TTI VANGUARD
ADVANCED TECHNOLOGY RESEARCH MEMBERSHIP

Transformed by Digital HIGHLIGHTS

March 3–4, 2020 • Seattle

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Fixing Social Media—Mr. Ethan Zuckerman, MIT

- The rise of online social media to its current status as a dominant form of interaction is a recent phenomenon, and despite the deluge of criticism of its most popular platforms as a collective bane of human discourse and degrading force of society and democracy.
  - As a social scientist, MIT's Ethan Zuckerman has joined others in studying whether social media is bad for individuals or for society as a whole.
    - Although anecdotes abound, research is decidedly inconclusive.
      - "We don't have much clarity on whether Cambridge Analytica had much to do with the 2016 elections, either in the United States or in the UK," says Zuckerman. "We have little clarity on whether social media is bad for teenagers: There is a wonderful recent study that shows a very small correlation between teenage unhappiness and heavy social media use; it is as [strong] as eating a lot of potatoes, which is to say that you are much more likely to be unhappy as a teenager if you are overweight, wear glasses, or are a geeky kid."
    - The body of scientific research in this area is small, notably because of lack of access to relevant data.
      - On the one hand, social media platforms hold their data tightly; on the other hand, researchers take to heart the responsibility to not probe an individual's privacy too deeply.
        - "We probably want to be very careful about analyzing data about whether an individual gets bullied or what people's interactions are online," says Zuckerman.
  - What is unambiguous, however, is that other forms of modern media considered their potential social impact from the get-go, while social media on the Internet did not.
    - Zuckerman uses his time with TTI/Vanguard to provide an early history of radio, variously in the United Stated, the Soviet Union, and the United Kingdom, considering how their disparate approaches conformed with the respective national zeitgeist and the future of the medium, and how the lessons learned might be used to shape a more responsible relaunch the concept, structure, and funding for online social media.
  - "If social media turns out to bad for us—either individually or socially—we really shouldn't be all that surprised about it," says Zuckerman, "because there has never been a strong civic component to the design of these systems."
      - Today's social media platforms have become masters of "surveillance capitalism," where the firm monitors every aspect of users' online behavior, "takes as much of [users'] attention as they can, bundle it up, and sell it to an advertiser."
      - "For the most part, people have not sat down and said, 'Is interacting on Twitter the right way to have a civil conversation between people who disagree about things?'" says Zuckerman, who considers Twitter, like Slack, an interaction forum for members of a common clique or workplace, rather than an intentional online space for the civic good.
  - Zuckerman does not believe tinkering around the edges of existing social media platforms will fix them; instead, he proposes the creation of a new, nonpartisan, academically rooted design—a new type of social media platform entailing a collection of social media "rooms," each with an appropriate self-governed ethos for discourse, generally accessible through single sign-on, and all publicly funded through a tax on Internet firms that engage in surveillance capitalism.
- First, a look back at commercial radio, 1912–1922:
  - The year 1912 marked the use of the triode vacuum tube as a radio amplification device; this ushered in the era of broadcast radio.
    - "Not until 1912 did it become possible to modulate voice or modulate sound and send it over radio," says Zuckerman. "Within ten years of that invention, we had commercial radio as we know it in the United States."

        - This was lightning speed; consider that it took nearly three times as long from its inception for the commercial Internet to come into its own.
    - Not only was the rise of commercial radio fast, by 1922 radio had developed according to markedly distinct business models depending on country.
        - Radio in the United States:
            - Broadcasting was all the rage, as department stores, hotels, churches, and universities all rose to prominence as radio stations, although their reach was largely limited to the premises, since few people yet owned radios of their own.
                - Still, the house band, Sunday-morning choir, prominent orator, et al., was broadcast to those within the facility.
            - Everything changed, however, with the expanded penetration of radios into American homes, and essentially simultaneously with the innovation of "someone calling into a radio station and reading an advertisement over the air."
                - "Commercial radio, as we know it, started when a real estate salesman on Long Island bought ten minutes of radio time and pitched a new development of housing," says Zuckerman. "This was incredibly controversial at the time, because people are very worried that advertisement making it into the sacred space of the home would ruin this medium forever, but it turned very quickly into a consolidation around this model."
        - Radio in the USSR:
            - The end of the War to End All Wars and the Bolshevik revolution ushered in the USSR, with a vast expanse of land populated with poor, illiterate peasants, who—the government believed—needed to be convinced how good they had it now under the new regime.
            - Radio—fully under the control of the state—provided a perfect propaganda opportunity, although citizens couldn't afford radios on which to receive the messages being broadcast.
            - The Soviets, therefore, resorted to broadcasting their messages over loudspeakers—in town squares, factories, and anywhere else a large number of people might gather.
            - Once the price of a radio dropped and Soviet citizens could afford one, what they purchased had the graceful simplicity of a single on–off–volume knob; no need to tune, because there was only one station—the national station—to listen to.
        - Radio in the UK:
            - Not wanting to replicate the chaotic radio environment of the United States, the British formed a consortium of home radio manufacturing firms—the British Broadcasting Company (later, Corporation) to be subsidized by a royalty on the sale of domestically made radios.
            - From the start, the BBC committed to "inform, educate, and entertain"—that is, the British invented and implemented the concept of public-service broadcasting, but not under control of the state.
            - In fact, the BBC has, throughout its history, taken great pains to remain politically neutral.
                - "Very early on in this process, there was a massive nationwide strike in Britain, and the BBC revealed itself to be a neutral broker by putting both the Prime Minister and labor leaders on the radio, establishing the idea that this was to be a space for everybody," says Zuckerman. "The BBC figured out in the 1920s how to demonstrate significant independence from the government through its actions."
- Just as the BBC did with radio from the outset, the United States eventually did, albeit on a limited scale, beginning under the leadership of Federal Communications Commission chair Newt Minow in 1961.
    - Well-known as "a hardcore Democratic activist," the broadcasters industry's movers and shakers were shaking indeed—shaking in their boots that Minow would excise game shows and other programming that contributed to what he deemed the vast wasteland of television.
    - Yet, Minow did not ban shows; instead he created alternative infrastructures: on the one hand, to educate children, and on the other to enable good public discourse.
        - "He started investing heavily in satellite infrastructure, which ended up being the backbone behind NPR and PBS," says Zuckerman. "And he started making it possible for new projects, like the Corporation of Public Broadcasting to come into being."
            - Zuckerman singles out the Children's Television Workshop for special acclaim, appreciating that, instead of experimenting with a variety of children's programming and evaluating after the fact, CTW instead hired psychologists, educators, artists, and puppeteers who spent more than two years to research whether television could provide an alternative to preschool, and only after deep evaluation and planning did Sesame Street come into being.

- Minow's thrust was to carefully build the infrastructures to enable patching of the holes in the broadcasting landscape that the market had failed to do on its own.
- By this point, Zuckerman's focus on the history of broadcasting should be clear: The online social media environment entirely skipped the process of business model experimentation and settled immediately on surveillance capitalism; it is time to fill in the gaps to serve the needs of a democratic society.
  - "We ended up with that U.S. model: very light regulation, everybody competes, and we end up with a pure free market, without very much thought on what we want these platforms to do in terms of public service," says Zuckerman. "This leads us to a moment of market failure; these platforms do not give us what we need as civic actors."
    - Note that this free-market environment also holds true for China's social media scene, despite also being characterized by embedded state-imposed censorship.
  - This is not to say that the Internet lacks examples of the public-service model—Wikipedia is the quintessential example—"but they are the exceptions, not the rule," says Zuckerman.
- "If we wanted to build social media systems that were good for us as citizens of a democracy, what would we actually do?" poses Zuckerman.
  - Just as with the period leading up to the launch of public broadcasting, the first step is to consider characteristics of a social media platform to benefit society.
    - "Can we build social media that is plural in purpose, public in spirt, and participatory in governance?" he asks.
      - That is, what design elements are necessary to create social media capable of informing, connecting, and mobilizing the citizenry? What would amplify voices and ideas, enable deliberation, and encourage diversity (of people, thought, and opinions), all while being a sandbox for the practice of governance?
  - These are not simple questions, and answers will not come easily, but the effort will be worth it if the outcome is a social media platform—or a federation of social media platforms—that serve the public interest and engage people in the civic process.
    - "Depending on how you build social media systems, they do some of these [desired] things very well or very poorly," says Zuckerman.
      - Take Facebook, for example: It is a particularly poor enabler of deliberation, lacking facility for polling, threading of discussions, imposing turn-taking among conversation partners, or encouraging diversity for those who don't come by it naturally, since by design it replicates one's offline social network online.
  - To get to something better requires first moving beyond the default, which itself entails getting over the failure of imagination that Facebook and Twitter have lulled us into.
    - Zuckerman has no interest in fixing Facebook; he wants to build something radically better, just as the Corporation for Public Broadcasting did with television and radio.
  - Let's breakdown the three P's of desirable social media by offering examples of each:
    - *Plural in purpose*—The physical world has a wide variety of social spaces, each with its own set of social norms; churches differ from schools, which differ from poolhalls and from granges. Online spaces should similarly offer the opportunity for specialization.
      - Example: Esra'a Al Shafei, who presented to TTI/Vanguard in May 2012 on the related topic of social media in Bahrain, has launched Majal, a safe social site for LGBT youth in the Arab world, where being who they are puts them at great risk.
        - For personal protection and to encourage honest sharing and discourse, by design Majal does not use real names and only permits avatars, not photographs.
        - And there's more that Majal does to ensure the safety of its community members: "It has a system that requires you to make comments and have them approved by the rest of the community for several times before they change the rules [for the new user] and allow you to start a new thread."
      - "For *that* room, it is the right ruleset," says Zuckerman. "You need a combination of tools that enable certain types of social norms that allow different kinds of conversations to happen."
        - Not every space will be for serious purposes—indeed Zuckerman anticipates many will have entertainment/fun as the primary objective—but each can be tuned to the needs of its users.
    - *Public in spirit*—Some spaces will address a particular public need.
      - Example: Wael Ghonim is an Internet activist who served as an administrator of the Facebook page "We are all Khaled Said"—which, not by his explicit design, sparked the Egyptian revolution of 2011 (an important aspect of the Arab Spring).

