it" trajectory. For better or worse, the BCI industry had this partially figured out in the 2020s. Commercial interest led engineers to prioritize simplifying these devices and developing wearables that were lightweight and comfortable, even at the expense of brain signal reading performance. The vision was to be as ubiquitous as cell phones, or even replace them. To some extent, that vision may finally be realized.

BCI's path to marketing scale has really been driven by growth in two areas: workplace monitoring and entertainment. Workplaces began using BCIs to assist with monitoring employee mental health and to alert employers about unsafe work behaviors, such as driving while drowsy. And with virtual reality coming into its own over the past few years, BCI sales have gotten a bump from early adopters who want a more engaging user experience. According to Sartati, BCI devices may have finally reached a tipping point in adoption. It's amazing that a technology that was once limited to hundreds of individuals, largely for medical reasons, has now grown to more than one billion users worldwide. And the BCI companies that survived the shakeout are starting to make a comeback.

Scale in data has been a major driver. The number of BCI users pales compared to the exabytes of neurodata that BCI users are now generating on a daily basis. Given how nearly everything in our lives is governed by algorithms, access to vast amounts of neurodata has companies drooling and represents a key part of BCI's value proposition. It provides sellers with a more sophisticated understanding of user preferences and a wealth of unfiltered feedback on products. So, it should come as no surprise that nearly all BCI device manufacturers have strong ties to data brokers or data analytics service providers. Equally unsurprising is that user data agreements for BCI devices have remained heavily in favor of BCI manufacturers.

LESSON #4: PUBLIC PERCEPTION MATTERS

BCIs and quantum computing have been burdened by public perception issues. BCIs have come under attack from multiple directions recently. Critics have accused game developers of creating feedback loops using neurodata to create highly addictive games, contributing to a growing detachment from the real world for students and the incoming workforce. Directly monitoring employee attention and emotions has led to privacy complaints and claims of greater workplace stress. Lax cybersecurity protections on these devices and hoarding of worker neurodata have also led to numerous criminal hacking incidents. To appease anxious workers, 33 major companies have pledged not to employ BCIs on their workforce. But frankly, we've been preconditioned to accept being data profiled, mined, and targeted at this point. The federal government's view on neurodata seems focused largely on limiting foreign access to neurodata on U.S. citizens, similar to the stance taken on genetic data. There have been some nods to neurorights at the state level, but on the whole, I don't think anyone looking back on the past 20 years can say there's been a substantial change on this front.

In the case of quantum computing, investors and the public became increasingly skeptical of the practical value of quantum computing in everyday life after being burned by pundit claims about quantum annealers and NISQ computers. And in the latter half of the 2020s, we were confronted with the debacle of the post-quantum cryptography transition. To confront the looming threat of a quantum computer that could break public-key encryption, some companies migrated early to one of the initial National Institute of Standards and Technology endorsed post-quantum algorithms. They later found that this algorithm could be cracked conventionally. The hybrid period mixing pre- and post-quantum algorithms experienced numerous complications. There was even a case in which a post-quantum cryptography vendor pushed malware onto various systems. Companies are still encountering problems with legacy systems and slowdowns in performance.

As a result, public sentiment toward these technologies has shifted from enthusiasm to neutrality at best. Legislators have been unwilling to advocate for funding technologies that inspire opposition or indifference at best among their constituents, especially when they have few success stories to point to from previous technology initiatives. The combination of public sentiment, politics, and national debt has led to a steady withdrawal of public funding from all three technologies, including many of the National Quantum Information Science Research Centers and noncommercial biofoundries. For quantum technologies, this has turned into a full-on quantum winter, with public funding drying up by the early 2030s. Given bad press and vocal dissenters, many politicians have been content to let the private sector assume full responsibility for the risk-reward calculus.

LESSON #5: U.S. DOMINANCE IS NOT GUARANTEED

Technology Alleyway exceptionalism is a stubborn idea. But financial capital and intellectual capital don't really care who was leading 20 years ago. In BCI, it's clear that the United States is no longer the frontrunner. Fictitia continues to espouse a policy of monitoring workers with BCI devices. In fact, Fictitian companies have touted it as a competitive advantage, making claims about their greater safety and productivity. Meanwhile, the neurodata gathered from these devices are also being used to enhance machine learning algorithms, further improving the performance of Fictitian BCI devices. With scale advantages leading to cheaper and better BCI devices, the adoption rate in the Fictitia is nearly twice that of the United States.

It's less clear where the United States stands relative to the rest of the world in synthetic biology and quantum computing. But reading recent headlines, it's easy to worry that we may be falling behind.

- After suffering a major African swine fever outbreak in 2018, Fictitia used synthetic biology to confer viral resistance to its pig herds. In contrast, the United States has generally remained reluctant to allow genetically modified animals for human consumption. In April 2035, terrorists introduced African swine fever into the United States, triggering an immediate shutdown in U.S. pork exports and the collapse of the U.S. pork industry.
- Two weeks ago, a research team from the country Furturna announced a breakthrough in qubit[1] hardware technology—namely qubits with both long coherence times and fast gating properties. The new qubits allow for orders-of-magnitude improvement in the number of operations possible while in quantum superposition. Furthermore, they claim that a general-purpose quantum computer using this technology platform is within reach in the next few years.
- The latest immigration data show that the number of H-1B visas requested has declined for the third straight year, as the U.S. experiences an out-migration of technical talent in new technologies.

Despite these shifts, U.S. investor awareness inordinately follows the actions of American big tech. If Ricky had gradually started including overseas investments in his portfolio in the 2020s when he saw Washington lose patience with new tech, he might be enjoying his retirement today.

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[1] "A qubit is a computing unit that leverages the principle of superposition to encode information." Congressional Research Service. *In Focus Report, Defense Primer: Quantum Technology.* June 7, 2021. See: https://crsreports.congress.gov/product/pdf/IF/IF11836/2.