        - "Wael came out of the Tahrir protests incredibly frustrated that those tools that were so good for mobilization were terrible tools for deliberation and discussion," says Zuckerman, leading him to launch the online community Parlio, where people were encouraged to share opinions and engage with public figures.
        - Parlio's etiquette statement began by saying, "Be curious, open-minded, and civil," and went on to encourage diversity of thought while creating a "community of trust and respect that expands our horizons."
        - This network, which Ghonim launched in 2015 explicitly for participation by future community leaders, was acquired by Quora the following year—and shut down.
    - *Participatory in governance*—Instead of Facebook, which sets its rules of governance in Silicon Valley and enforces them with "poorly paid people in the Philippines, who are trying to figure out whether your speech is allowable or not," says Zuckerman. This works poorly for Facebook's users, which are frustrated when their speech is disallowed, and is a pure cost for Facebook, which would prefer to never step in and instead only reap the profits from advertisers to whom the social network delivers its users.
        - "For Facebook, governance is the last thing they want to work with," he says.
        - Self-governing spaces are better.
        - Example: Reddit—For all its ills, each of the hundred-thousand-plus subreddits conforms to its own rules, with community moderators granted local control.
            - The outcome is some heinous subreddits, although most function civilly for the benefit of their users.
                - "We are doing a lot of research on Reddit," says Zuckerman. "It turns out to be a tremendously fascinating and diverse space, with a number of very small cesspits in it that tend to stink up the entire place, but it is not entirely a cesspit; there are some really wonderful, high-functioning communities on it."
            - Among the positive forums is r/science, which includes over 23M members and has over 1000 moderators daily enforcing its principal rule of conversation, which specifies that all commentary must be accompanied by citation to peer-reviewed research.
        - "What I am trying to get to is something that is a bit of a throwback in architecture, which is getting away from companies that are hosting sites for 2B people, and getting to something that is a distributed and federated experience," says Zuckerman.
- "It actually is pretty easy to create distributed social networks, but they fail," says Zuckerman, who attributes this to individual loyalty to a small number of social networks—typically three—with no ready way to encourage people to be involved with a broader range of forums.
    - However, were assorted social networks aggregated onto one platform with a neutral single sign-on, users could be more fluid in their participation.
        - "I would use LinkedIn," says Zuckerman, "if LinkedIn showed up in the same place as Twitter and Facebook, which I both use fairly heavily. It doesn't; therefore, I don't."
    - It works to the advantage of existing social networks to keep their users locked within their walled gardens, but no such limits exist for a new, built-from-scratch platform.
- Zuckerman's criteria for a civics-enabling social media platform:
    - Neutral single sign-on;
    - Open API to federate social networks;
    - Safety resources to protect against, for instance, child exploitation imagery.
    - Of course, none of this will get off the ground without a firm basis of net neutrality.
- He has built a prototype platform that satisfies these criteria in his lab.
    - "It brings together Twitter, Mastadon (which is an open Twitter-like protocol), and part of Facebook," says Zuckerman. "What is great about it is that, once you put this stuff together, you are no longer governed by Facebook's algorithms for what you see."
        - For instance, Zuckerman's platform includes a gender slider (enabling a user to quiet the voices of men), the ability to mute 2020 election news, and more.
    - "This is not meant to be a commercial product; it is meant to be a provocation," he says.
    - To move beyond this proof of concept, Zuckerman envisions drawing from the well of a new tax proposed by 2018 economics Nobel laureate Paul Romer that would skim a small percentage of the profits of the dominant digital platform companies that have gained global prominence by aggressively pursuing surveillance capitalism.
    - "I want to use part of Paul Romer's tax to start up something that I'm calling the Institute for Digital Public Infrastructure (DPI)," says Zuckerman. "I want to start something that looks a little bit like

Children's Television Workshop, that looks a little bit like the Corporation for Public Broadcasting, and that would have—on a national level for each nation that takes this on—a thinktank that tries to figure out what we should do about building Internet tools and Internet spaces that are actually good for us as communities."
    - The three-part mandate of a DPI would be to establish a vision for digital media to benefit citizens and people, to establish a workable legal and policy regime, and to build in infrastructure components—such as user-controlled single sign-on, differential privacy (for user behavior research), programmable social network aggregators, and so forth—to both serve the users and gain research-grade insight on what works and what would benefit from improvement.
  - A 1% tax on Google and Facebook would yield hundreds of millions of dollars—more than the current combined funding for Wikimedia, Mozilla, the Internet Archive, and Media Cloud.
  - Now, Zuckerman recognizes the political challenges of implementing a tax for this purpose in the United States, and therefore proposes the first instance of a DPI in The Netherlands, where the Public Spaces experiment is already underway.
    - "Public Spaces is all the broadcasters in The Netherlands getting together with all the major cultural institutions and trying to figure out how they can move from closed-source, Silicon Valley-based spaces for conversation to open-source, Netherlands-based spaces for conversation," says Zuckerman. "The next step beyond that is [to ask], 'What do we think good conversation looks like, how do we study it, how do we build it, how do we get closer to it?'"
  - Jimmy Wales has also launched an social networking service—Wikitribune Social (WT.Social)—which is funded through subscriptions/donations (akin to PBS or NPR)—as an alternative to Facebook and Twitter that would elevate legitimate news and demote fake news by providing "evidence-based news with links and clear sources."
  - Harkening back to Brewster Kahle's May 2016 address to TTI/Vanguard on locking the Web open, Tim Berners-Lee has launched the Web decentralization project Solid (Social Linked Data), which Zuckerman describes as follows: "In this new architecture, everyone has control over their data, gives out packets of it to different services to try to find a way to interact and have some common space for conversation going back and forth."
- All of these effort strive inspire a new generation of infrastructure developers not to "tinker around the edges of these spaces that we're interacting with," says Zuckerman, but rather to transform them entirely, not relying on the coercive business model of surveillance capitalism, but to generate civically funded, civically minded platforms to encourage constructive public discourse.
  - "The idea is to be content-neutral, but to create these spaces that are self-governing, and see where it goes," he says, recognizing that some of the spaces will be toxic, but also that one wouldn't be shunted into them unawares by the platform's algorithms, as is the case now.
    - "The hope is that, by people interacting with a multiplicity of communities, you have different examples and that you know when you are moving into a toxic space."
  - "The Internet is a series of spaces, and each of those spaces has to have a purpose and has to have rules associated with it," says Zuckerman. "That is the conceptual shift I am trying to get everyone to make."

When National Currencies Go Digital—Ms. Aditi Kumar, Harvard Kennedy School

- Since the end of World War II, the U.S. dollar has been foundational to the international monetary system, but that could soon change, given that China is on the brink of launching its central bank digital currency (CBDC), the digital yuan—formally known as digital currency/electronic payments—which will be backed by the full faith and credit of the government.
  - This endeavor, which has been under development since 2014, kicked into high gear in mid-2019 after Facebook announced its intention to launch its digital currency, Libra.
  - Aditi Kumar, who leads the Economic Diplomacy Initiative at Harvard Kennedy School's Belfer Center, considers the international and U.S. national security implications of China's move.
  - Toward this end, she assembled a political-star-studded cast to play out a scenario, set in November 2021, in which China surreptitiously had used the digital yuan to fund North Korean military ambitions, culminating in a test flight of a nuclear-capable missile that could reach the Continental U.S. from the Hermit Kingdom.
    - Although fictional, the potential consequences are dire.

- Moreover, a centralized digital currency, as China's CBDC will be, carries severe implications for privacy, and if China is first-in and gains a digital-currency foothold with nations under its influence, the United States could be left behind.
- Kumar first describes "Digital Currency Wars: A National Security Crisis Simulation" and proceeds to discuss the broader impacts of a digital yuan and a move to CBDCs more generally.
  - "This is a story of the United States being very unprepared for the digital world toward which we are heading, in which we lose our ability to use economic tools like sanctions to serve our national security interests, we [put at] risk our ability to track illicit finance flows (including money laundering and terrorist financing), and we further erode our leadership in setting the norms and standards for data privacy and the ownership and access to data," says Kumar.

- The crisis simulation:
  - In staging "Digital Currency Wars," Kumar's intention was to illustrate the possible contours of a digital-yuan world.
    - The players were senior members of the Belfer Center leadership and cabinet-level dignitaries from past Democratic and Republican administrations alike, including Ash Carter and Larry Summers, who reprised their respective roles of Secretary of Defense and Treasury.
  - The simulation featured a Situation Room meeting of senior administration officials hashing out a response to North Korea's 2100-mile missile test launch that included the successful release of a simulated warhead.
  - In dramatized news commentary about the missile test, former *New York Times* Beijing bureau chief David Sanger explained the role of the digital yuan: "The digital yuan is an opportunity for the North Koreans to break free of the American hold on dollar transactions. The reason that financial sanctions have largely worked against North Korea is that most transactions have to clear banks in dollars; there has always been a fair bit of black-market trade, particularly over the North Korean–Chinese border, and you see oil flowing across and you see people trading in goods, but the North Koreans can't really buy much on the outside market without having dollars. Now, this digital yuan, backed by the People's Bank of China and supported by Chinese commercial banks, gives an opportunity to do full transactions without having to go through a dollar clearance process. So, if the Chinese decide to break free of enforcing the sanctions, they can do so, and there is very little visibility into how these transactions work, so the United States would have a very hard time proving that the Chinese were participating in sanctions busting."
  - Kumar expresses the primary takeaway from the crisis simulation: "U.S. policymakers are really underprepared for this development, and part of that is an understanding of what digital currencies are and what they might be."
- The nature and scope of digital currencies:
  - Digital currencies are hardly limited to the familiar financial products and platforms of Bitcoin, Venmo, Zelle, ApplePay, and the like.
    - The various instantiations of today's digital cash—Venmo, Zelle, ApplePay, credit cards—are issued by the authority of a private firm, and that firm bears any related liability.
    - Decentralized cryptocurrency exchanges, like Bitcoin or Ethereum, rely on peer-to-peer technology with no central administrator; they therefore lack a means to manage liability, but appreciably protect the privacy of transactors and the security of transactions.
      - However, cryptocurrencies are unlikely to supplant government-backed currencies due to their volatility. "They are not a stable store of value," says Kumar, "and they are not a widely used medium of exchange, which are the two fundamentals of money."
        - "Bitcoin is not money; it is a speculative asset," she says. "It is not something we are going to use to buy coffee, because we don't actually know how much it's worth, so we can't tell how many bitcoins are equal to a cup of coffee."
      - Moreover, some bitcoin exchanges have been vulnerable to hacking—case in point: Mt. Gox—suggesting the benefit of a central authority.
    - At the national level, the ultimate central authority-backed digital currency is a national CBDC.
      - "You do need somebody to guarantee the value and guarantee the security for [a digital currency] to be used as money," says Kumar, as she makes the case for centralization.
      - On the flipside, the central authority would then have a full record of every transaction: "There is one authority in the middle of it that shows them everything that is happening in the system," says Kumar.

        - The degree of trustworthiness assigned to that repository of transactional information depends on one's point of view: Is the U.S. government to be trusted? Is China? Is Facebook?
            - Kumar notes that most of the world's major central banks are exploring CBDCs.
- People in the United States tend to discount the benefits and ignore the risks of a national digital currency, largely because of the long-term international primacy of the dollar, on the one hand, and the significantly digitized nature of U.S. commerce, whether through the use of credit cards or the adoption of more recent digital forms of monetary transfer.
- A digital dollar would be different than the country's fiat money, but exactly how it would be managed is a matter of debate: Should the Federal Reserve be in charge? Should the Commodity Futures Trading Commission? Should a different existing entity? One yet to be created? Crisis scenario panel members engaged in considerable debate, but reached no consensus.
    - In the meantime, Mark Zuckerberg testified to Congress this past October, saying that with China preparing to launch its DCEP, the U.S. must move quickly to not be left behind.
        - (He meant the U.S. must move quickly to approve Facebook's launch of the Libra, but those with a more national and less proprietary mindset might say the same for a U.S. CBDC.)
- So, what is Libra?
    - It is a permissioned blockchain digital currency proposed by Facebook and backed by a consortium of private firms (although notably fewer than before, since PayPal, eBay, Mastercard, Stripe, Visa, and Mercado Pago all backed out in October 2019.)
    - The benefit for Facebook Messenger users, especially those with international friends and family, is clear, as Kumar explains: "I have family in India who use Facebook. If I could just send them money on Facebook Messenger without having to pay foreign exchange fees, that would make my life so much easier. I already have the Messenger app on my phone."
        - Consider the current cross-border transaction process intermediated by the Society for Worldwide Interbank Financial Telecommunications (S.W.I.F.T.): "If I wanted to send money to my family in India, usually my community bank will not have a relationship with a bank in India, where I give them some payment instructions and they wire the money over to the corresponding bank in India, which is why we have a network of correspondent banks to facilitate cross-border transactions, maintaining reserves in lots of different currencies, maintaining relationships with lots of other correspondent banks in the respective currencies, and facilitating these transactions," says Kumar.
            - Complicated, yes, and largely dominated by U.S. entities, because many correspondent banks are based in the United States, conferring on America an advantage over other nations (despite S.W.I.F.T. being based in Belgium).
                - The U.S. terrorist tracking program acquires intelligence by subpoenaing S.W.I.F.T. for particular international transaction records.
            - Not only would Facebook like to operate outside around this system; so too would China.
    - But Kumar describes Facebook's proposed currency as "regulators' worst nightmare" because of the social network's reach into the lives of 2B people spread across the planet and the power that it is trying to accrue to itself.
        - To launch Libra, Facebook contends it will, with members of its consortium, create a basket of existing national currencies to back the cryptocurrency, and retain that basket to underwrite confidence in Libra.
        - "If we need more money in the system, Facebook would think about issuing more money," says Kumar. "So everything that the Fed is doing right now, including interest rate cuts, those powers get slowly transferred over to Facebook—which is insane, but this is what they are proposing."
- What does China have in mind for its digital yuan?
    - A window into expectations for the digital yuan, which is being developed under the auspices of the People's Bank of China, has opened in the form of a trove of more than 80 recently publicized patents, variously covering proposals for issuing and supplying China's CBDC, a system for its interbank settlements, and integration of digital wallets into existing banking infrastructure.
    - "It is a currency that would be issued by the People's Bank of China, just as they issue cash today," says Kumar. "It is the same thing, except now they are issuing digital tokens."
    - Instead of the People's Bank disintermediating the nation's existing banking structure and issuing digital script directly to individuals and businesses, it is expected that the ledger will be overseen by the People's Bank and operated through a narrow collection of permissioned nodes: China

Construction Bank, Industrial and Commercial Bank of China, Bank of China, Agricultural Bank of China, Tencent (owner of WeChat Pay), and Alibaba (owner of Alipay).
    - "If I [as a Chinese person] want to send you money, my bank will switch over money to your bank," says Kumar. "It's fast and seamless, and on the backend it solves a lot of inefficiencies in the banking sector, and it doesn't need things like blockchain or whatever. You need those when there is not a lot of trust in the system, but in this case there are only seven institutions, and they trust each other, so all they need is a common Excel spreadsheet in the middle for them to move balances around."
- Why the move to CBDCs now?
    - Of the 63 central banks surveyed by the Bank of International Settlements—which collectively represent 90% of global economic output—more than two-thirds are in the process of researching CBDCs.
        - Emerging-market nations are most attracted by payments efficiency, financial inclusion, and the safety of financial payments.
            - Example: Cambodia, where much of the populace is unbanked, could quickly engage with global commerce and finance simply by outfitting everyone with a basic smartphone with the Alipay (or a Cambodia-equivalent) app.
                - "People would become part of the system," says Kumar, "and the government could even use it for welfare payments in a way that it can't today by just putting money into people's accounts."
            - Example: India, where tax collection is an ongoing problem: "Because tax collection is so low, the government cannot fund services—schools, roads, etc.," she says, "and that is creating a vicious cycle of inequality and poverty in the country."
                - Although stripping the value of existing currency notes landed like a lead balloon, the introduction of an Indian CBDC would decrease tax evasion without seeming inherently draconian.
    - And why China?
        - Mobile penetration in China is high, with nearly everyone regularly using WeChat Pay and Alipay, so what does China stand to gain from moving to a CBDC?
            - On the one hand, the central government could gain even more visibility into the lives and activities of its citizens than it already does; on the other hand, it could facilitate international commerce, both to bolster its own standing and to undermine U.S. influence.
            - On a quasilocal level, China could encourage Cambodia, Thailand, and others in its economic sphere to broadly adopt its app-based digital payment platforms and transact friction-free with Chinese interests using the digital yuan.
                - "It becomes a very efficient way for money to move across borders for countries that are already in China's orbit, says Kumar.
            - Nations participating in the Belt and Road Initiative to enhance infrastructure for China-centric global trade could also find adoption of the digital yuan efficient for cross-border commerce.
                - "In the same way that they are putting facial recognition technology in some of these BRI places, they could put ATMs for digital yuan," suggests Kumar. "There are lots of ways they could proliferate the financial infrastructure in countries that don't have their own."
            - Alternative—or in addition—to establishing cross-border commercial pathways explicitly, China's central bank could share its technology stack or expertise to accelerate the progress of other nations to establish their own digital currencies.
                - This would establish efficiencies for partner nations, while also providing a win for China in the form of global influence—and perhaps by establishing technological backdoors in products that the Middle Kingdom provides, as is a current concern with Huawei.
                    - Indeed, as Francis McInerney reminds, the correct translation of *China* is *The Center of Everything* (hence, Middle Kingdom); this Asian giant is taking concerted and deliberate steps to reestablish itself in this central capacity, which includes putting the United States back in its (diminished) place, as also discussed extensively by Marko Papic at TTI/Vanguard's December 2019 conference.
        - The big win comes in the form of cross-border transactions based on the digital yuan instead of the dollar.
            - "For emerging economies, and also for some advanced economies, it is a huge value proposition to be able to create a simplified system that avoids the cross-border system that exists today, which is primarily dominated by U.S. firms," says Kumar.

        - As stated by the UK's Central Bank Governor Mark Carney—and similarly believed by China's central bankers—"[We want a] synthetic hegemonic currency that could dampen the domineering influence of the U.S. dollar on global trade."
        - This is not to say that the international perceived value of the U.S. dollar stands to degrade in short order, but rather that a more frictionless cross-border transactional process will benefit those that provide it and use it.
            - "My point is that, on the margins, countries that are already looking for ways to do bilateral trade that doesn't need to go through the U.S. system at all—such as China and India—could move onto a different system," says Kumar, "and in cases where countries are looking to avoid U.S. scrutiny, this is an alternative."
            - A case in point: North Korea, as per the crisis scenario, which would welcome a workaround from S.W.I.F.T.'s subpoena-able involvement in its acquisition of military funds.
    - More generally, Russia (with its SPFS), China (with its Cross-Border Interbank Payments System (CIPS)), and a subset of EU nations (with their Instrument in Support of Trade Exchanges (INSTEX)) are all devising non-dollar-denominated alternatives to S.W.I.F.T.
        - "INSTEX was supposed to give the Europeans a way to transact with the Iranians and uphold their side of the Iran deal, because they hadn't walked out of it yet, but didn't want to run afoul of any U.S. sanctions," says Kumar, "and the way not to run afoul of U.S. sanctions was to avoid S.W.I.F.T."
        - Successful S.W.I.F.T.-avoidance proofs of concept have been developed between the central banks of Canada and Singapore, Hong Kong and Thailand, and among members of the European Central Bank working group, which is currently led by Christine Lagarde.
- If enough financial activity tips from U.S.-centric infrastructure to China-centric infrastructure, it could help shift the global balance (again, see Marko Papic).
- Moreover, transactions that occur beyond the view of U.S. authorities could undermine the intent of sanctions the U.S. government might impose.
    - "The digital yuan creates a system in which the United States literally could not do anything without Chinese cooperation or the cooperation of other major economies that have their own payment system," says Kumar. "It means that we cannot unilaterally withdraw from the Iran deal because we know that the Europeans would be just fine trading with Iran, and if Iran can still sell its oil to the Europeans and to China and to India, they could do so. We wouldn't have the power that we have today to move unilaterally."
- A final geopolitical implication for China making an early and decisive move toward a national digital currency pertains to its ability to set standards for data privacy and security that conforms to its own ideals, rather than the more personally protective ethos of the West.
    - "They could arrest people in Hong Kong because they could see that they were buying masks, for example," says Kumar. "And if a company outside of China were to adopt the digital yuan, like Taiwan, they could identify political dissidents and pick them up."
- If faced with an objection by United States (or any other nation or federation) to its launch of a digital yuan, China could innocently sidestep complaints about intended overreach and stand by a claim that its CBDC is purely for domestic efficiency.
    - But McInerney sees past this ruse by recognizing an existential threat to China's Communist Party, which he dubs "cloud inflation": "That is the rate at which processing power not only grows but the number of devices and apps grow," says McInerney. "If that rate outgrows the Party's ability to control it through Alipay, then the Party collapses. You can plot the rate of cloud inflation and say when that date comes. The answer is the social-credit system. The key to [China's] survival is to expand the social-credit system globally, so you take the Great Firewall and you bring us all in. What you have described is a vital vehicle for bringing *us* in to the social-credit system so that it can monitor our behavior as it does its own citizens'."
- It is essential, then, for the United States to move expediently to get out from behind the eight ball and explore the digital dollar, set standards for private sector tokens (notably, Libra), and not create reasons for allies to avoid the dollar, such as pulling out of multilateral geopolitical pacts.
    - "We need to have an answer to the Chinese system," says Kumar. "If this is the way currencies are going to go, then the United States should be part of the effort to shape it. Sitting it out completely means that we might end up with a very fragmented currency system, where everybody has their own digital currency, and we lose that purview."

- "We are moving toward a system in which the United States won't be financially dominant, and we will have to figure out how we are going to create support for the initiatives we consider important for our national security in that environment."

Pizza-as-a-Service—Mr. Clayton Wood, Picnic

- Pizza! Who doesn't love it? Well, maybe the low-paid food workers who perform what is generally acknowledged to be a tedious task.
  - In the current low-unemployment environment, as those folks seek happier times in less cheesy workplaces, pizza establishments are facing an existential challenge—a challenge Clayton Wood and Picnic are ready to take head-on.
    - "We're not replacing jobs," says Wood. "We're replacing job openings."
  - Picnic's robot automates the pizza-making process and outputs a consistent and high-quality pie with minimal human intervention.
  - The firm uses a pizza-as-a-service model, charging a monthly fee of less than two full-time minimum wage employees for the use of the combined food storage, ingredient-dispensing, and baking apparatus.
  - With Picnic's setup, one worker can facilitate the production of nearly 100 pizzas hourly.
    - Compare to the hour required for four workers to handcraft just 16 pizzas.
  - Wood describes a few tasty demonstration projects and touts not only the improved volume of output, but also the improved product, that Picnic's robot creates.
- Before detailing the efficiency of the pizza-making robot, Wood paints a messy picture of the back-of-house reality at a pizza joint.
  - Customer desire for pizza is notoriously periodic, peaking markedly during the dinner rush.
    - A pizzeria might need just four kitchen workers during the day and late evening, but ten during peak hours, but few would be satisfied with a daily three-hour shift.
  - Turnover in the food service industry is therefore high, leading to a revolving door of pizza preparers who receive minimal training and oversight.
    - The upshot is significant food waste, as shredded cheese gathers as much on the countertop as atop the sauce.
    - Equally problematic is the worker who overdoes it with the cheese, drowning the pie in a deep puddle of molten goop.
      - Not only is this wasteful, but it also yields an inconsistent product, which harms the brand.
  - And workers might be low paid, but their wages add up for the restaurant owner.
- Automation can overcome all of these obstacles, as Wood illustrates with his tale of installing machinery at the Seattle Mariners stadium to bake pies for fans with access to the baseball stadium's private suites.
  - With just one pizzamaker staffing the system, over the course of five weeks 275K attendees enjoyed 1900 pizzas.
  - The pizzamaker was thrilled to keep his hands clean, with his job limited to overseeing the apparatus, laying out premade rounds of dough to start each batch and cutting and boxing the baked pizzas on the back end of the process.
    - Wood sees automation as an opportunity to free the food service operator from mundane tasks, freeing that person to pursue more creative kitchen activities, perhaps experimenting with novel toppings or new crust recipes.
  - The Picnic robot took care of the rest, dispensing precisely measured amounts of sauce, toppings, and cheese to each round, and baking them for the allotted duration at the proper temperature to create a uniform pizza each time.
    - As the first module of the robot accepts the dough, a vision system determines its size and shape, and passes the specifications to the remaining modules that layer on sauce, toppings, and cheese.
    - With the ability to dispense up to 12 toppings for the basic three-module robot, every made-to-order pizza is fresh and customizable.
  - Like pizza, many other foods are assembled (e.g., sandwiches, salads, wraps, bowls—even decorated cakes); an appropriately configured robot could fill those niches, as well.
  - The robot is sized appropriately for a commercial kitchen; customers need not retrofit their existing space to accommodate automated pizza-making equipment, and the PaaS model obviates the need for up-front capital investment.
    - The machinery looks more like an appliance than a conventional robot: It has moving parts, but is itself stationary.

        - (The lower half of the unit is to store refrigerated ingredients; were that not needed, it could sit on a countertop.)
      - "Roll it in, plug it in, and you're ready to make pizza using any recipe," says Wood.
    - This mode of food production comes with social benefits in addition to reducing food waste: disabled workers can operate the robot, dietary needs can be easily accommodated, and—particularly important in light of the current COVID-19 outbreak—is no-touch–no-hands food production.
    - As is true with any piece of machinery, the robot will require periodic maintenance, which can be scheduled during times of low demand; properly maintained, each machine should function for roughly seven years.
- A backend business intelligence dashboard serves up graphical visibility into production, including order patterns, ingredient inventories, fleet management (if delivery is part of operations), and so forth.
- Digital from the outset, Picnic's automated food production is satisfying an otherwise unmet need in the food service industry.
- Many firms are addressing food delivery, but producing tasty, hot, attractive food is a prerequisite for delivering it to people's homes or workplaces.
    - When food for delivery competes with a kitchen staff's preparation of food for in-restaurant consumption, the experience of on-premises customers degrades.
    - Alternative food production facilities are popping up to meet the food-for-delivery demand.
        - Low-rent ghost kitchens are perfectly suited for subscription-based food-as-a-service automation, as are parking lot kitchens, which cost even less to run.
        - Mobile kitchens (food trucks) carry the food to the customers; these, too, can be outfitted with a Picnic pizza-making robot.
    - As conventional restaurants face all manner of disruptive innovation, they must be creative with their own operations to survive and get ahead; in some cases, this will entail reinvention of their core business.

E-Voting and Election Integrity in 2020—Dr. Richard DeMillo, Georgia Institute of Technology

- In a conference entitled *Transformed by Digital*, Georgia Tech's Rich DeMillo goes against the grain by talking about a phenomenon whose digital transformation has been for the worse: voting.
    - At the national level in the United States, elections have always been chaotic and prone to corruption, but in the wake of Florida's hanging-chad fiasco during the Bush–Gore election of 2000, something had to change.
    - The Help America Vote Act of 2003 made $4B available to states to revamp their voting processes, and despite a contemporaneous outcry by academicians like DeMillo and Avi Rubin, who addressed this topic at the February 2004 TTI/Vanguard conference, many states jumped on the technological bandwagon and purchased Diebold's Accuvote direct recording equipment (DRE) as their next-gen voting platform.
    - Georgia was first among those states, granting a $54M contract to Diebold to replace its old voting system with more than 19K ATM-like voting computers.
        - They might be *like* ATMs, but they *are* computers, and as is true for any computer, they can be programmed, including being programmed to cheat.
    - DeMillo looks to his home state as he illustrates what he says was "the start of the long, sorry story of what can go wrong."
        - The story begins with long-ago revelations of vulnerabilities in DREs, continues with a major breach of Kennesaw State University's Center for Election Systems, proceeds to discuss the equally unsatisfying recent addition of ballot-marking devices (BMDs), and entirely excoriates the concept of voting by mobile phone.
    - None of this is to say that the voting process is inherently doomed (although it is a separate question whether public confidence in election integrity is a boat that has sailed).
        - 70% of U.S. voters will use pens to mark paper ballots during the 2020 election cycle, sliding them nondestructively into an electronic scanner, thus permitting real-time risk-limiting audits and even conduct a full recount if necessary.
        - But 70% means some 75M potential voters—some in crucial, swing-state districts—are poised to rely on an insecure electronic platform to mark their ballots this year.
        - DeMillo believes that BMDs should be reserved for only those people who require assistive technology to vote independently.

- As one might surmise from the title of his 2019 paper, “Ballot-marking devices cannot assure the will of the voters,” DeMillo has no optimistic note on which to conclude; instead, he will—as he has done for the past four election cycles—request an absentee ballot and fill it out by hand.

- The problem with direct recording equipment (DREs):
  - As long ago as 2003, as Rubin reported, deployed DREs were seen to misassign votes to opposing candidates, in at least two races, and to record orders-of-magnitude more votes than voters in another.
  - Then, in 2006, researchers including past TTI/Vanguard speakers Edward Felten and J. Alex Halderman published how they, as well as Rubin and others, had successfully hacked into Diebold DREs in just a minute (or a few) with no need for special tools.
  - More recently, in 2016, cybersecurity researcher Logan Lamb went poking around the Kennesaw election center’s website in search of insight on its operations, when he came across open files that appeared to be usable for nefarious purposes.
    - To explore more deeply, Lamb wrote a simple script to scrape unprotected documents from the site, launched it, went to lunch, and came back to a 15-GB downloaded trove of personal information for millions of voters, passwords for poll workers to use on election day, ballot preparation databases, and much more.
      - This was the fourth largest data breach that year.
    - Moreover, Lamb discovered an unpatched Drupal vulnerability that, if exploited, would permit an attacker to perform a wholesale infiltration of Georgia’s election system.
  - Thus, whether attacking DREs directly or the state-level system coordinating the voting effort, Georgia’s election system appeared to be anything but secure.
  - And it wasn’t just appearances: Among Lamb’s findings was clear evidence that a Shellshock attack and coverup had taken place during 2014, closely aligning with allegations later put forth in the Mueller Report.
    - DeMillo notes that changing perhaps 1000 votes per polling place in some counties in the Upper Midwest could have been enough to tip the 2016 vote in Donald Trump’s election.
      - Did this happen? There is no paper trail to audit.
  - Moreover, further details might never come to light because the Center for Election Systems wiped its servers clean a mere four days after an election integrity lawsuit was filed against Georgia’s then-Secretary of State (now Governor) George Kemp and various county-level election officials.
  - In the summer of 2019, a federal judge ruled that the use of DREs unconstitutionally thwarted Georgians’ right to vote and ordered that a new system be in place for the 2020 elections that “any new balloting system adopted by the State should address democracy’s critical need for transparent, fair, accurate, and verifiable election processes that guarantee each citizen’s fundamental right to cast an accountable vote.” Thus begins the era of the BMD.
- The problem with ballot-marking devices:
  - Georgia’s new system involves a hodgepodge of hardware through which citizens cast their votes.
    - The voter stands before a large tablet—large enough to be seen from across the room, arguably undermining the right to a private ballot—and uses its touchscreen to select candidates and responses to ballot measures.
      - In contrast to hand-marked ballots, where the voter directly expresses intent with no intermediary, marking a BMD is akin to whispering voting intent to a stranger in a back alley and hoping that the stranger honestly conveys the message.
        - In this analogy, the stranger in the alley is the touchscreen machine, which is under the control of software written by an outsourced Java coder, who might or might not work for a U.S. firm; that is, the stranger should be regarded as totally untrusted.
    - Like Pacific Coast states, Georgia’s ballots are lengthy, making it hard without a cheat sheet to remember every response after tapping “cast ballot,” despite this being an integral component of the new Georgia voting process.
      - Upon casting a ballot, the voter receives a printout from a consumer-grade printer connected to the tablet by a USB cable.
      - The voter is supposed to pore over the printout for accuracy—a slip of paper topped with as many barcodes as ballot choices, followed by a cursory listing of each ballot item and voter’s selection (but not alternative options), all in very small print.
    - After (purportedly) conducting this review, the voter is to walk the paper across the room to a scanner and enter it into a slot to be read and stored for an audit or recount.
  - What could go wrong? Plenty, says DeMillo.

        - Fewer than half of voters make an attempt to review the paper ballot, and far fewer properly review responses for each ballot item.
        - Even if a voter discovers a discrepancy, there is no recourse.
            - Poll workers have no instructions on how to ameliorate the problem.
                - Should they take the voting machine offline? Close the polling place entirely? Either would provide a perfect vector for denial-of-service-style voter suppression, which could be done with a limited number of insiders on a neighborhood-by-neighborhood basis.
    - DeMillo recognizes that there is a role for BMDs, which provide a viable means for disabled individuals, notably the blind, to be able to vote independently.
        - Still, such machines should only serve this limited population, rather than be the default for all voters.
        - DeMillo notes that efforts to accommodate disabled voters generally fall flat due to user interfaces that do not meet the needs of the intended population.
- The problem with BMDs' printers:
    - Alternatively, an attacker could self-insert between the BMD's tablet and printer, transposing a cast vote into one for an opposing candidate in the barcode; the voter would be none the wiser, even if diligently checking the printed ballot.
        - DeMillo's students rigged up such a simulated exploit in short order by hacking into the system via the printer's communication port, monitoring each printer event, interrupting it, and sending a spoofed ballot, which the voter then carries to the scanner to be tallied.
            - The result: Five sequential votes were cast for candidate A, but the printed output encoded four votes for A and one for B.
        - Although Georgia state law specifies the text of the ballot be scanned and votes recorded accordingly, vote-recording software is coded to rely on barcodes instead.
    - Were an attacker to poison as few as 4% of ballots with undetected fraudulent votes, the margin of victory would swing by 8%, which in most contexts trades the winner for loser.
    - For DeMillo, the so-called efforts of the powers that govern Georgia's elections harken uncomfortably back to the successful voter suppression tactics instantiated in the Mississippi Plan of 1890: residence requirements, poll tax, literacy test, cumbersome registration, voter disenfranchisement, easy-to-conceal corruption, say that you're safeguarding elections, and presenting an appearance of inclusion, while jiggering the system for targeted exclusion.
        - For instance, expensive/scarce computerized voting machines can be doled out to make it easy for members of some demographics to vote (i.e., those who favor the party in power), while creating hours-long lines for the rest (or enough of the rest to throw the election in favor of those in control).
- The problem with cellular voting:
    - Voting over cellular networks—or over the Internet, more generally—is fraught, due to mistransmission rates as high as 5%, not to mention the potential for hacking.
- Can the federal government impose a national solution? No.
    - Article 1, Section 4, of the Constitution states, "The Times, Places and Manner of holding Elections for Senators and Representatives, shall be prescribed in each State by the Legislature thereof…."
        - The upshot is that states rule the roost when it comes to conducting elections.
        - "Every national election is really thousands of elections taking place," says DeMillo. "There's no one in charge."
- Scanned, hand-marked ballots are optimal.
    - As noted above, the use of hand-marked ballots that are then scanned for counting and retained for recounting is the most secure mode of conducting an election.
        - During a full recount of the Minnesota senatorial race among Al Franken, Norm Coleman, and Dean Barkley—in which Franken and Coleman amassed 41.99% an 41.98%, respectively—only 14 ballots of nearly 2.9M had ambiguous markings.
            - That is, hand-marked ballots are a straightforward conversion of intent, plus the original paper ballot remains intact for any post-election review.
    - At first blush, the use of scanners could be considered yet one more vulnerability, but DeMillo counters this charge.
        - A risk-limiting audit, based on Wald's sequential probability ratio test, can be effectively used to assess the incidence of scanning errors; a full manual recount remains possible as a worst-case scenario.

- If you live in a jurisdiction that does not vote using hand-marked ballots, what to do to improve the voting process (given that the people in the position to make decisions were carried into office on an electronic-voting system)?
  - Run for a position on the board of elections to uphold this essential pillar of democracy.
  - As DeMillo does, always vote on paper with an absentee ballot.
- With the decadal census about to commence, DeMillo has commensurate concern with the digitization of this essential civic process as Internet form completion is augmented by census workers going house to house recording responses on unsecured tablets.

AI Patentees and the Artificial Inventor Project—Dr. Ryan Abbott, University of Surrey

- Although no one is seriously arguing that the age of artificial *general* intelligence is nigh, there is clear evidence of artificial intelligences that are capable of inventiveness.
  - Ryan Abbott, law professor at the University of Surrey, is currently representing entrepreneur Stephen Thaler and his AI creation Dabus (device for the autonomous bootstrapping of unified sentience) in an effort to have patent offices in various jurisdictions list Dabus as the inventor on two patentable inventions: a "beverage container based on fractal geometry," intended to be easily gripped by a robotic hand, and a flashing light intended to attract human attention in emergency situations.
    - Both inventions would have sailed through the U.S. patent process, had a human been listed as the inventor.
      - The *inventor* field of the application was initially left blank, but later updated to claim the machine to be inventor, leading to rejection by the U.S. Patent and Trademark Office.
      - Submissions have similarly been made to the patent offices of Canada, China, Germany, Israel, South Korea, Taiwan, and the United Kingdom.
    - Thaler is the first to claim no expertise germane to either invention.
  - By addressing all manner of issues surrounding the purpose of patents in general, and inventions by AIs in particular, Abbot makes his case for granting inventor status directly to an inventive AI (rather than the AIs user, owner, or programmer) and patent ownership to the human or corporate entity that owns it.
- How does Dabus work?
  - Thaler's early version of Dabus consisted of a self-evolving deep neural network, which when trained on data established connection weights—weights that adjusted after subjection to a degree of introduced noise, yielding novel data, and hence readjusted weights.
    - This process used internal feedback to iterate until Dabus generated an interesting output worthy of being considered an invention.
  - The current version includes a large number of smaller neural nets, each of which encodes some concept; the iterative process bonds individual conceptual spaces into a "consequence chain," which might culminate in a consequence adequately significant to be deemed an invention.
  - Note that at no point in Dabus's invention process does Thaler intervene.
  - As far back as 1998, Thaler was granted a U.S. patent for an invention devised by a predecessor of his current AI; in that instance, he listed himself as the inventor.
  - More recently, John Koza's Invention Machine—a genetic-programming-based AI—received a patent for a digital controller in Koza's name.
- Adding to his motivation for this discussion on AI patentees, Abbott introduces the more familiar AI, IBM Watson and the insights business model Big Blue has developed.
  - In this business model, a firm contracts with IBM to run a large amount of its own data through Watson's suite of algorithms, with the anticipated outcome of some novel insight associated with their data.
    - "The insight goes to the client, the client owns the insight, and the client—by contract—also has the right to file a patent on the insight, and some of the clients do," says Abbott.
  - "Just contracting to have research done doesn't make you an inventor, handing data over doesn't make you an inventor, sometimes identifying a problem can make you an inventor, but not when the problem is known or obvious," says Abbott. "Programming an AI to solve a problem might make you an inventor, but not if you didn't know the problem being solved or the solution being generated. To be an inventor in the United States you have to have formed a complete and operative idea of the invention in your mind. The person who looks at Watson's output and says, 'Ooh, this is patentable!' might be an inventor, especially if Watson says, 'Here are ten different compounds; go figure out

what one fits best.' But if Watson just comes out with, 'Viagra also treats male pattern hair loss,' or if you are looking for two materials that stick to each other, and Watson says, 'Here's material A and material B,' at least some of the time there is no one who fits into the traditional mold [of inventor]."
    - "We have a rule for what makes someone a human inventor, versus someone who reduces something to practice," says Abbott. "If the AI functionally does what we consider inventive activity, it should qualify."
- Although patent law in this area remains an open book, more has been decided in the intellectual property regime of copyright law.
    - Since 1988, the UK has protected computer-generated works by granting copyright ownership to the producer of the work, but with a shorter copyright term than conventional.
    - In contrast, a 1973 policy of the U.S. Copyright Office explicitly prohibits nonhuman authorship, automatically shunting computer-generated works into the public domain.
        - The U.S. precedent cited in this policy decision was a photography-related case in 1886—*Burrow-Gives v. Sarony*—which deemed that it was Sarony and his photographic skill, rather than his camera per se, that warranted creative protection.
        - "If you have an AI that makes a song that you think is going to be valuable, or a novel or a short film, and you disclose that the AI made this, you can't own it, and it goes into the public domain," says Abbott. "This makes it awfully tempting to take credit for work done by an AI, and the AI is probably not going to complain."
    - Still, the validity of this policy has not yet been directly contested in the age of artificial intelligence; the closest analogy is a collection of "monkey selfies" in which Indonesian macaques triggered a camera situated for the purpose by UK wildlife photographer David Slater.
        - Slater claims copyright protection based on having traveled to the region and set up his equipment, while the U.S. Copyright Office maintains that the photos are rightfully in the public domain.
        - "There was so much discussion about this case," says Abbott, "that the copyright office took their 1973 policy, called it the 'human-authorship requirement,' and specifically listed on their website and their guidance that a photograph taken by a monkey can't get copyright protection."
        - Relatedly, Abbott was involved as a consultant when the People for the Ethical Treatment of Animals (PETA) subsequently sued Slater in an attempt to have copyright granted to each selfie-taking macaque.
            - "That case got dismissed," he says, "but not on the basis of the human-authorship requirement. It got dismissed on standing: The 9th Circuit Court of Appeals in California said that an animal can't sue unless Congress gives the right to sue, so no lawsuits for monkeys."
- Given that it is a criminal offense in the United States to falsely list someone as inventor on a patent application, the lack of legal guidance or recourse when an AI invents is subverting the purpose of the patent process (and, arguably, Abbott would say the same regarding copyright's human-authorship requirement).
    - A patent grants limited property rights to its owner in exchange for publicly sharing details of the invention; once granted, a patent owner may sell, license, assign, or give away those rights.
    - The objective of the patent system is to stimulate invention.
        - "We think that, without patents, certain sorts of research and development will be underproduced because there aren't enough financial incentives, so patents are incentives for people to [share] intangible ideas that, otherwise, people might copy for free," says Abbott.
    - If/when AIs become the dominant engine of invention, requiring every inventor to be a human being would quash the rate and quality of innovation.
    - A machine might not have a use for a patent, but patent protection would incentivize people to make, own, and use patent-capable AIs.
        - "If you allow [the AIs'] output to have more value, it would incentivize people to build inventive machines and result in more innovation for society," says Abbott.
        - Moreover, without patent protection, the novel ideas/inventions that AIs generate might remain secreted away, rather than benefitting society through open disclosure and serving as impetus for further innovation by others.
            - "If you have an inventive machine, but cannot get patents on its output, you would presumably keep those inventions secret and not disclose them," he says.
- When relevant, Abbott believes that the AI should be listed as the inventor, both because it is accurate, and also because it would prevent not-quite-inventors from taking undue credit and thereby diminishing the contributions of truly inventive humans.

- "If I just ask Watson to invent 1000 things for me, and I list myself as the inventor on 1000 patent applications, it changes what it means to be an inventor," he says.
- On the flip side, Abbott believes that the AI should not be listed as the patent's owner; the AI's owner should be, "consistent with general properties of ownership," he says.
  - Not only does an AI lack legal rights, but ownership would provide no benefit to the AI, since it would have no ability to exploit a patent.
  - Licensing would be done by the AI's (and the patent's) owner.
  - Moreover, Abbott believes that the ownership of any patents associated with an AI that builds another, better AI—or patents associated with that better AI's inventions—should also accrue to the owner of the first AI: "If we're having inventive machines making inventive machines, the owner of the first inventive machine would own the second one and capture that value. We want AI building AI, and the person who owns the beginning of the process is the person who owns further iterations."
- The U.S. Patent Office, anticipating the coming deluge of AI patent applications, recently conducted a request-for-comments period in advance of developing and implementing a policy on AI inventions; similarly for the World Intellectual Property Organization.
  - "This is an issue that is on the minds of regulators in industry and business," says Abbott, who holds out hope on behalf of AI inventors and their owners, in part based on the most recent substantial revamping of patent law in the 1950s, when Congress did away with the so-called flash-of-genius test, recognizing that how an inventive idea comes about matters little compared to the fact that it did.
    - "We really don't care whether something comes from Einstein or a room full of monkeys," he says. "All that patent law is trying to do is incentivize the development of valuable intellectual property. So whether a machine or a person is coming up with something, either way we just want to socially generate more innovation."
- Abbott's representation of Thaler's Dabus is an effort to force the hand of patenting authorities.
  - To date, the UK's Intellectual Property Office has rejected the Dabus patent application, but a High Court appeal is in the works, with the expectation that the case will continue up the legal ladder.
    - The IPO answered the appeal of the initial patent application with the unusual act of providing a press release in advance of issuing their decision.
      - "It was an interesting refusal," says Abbott. "It essentially said, 'We accept your claim that the machine has done all the inventive work and that there is no person who is an inventor, but we gave you a chance to put someone's name on it anyway, and because you didn't we are going to reject your application.'"
        - Another appeal is in the works.
  - Other countries that rely on the European Patent Office, including Monaco and Cyprus, have no provision requiring the inventor to be a natural person.
  - Israel adopts yet another approach by not requiring the disclosure of inventors at all.
  - "It may end up that some countries permit inventions like this, and some don't, and that is going to be a source of international tension," says Abbott.
- "This is going to change a lot of standards in patent law, IP law, and law more generally," contends Abbott.
  - Take the nonobviousness requirement, which sets the bar of inventiveness at something that a person skilled in the relevant arena would not have found obvious.
    - This is a two-part conundrum in this changing atmosphere of who/what is an inventor:
      - The working definition of a skilled person is an average worker in a scientific field.
        - If AIs become workers, the skill set expands to include things at which machines excel, including searching/comparing vast amounts of information, beyond what even a human expert could do.
      - Obviousness is measured against prior art, something that a machine can be designed/programmed to assess with far greater thoroughness than even the best informed person.
        - "Someone using an AI like Watson has access to a whole lot of information that they wouldn't otherwise know," says Abbott, "and knowing more information makes things more obvious, because almost every invention really just combines a few existing things."
      - With AIs in the mix, either as lone inventors or assistive technology to humans, the standard for inventiveness rises.

        - "When something like Watson is better than the average researcher, in some area of research, you could just copy it and have it take over inventive activity on a wide scale," says Abbott,
    - Thus, "what a machine finds obvious" becomes the new standard, which suggests two potential futures:
        - In one future, without alterations in the patent system, such as compulsory licenses or decreased durations for patents, anticompetitive patent thickets would form as AIs spew out a never-ending stream of inventions.
            - It is not too much of a mental stretch to imagine an AI that maps out the full (finite) space of monoclonal antibodies, with its owner patenting them all and monopolizing the entire field of biotherapeutic medicine.
                - "You can have billions of antibodies, and maybe you can have trillions of antibodies, but not too many that a machine couldn't just sequence every possible antibody," says Abbott. "If you did that, and you published them online, that might prevent anyone from getting a new patent on a monoclonal antibody, which is the foundation of every patent portfolio of every biological drug that is generated."
        - In the other future, all goes smoothly, as the standard for inventiveness rises in lock step with the pace of invention.
        - "What patent law wants to do is encourage certain human activities, and the valuable human activity will be encouraging people to build increasingly inventive machines," says Abbott.
    - When posed with the question of whether AIs should be granted legal rights, Abbott believes not: "With animals, I think there is a much better ground for giving them moral rights, because animals have some form of consciousness and interests, although where that line is is hard to say. But an AI really doesn't. An AI can *behave like* a person, but an AI is not *like* a person: An AI is not conscious, it doesn't have desires; it just executes programming."
        - However, to the extent that AIs might come to improve human activities akin to how corporations enhance entrepreneurship and commerce, some legal rights for AIs might become appropriate.
    - Will the human inventor necessarily be left behind in either scenario? Perhaps not, since people will also have the benefit of AIs' contributions, just as search engines, for instance, have increased the scope of prior art that a patent applicant must consider today.
- More generally, the combination of a human and AI inventor might outperform the best in either category alone—but if the world of board games has a lesson to teach, maybe not.
    - First human experts could always beat a game-playing machine, but eventually machines took the upper hand at not only chess, but also at Go.
    - Then the combo of master human + machine outperformed either alone.
    - "On the other hand, the same year that AlphaGo beat the world's best Go champion, the chess engine Cryptic beat the world's best human + AI team, so at some point in this, people may just get in the way," says Abbott.

Transforming Art with Augmented Reality—Ms. Ginny Ruffner, Artist

- Seattle-based artist Ginny Ruffner views life is as a sequence of disruptions to mitigate, particularly since the monumental disruption she endured in 1991 when involved in a horrific three-car crash that left her in a coma for five weeks, a hospital for five months, and a wheelchair for five years.
    - Although still mobility-challenged and with a speech system unable to keep up with the pace of her mind, Ruffner is less defined by her physical challenges and more by the creative, resilient, and ever-inquisitive approach she takes to her art and to overcoming the disruptions that present themselves in that realm.
    - Ruffner takes TTI/Vanguard on a guided tour of her artwork—ranging from public art to museum environments and exhibitions—as she expresses herself in glass, metal, pop-ups, and in combination through augmented reality.
    - Each project presented Ruffner with obstacles; for each, she rose above them to instantiate her optimism in physical or/or digital form, often botanical and with no small sense of whimsy.
- *Urban Garden* (2011)
    - At the corner of Union Street and 7th Avenue in downtown Seattle stands the 27-foot-tall metal flowerpot from which sprouts a daisy, tulip, and bluebells, all of which are kept perpetually moist thanks to a self-tipping watering can.

        - Of course, the Seattle weather does a pretty good job on its own of keeping things moist, plus metallic flowers that variously spin and open/close might benefit more from a bit of WD-40 than water, but each two-gallon dump of water is diverted to give life to actual gardens elsewhere on the Sheraton Grand Seattle property.
    - The principal challenge Ruffner faced when designing *Urban Garden* was in the form of setbacks from overhead electrical cables, causing her to alter the structure into a taller, more upright form than was her initial intent.
        - In the end, the change proved advantageous, reducing the propensity for "extreme play" on the sculpture, although the need remained to design in protective constraints:
            - Sensors on the moving elements stop the cable-and-pulley motion of a flower or can if someone is hanging from it.
- *Oasis* (1993)
    - The Phoenix Arts Commission enlisted Ruffner to enrich what had been a barren bit of the campus of William T. Machan Elementary School into a colorful, shade-providing, inquisitiveness-provoking bit of child-focused public art.
        - Ruffner infused the project with cultural relevance by enabling the superposition of maps of native lands on an extensive tile mat.
        - Although colors have faded somewhat in the intervening decades, Ruffner met the challenge of creating outdoor artwork that could withstand the harsh desert elements over the long haul, although the technological elements are no longer active.
- *Mind Garden* (2000)
    - Moving indoors, this museum exhibition stressed Ruffner with a need to fight gravity: The Seattle Art Museum (located across 1st Avenue from the Four Seasons Hotel), presented the artist with severe weight restrictions: Nothing hung from the ceiling could exceed two pounds.
    - Her solution was to augment the wall-mounted and floor-grounded sculptures composed of glass, steel, and bronze with hanging elements created entirely from dried roses.
        - The petals from 50K freeze-dried roses had an effect that was more than simply visual: "It's the best-smelling exhibit I have ever seen!" says Ruffner.
- *Possession of Creativity* (1990)
    - This 9' x 9' x 18' installation at the Renwick Gallery of the National Museum of American Art featured a steel tornado with 1000 glass drops, which glimmered in the combination of natural and applied illumination.
    - The finished product belied the security and structural challenges of installing the piece.
        - With the museum situated practically within spitting distance of the White House, each member of Ruffner's installation team had to undergo a security check.
        - Moreover, given that the Renwick first opened its doors as an art gallery in 1874, the building is ill-equipped to accept a piece of the physical scope of *Possession*, which had to be brought in through the front door and hauled upstairs manually.
        - Finally, steel and glass—being heftier than rose petals—required careful support from tensioning wires anchored in the ceiling and walls of the gallery.
- *Aesthetic Engineering* and *Poetic Hybrids* (2015)
    - During Ruffner's time as a visiting artist at the Institute for Systems Biology in Seattle, she had the pleasure of exercising her geeky side, but without the constraints of scientific rigor; that is, she could invent, design, imagine, and hypothesize, but when creating art she could wander outside the bounds of truth.
    - In the natural world, evolution is a slow process and only members of the same species can breed, but genetic engineering breaks this mold by permitting cross-species—and even cross-kingdom—gene sharing; Ruffner riffed off of this by imagining all manner of plant–animal hybrids and even plant–inanimate-object/phenomenon hybrids, such as *When Lightning Blooms*, which was inspired by the question of what lightning would look like and smell like were it to bloom, and how long it might last.
- *Melting Evolutionary Theories* (1989)
    - Although Ruffner's excursion into the domain of scientific research was but five years ago, even before her accident she was exploring the origins of life, as in this two-foot-tall work in hand-blown and hand-painted borosilicate depicting several takes on origin stories: Adam and Eve, the snake, a chicken (crossing the road), all perched on a dinosaur skeleton.
    - Here Ruffner's challenge was to meet her self-imposed goal of creating such a large sculptural glass piece.

- *Creativity* (2003)
  - This mixed-media museum installation featured a series of six large gold frames, each with an even larger structural element—head, arrow, chain, flower, trap, heart.
    - Her artistic goal was for the viewer to "contemplate art, life, and creativity."
    - To help guide the viewer, Ruffner created a companion pop-up book with a 3-D paper-and-word element associated with each component of the installation in lieu of a conventional exhibition catalog.
- *The Imagination Cycle*
  - This unending pop-up book solved the problem of perpetualism: "The challenge was to print both sides of the page and make a book that was unending," says Ruffner. "When you get to the end you have a whole new set of pop-ups."
- *Reforestation of the Imagination* (2018)
  - Ruffner's most recent large-scale work, created in collaboration with digital-media artist Grant Kirkpatrick, debuted at Seattle's MadArt Studio before enjoying an extended tenure at the Renwick Gallery for the latter half of 2019.
  - This sculptural scene of bronze-and-glass desolation requires viewer interaction to reveal life springing anew: When viewed through the camera of a smartphone or tablet with the Reforestation app installed, severed tree trunks sprout fantastical blown-glass flowers as the forest reimagines itself—just as human creativity can do when nurtured.
    - Ruffner provided woodgrain postcards—17 distinct versions—to the TTI/Vanguard attendees; each serves as a marker enabling a particular AR flower to bloom.
    - "This is free art," she says. "You can take it home and impress your kids."
  - Hardly a digital native, Ruffner has struggled along her journey to learn CGI and AR, but she has found it intensely rewarding.
- Next up for Ruffner is a 10' x 7' tapestry of the periodic table of the elements, where each element serves as the basis for an augmented-reality pop-up that illustrates a characteristic of that element or of materials more generally.
  - Examples: electron repulsion, superconductivity, combustibility.
- Thoughts on AR as an artistic medium:
  - Although AR art has an ephemeral quality, Ruffner remains unruffled by this.
    - "I don't worry about art going away," she says. "It becomes an opportunity to make more art."
  - Today's technology for viewing AR does not excite her, whether the form factor of headsets or glasses, on the one hand, or handheld smartphones or tablets, on the other.
    - Instead, Ruffner enthusiastically awaits the endgame of deviceless AR and VR.
    - "The devices get in the way," she says.

Music's New Hologram Touring Industry—Mr. Scott Ross, Eyellusion

- Fans develop true relationships with their musical idols, identifying intimately with singers and bands as favorite albums become embedded as the soundtracks of people's lives.
  - Grief sets in after a legend plays a final performance, whether because of death or retirement.
  - What a fan wouldn't give to see their favorite performer just one last time!
  - Scott Ross of Eyellusion is satisfying this emotional need for the fans of certain performers by applying the technology of Pepper's Ghost to the concert stage, carefully crafting an ersatz hologram of a deceased musician who appears in all their past finery, perhaps performing with remaining band members or with a current idol who also idolized the recreated star.
  - Ross's work in this area is rooted in his the expertise in cinematic visual effects that he honed while at George Lucas's Industrial Light and Magic and further refined after cofounding Digital Domain with James Cameron and Stan Winston, where, beginning in 2003, he poured himself into the HARD project (Human Animation Research and Design) of devising virtual humans.
  - His satisfaction deepens when sharing in the joy and engagement of fans communally gripped in exaltation while watching Michael Jackson dance, Tupak Shakur rap, or Frank Zappa get weird yet one more time.
  - Ross describes the technology of Pepper's Ghost and the taxing process of preparing for a performance, as well as sharing examples of his successes.
- Pepper's Ghost:

- This illusion technique, which was popularized in 1862 by John Henry Pepper, involves projecting an image onto a reflective surface that is simultaneously angled 45° from the projector and from the audience's viewpoint; to the audience, it appears as if the image is part of the on-stage action.
- Ross's setup differs somewhat, with a down-facing projector (these days, either an HD laser projector or 4K projector) aimed at a horizontal reflective surface that transfers to a carefully erected transparent screen angled such that the audience sees the image but not the screen itself; live performers remain visible on stage, but behind the screen.
  - An alternative setup dispenses with the projector and uses large horizontal LED panels in lieu of the reflective surface.
- The result is the illusion of the projected image and live performer(s) sharing the space.
- A principal challenge of a well-crafted Pepper's Ghost 3-D holographic illusion is to achieve complete transparency of an adequately sizable foil screen to create a convincing illusion; make it too large, or impinge too much breeze on it, and the integrity of the foil and the sanctity of the illusion becomes compromised.
  - "It is called a patented foil, but what is patented is the tension that can hold this very thin foil on a very large surface," says Ross. "That tension has to be such that you can't see it. Anytime you do a large-scale hologram device for the public, you have to license that foil from one of the three [patent] holders," such as Ventana 3D.
  - Foils larger than 8' x 8' become problematic, leading to a need to visually confine the virtual human, which places constraints on the choreography of the holographic performer.
  - Operationally, it is no easy feat to prepare on site for a musical performance that includes a holographic virtual human.
    - "Setup time is difficult," says Ross. "It takes two or three technical and engineering people to set the device up, and the frame is difficult to transport."
- Despite using holographic terminology liberally, Ross emphasizes that his illusion is actually Pepper's Ghost: "What it isn't is a hologram. You can't capture a hologram in a moving electronic image."
- The bottom line is that "for the average consumer, it works really, really well," he says.

- Intellectual property challenges of recreating a deceased performer:
  - As one might imagine, negotiations can be sensitive when dealing with the estate or family members of a dead performer.
    - On the one hand, stakeholders can care deeply about how the individual is presented to the audience; on the other hand, they can care deeply about monetary compensation.
  - Every musical performance also requires a sync license, which can be costly.
  - However careful planning might be, there is always the risk that fans or family members might be upset by some aspects of the recreated celebrity.
- The production process:
  - The deceased performer is created in pieces:
    - First is a body double, who is filmed dancing, playing instruments, or otherwise performing.
    - Second is a computer-generated head that is overlaid by another actor's lip-sync of the song or scripted words.
    - "We would put a green-screen helmet on the lookalike's head with data points to be able to track the person as they were moving, then create a CG maquette of the head, usually from a sculpture but nowadays from reference footage, and track that head onto the body."
      - Frame by frame, every changing expression, the position of every hair, and every shift of the eyes must be individually animated in CGI, guided by photography or videos of the performer captured during their lifetime.
  - For any deceased performer, a choice must be made regarding the age of the individual to project in the hologram.
    - "We feel as though the performer that we last saw and was the most iconic would be the best choice of the person to go on tour," says Ross, "because that is the person who lives on in our minds," although Steven Cherry thinks that Elvis fans might be more inclined toward the 30-year-old version than the 50-year-old.
- Snoop Dogg and Tupac Shakur on stage together at Coachella (2012):
  - In the leadup to Coachella, Snoop Dogg approached Ross with a request to assist him in creating something extraordinary for the audience, which would consist of "about 100K people standing in an audience, all on mind-altering substances."
    - "When this played, they actually thought that Tupac had come back!" says Ross.

- Michael Jackson at the Billboard Music Awards show (2014):
  - The fact that Jackson's estate is managed by the duo of his mother and an attorney made preparations for this show particularly challenging; "They have very different ideas of the way in which he should be presented," says Ross. "Eventually, a deal was struck, with the company paying Michael Jackson's estate $1M for a one-time use of his digital image."
  - Despite the high cost, the show—with its extraordinary performance value—was arguably worth the outlay.
  - "The integration of lighting and live-action material, with dancers appearing in front of the hologram as well as dancers that are similarly dressed or act in similar ways as the live-action dancers also in the hologram—to the viewers it will start to appear as though the hologram was live," says Ross.
  - Of course, credit goes to the Jackson body double, for he not only had to have a body type akin to the performer's, but also commensurate dance skills.
- Ronnie James Dio, European tour (2017); U.S. tour (2019)
  - Dio's widow approached Ross with a desire to reunite Dio's bandmates to tour again, with a holographic front man.
    - "It was an interesting process, because, in contrast to the Jacksons, we actually had a partner in Ronnie's wife, who was very supportive of the process," says Ross.
  - Dio's cousin served as the live-action body double, having studied the singer's prior performances.
    - Ross shot the cousin in high-definition digital video against a green screen, with the subsequently crafted CG head placed atop the body, and the lip sync was blended into the final product.
  - "This was the first time a hologram went out on tour with a live band," he says.
  - Upping the ante from the bare-bones Dio-plus-band performances of 2017, the 2019 tour was augmented by workaday theatrics of the modern concert experience, including a light show, explosions, auxiliary screens, and so forth.
  - Although the Shakur and Jackson shows were one-offs, the Dio tour led to increased interest in Ross's services.
    - "Now that we had a proof of concept," he says, "pardon the pun, but dead people started coming out of the woodwork."
- Frank Zappa (2018):
  - Ahmed Zappa, Frank's son in charge of the Zappa estate, was one of these excited family members, who along with Ross and past members in the Mothers of Invention created "The Bizarre World of Frank Zappa" tour.
    - True to the tour's title, Frank was sometimes presented as an in-the-flesh guitarist, but sometimes as an animated character, such as a penguin, nun, or piece of dental floss.
  - When it came time for the performance, Ross and his creative team were caught off guard by the audience's reaction: "All of a sudden there were these dyed-in-the-wool Frank Zappa fans, and all they wanted to do was make fun of what we were doing."
  - Still, reaction was quite positive overall, with fans appreciating the hologram-plus-band performance, even with the alternative option of attending a (literally) live show in which Frank's other son Dweezil would play songs from his father's repertoire.
- Upcoming projects:
  - Jerry Garcia rejoining his band on tour;
  - Kiss tour with at least some of the bandmembers preconstructed—they might all be alive, but not necessarily so lively anymore;
  - Expanding on the Snoop–Tupac concept, Ross has been approached by other current stars wishing to perform with their deceased idols, such as John Mayer having Jimmy Hendrix join him for one song in his live set.
- Although Ross finds the recreation of dead people the most satisfying aspect of this work, other opportunities have arisen:
  - Advertisements, in which an in-demand spokesperson, such as Michael Jordan for Nike, could seemingly appear live in retail spaces:
    - A body double—even one of moderate height—could be paired with a proportionately sized CGI head and projected as a Pepper's Ghost to entice sales.
  - Distance learning or in-class teachers, in which a hologram of a world-class instructor could appear, engaging students more than a simple video presentation might.
    - "A video is nowhere near as impactful in so many ways," says Ross, although this only pertains for live presentations/performances, where the person truly appears to be present on stage.

    - Political speeches, notably Narendra Modi appearing holographically in simultaneous instances to get his message out across multiple locations: “Modi showed up in 1000 holograph appearances, covering 814M voters,” says Ross. “As a result, he wound up winning the election in a landslide. The ability to get your message out in a very unique way is very powerful.”
- Ross’s implementation of his technology is good enough for him to say, “I think we’re getting closer to crossing the uncanny valley. There are secondary animations that could be added, but I think we pretty much have hair and skin tone and eyes down, and that is the most critical part.”
- His whole endeavor raises the question of who owns one’s digital identity.
    - Presumably during life, it is one’s own possession, but what about after death, particularly for nonfamous people who might not have given thought to preparing for this eventuality?
    - Digital Domains’ Digital Humans Group is launching Facebank, with an intention of digitizing every person on the planet, with each individual sharing their digital rights.
        - “The ability to use the digital likeness and manipulate it would be held by either the estate or the person and in conjunction with this company, Facebank,” says Ross.

Storing Digital Data in Synthetic DNA—Dr. Karin Strauss, University of Washington

- It is hardly news that global data generation has far outstripped digital storage capacity.
    - Using DNA as a medium for archival storage, Karin Strauss of the University of Washington—in a joint project with Microsoft—is adapting biotechnology tools in an effort to level the playing field.
    - Although the theoretical maximum is two bits per nucleotide, taking into account overhead for error correction and per-strand labeling, she estimates that storage density of one bit per base is a more practical target.
    - Strauss describes the process of encoding data into DNA, tagging each 150–300-base data packet appropriately, storing it, and later retrieving and decoding the stored data; she also suggests an application involving computation over DNA-stored data.
- Still, the ability to store data in DNA would be little more than a parlor trick were it not practical for real-world uses.
    - Con:
        - Speed—Given that each step involves wet chemistry, DNA data storage and retrieval takes many orders of magnitude longer than with conventional magnetic storage technologies—hours instead of nanoseconds.
            - Although optimization will generate improvements, it will still be slow.
            - The Carlson Curves portray the extraordinary pace of acceleration of DNA sequencing technologies, and synthesis is accelerating at a pace akin to Moore’s Law.
                - “The reason writing is not growing as quickly as the reading of DNA is not a technological issue; it is more of a financial-motivation issue,” says Strauss. “Writing DNA is fast enough and cheap enough for the life sciences industry. If we want to use it for data storage, we are going to have to improve that, as well.”
    - Pros:
        - Density—The density of DNA storage is commensurately larger than conventional hardware, with a terabyte fitting into a mere droplet, rather than a hard disk drive, and “an exabyte would fit in the palm of your hand,” says Strauss, rather than requiring a couple of Walmart stores-worth of cold storage.
            - “Even if ignoring the overhead [for metadata, spacing, and redundancy], it has 1000-times better storage density than any other technology that is deployed today,” she says.
        - Durability—Under proper storage conditions, DNA can be maintained in a nondegraded form for hundreds of years or longer; fossils provide a natural proof of concept.
            - “Creating the right conditions to preserve [DNA] is pretty easy, because you can pack it in a very small volume and then create those conditions only for that small volume,” says Strauss.
        - Persistent data accessibility—Throughout the history of computing, storage media have come and gone; you might have a 5.25" floppy disk, but do you have a drive with which to read it? Technologies to encode and decode DNA will continue to evolve going forward, but the storage medium itself will never become obsolete; after all, DNA is the most studied and most important biomolecule.
            - “The medium doesn’t change, and we’ll always have readers to read the information back.”

- Although nature devised DNA as a storage medium for the code of life—complete with read, write, and error correction mechanisms—synthetic DNA, entirely divorced from its biological role, can be used to store data of any sort.
  - With four bases—A, C, G, and T—each can be mapped to a pair of bits (e.g., A = 00, C = 01, G = 10, and T = 11).
    - "Every two bits become one of the four bases, so you can easily translate one to the other," says Strauss.
  - An end-to-end DNA storage system entails six steps:
    - Encode binary data into an electronic file that specifies the ordering of nucleotide bases.
      - To make the overall process reliable, each sequence is limited in length to the digital equivalent of 15–30 bytes.
      - As such, a digital file to be stored must be divided into small units, each of which is mapped into letters of the genetic code.
      - "Since all of the molecules will be put into the same mix, to identify which piece belongs to which part of the file, we have to add a sequence number," says Strauss. "This is no different than adding a sequence number to floppies or any kind of media where the data won't fit into a single unit of that storage."
      - Then, to identify the file to which all such strands belong, a few additional bases are added to serve as a file ID.
      - Finally, for subsequent error correction, a portion of the bits encode a hash of the payload.
      - In all, roughly half of the bases encode data, while the remaining half constitute overhead.
    - Synthesize (write) that sequence in molecular form.
      - The synthesis step translates the encoded strand from the electronic to the molecular domain, using an iterative, three-step process:
        - Addition, which adds the next base in the sequence; oxidation, which strengthens the bond; and deblocking, which readies the working end of the strand to accept the subsequent base.
        - "The bases are added one by one, but obviously you don't do this one molecule at a time," says Strauss. "You do this in bulk, using the method of array synthesis, which grows the molecules in parallel."
          - Not only can array synthesis generate diverse strands simultaneously, it also grows multiple copies of each strand type. "You get redundancy for free from the synthesis process," she says.
    - Preserve the encoded strands in silicon nanoparticles for long-term storage.
      - After removing the DNA strands from the growing surface, they are encapsulated in a glass encasement to separate them from environmental elements that could degrade them.
        - Strauss notes that DNA preserved in this way should have a half-life of 500 years.
          - "If you put in enough redundancy—and it's easy to put in redundancy because of the processes and the superhigh density of DNA—you can expect that the DNA will last for quite a while: hundreds of years, thousands of years," she says.
      - "Once the encapsulation is done, all these molecules that were synthesized together are placed into what we call a DNA library, which is like a tape library except much smaller," says Strauss.
    - Sequence (read) each strand to recover the order of bases expressed electronically.
      - Strauss relies on an optical reader to find the molecules pertinent to a particular data file.
      - Recalling that in double-stranded DNA, A always pairs with T and C always pairs with G, and that DNA replication proceeds from the molecule's 5' toward its 3' end, reading takes place by sequentially adding differentially fluorescing bases and spectrometrically observing the color of each new base as it joins the developing complementary strand; ultimately decoding the observations into the complementary sequence.
        - "We know that all the T's are tagged with green, so exciting those molecules and essentially taking a picture of what is going on on the surface where the DNA is attached, we can detect the fluorescence and therefore that there is a T attached there," says Strauss. "Therefore, what is on the other side must be an A. Then the process is repeated: The fluorescent group is removed with chemicals, and a new base is added, this time with a different color, so we can tell that the next base here is a C."
      - Current technology for reading DNA has been developed for purposes relevant to the life sciences, rather than for data storage; as such, to minimize contamination, each read destroys

the molecule involved. This need not be the case, and once DNA storage is deemed economically viable, technological advances should both accelerate the write and read times, and retain the synthetic DNA for future reads.
    - Nevertheless, the high density of DNA and its inherent ease of replication sidestep any drawback associated with destructive reads.
    - "It seems easiest, at least at this point, to copy first, so you have multiple copies. You take one copy out, you read it, and it is okay if you have to throw it away, because you have the other copies," says Strauss.
  - Decode the bases into binary form.
    - The process of indirect-observation reading is prone to errors, which require correction during decoding.
      - To begin, Strauss groups similar reads, which likely originated from the same portion of the stored file—but which of the various options is correct?
    - The use of trace reconstruction methods, which she describes as "essentially, majority voting on steroids," provides the likely sequence of the molecules initially stored away.
    - Finally, base-encoded tags are used to reorder the sequence, and each encoded molecule is decoded into binary form to recover the original file.
      - In the event that, after reading, some segments of the file are missing due to unrecovered molecules, planned redundancy comes to the rescue.
- Innovations and applications:
  - Encoder/decoder system—Strauss has used this process to encode/decode 1-GB files in synthetic DNA for a variety of data types—text, images, video, music, databases—with perfect fidelity.
    - "If you can store something in bits, you can store that same thing in DNA," she says.
  - Automation of the end-to-end process—Conventionally, handling liquid materials associated with DNA synthesis and sequencing involve considerable human intervention.
    - "Today, the reading of DNA is automated and the writing of DNA is automated, but everything in between—storing the molecules and preparing the molecules for reads—is all done with people pipetting DNA and other reagents around," says Strauss. "We wanted to show that it's possible to automate the full process."
    - Her three-part prototype apparatus entails an automated synthesis contraption consisting of a bottle for each type of base, plus bottles for a few other reagents, with tubes and controllers to facilitate programmatic mixing; a storage container for dried samples of synthesized DNA; a molecule recovery chamber in which samples are rehydrated and prepared to be read; and a handheld sequencer.
    - To facilitate and control the movement of liquids through the apparatus, Strauss uses digital microfluidics techniques, where a distinct voltage can be applied to each pad on a circuit board; done in an appropriate manner, the differential voltage can induce a droplet of water—sandwiched between the pad array and a sheet of cover glass—to deform and thereby move in a desired path.
      - "You can move droplets, merge droplets, split droplets, heat them up, or cool them down," says Strauss, "to automate all the processes in between [synthesis and sequencing] on a programmable platform."
    - "We wrote the word *hello* in DNA and were able to recover it on the way out," says Strauss.
  - Once the prototype system matures into an end-to-end system in a commercial datacenter, not only should it be possible to do storage, but also to compute over the stored data.
    - Example: search over a database of images:
      - First, for each image in the database, extract feature vectors; then have a neural network map those feature vectors into sequences of DNA.
        - "For similar images, those feature vectors will look similar to each other," says Strauss. "Then we will store the molecules [encoding the feature vectors]."
      - When presented with a query image, first extract its feature vectors.
        - "Then we will run it through our neural network, and it will give us something that will look like the other images that are similar," says Strauss. "However, 'looking like' doesn't give us any properties. What we have to do is invert it all, so where we have a C we will invert that representation into a G, and A's become T's, so that when we dip this sequence into the mix that represents our database, it will stick to images that are similar."
      - To retrieve the resulting double strand, Strauss proposes to first tag the single strand with a magnetic nanoparticle, such that "we can fish them out with a magnet."

Banking, Blockchain, and the Future of Telecommunications—Mr. Francis McInerney, North River Ventures

- Thinking big is the stock in trade of Francis McInerney of North River Ventures, so it is worth listening when he forecasts the end of the banking, electric utility, telecom, and petroleum industries as we know them.
  - His ruminations kicked into high gear after learning of two patents, each in distinct fields.
    - One, owned by OmniMesh—entitled "method and system for managing mutual distributed ledgers in a system of interconnected devices"—proposes putting blockchain on mesh-networking devices, enabling each such device to act as a server and for all such devices to collectively act as a massively distributed datacenter.
      - This leverages the flexibility accorded by the 1974 decision by the Federal Communications Commission (upheld by the Supreme Court in 1976) to permit users of the telephone network to attach their own devices to it.
        - Devices now are not, as they were then, merely plain old telephones, albeit creatively colored or shaped; they are instead anything with a wireless antenna and a processor.
        - That is, the reach of this patent is staggeringly broad—perhaps too broad to hold up, considers Ike Nassi.
    - The other patent, credited to Michigan State University professor Richard Lunt and his student Yimu Zhao, is for "transparent luminescent solar concentrators for integrated solar windows"—that is, a solar panel that could double as (or overlay) a window without impeding the view.
      - Given the expanse of glass surfaces—from windows on high-rises to the screens of digital devices, this invention suggests an unobtrusive new source of electricity.
  - Each invention has the potential to be impactful, but McInerney considers them in tandem as he lays out the "evisceration of four of the world's largest industries":
    - "We'll be using our machines and windows, and I will show you one of the most massive shifts in economic structure since we learned to mumble. Keep in mind that the amount of money we could see today affected by this is something between $8.5T and $11.5T a year in sales, and that is just in the four sectors I am going to discuss," he says. "Drop this model on all other sectors, and you will see just how big this can become."
  - He lays out his case.
- Blockchain on mesh-networking devices:
  - The FCC's 1970s decision not only invited non-Bell-provided devices to join the network, but it also did not limit the power or type of those new devices nor, importantly, the software that might run on them.
  - OmniMesh's patent taps into this opportunity: Not only does it take advantage of the long-recognized benefits of mesh networking—notably, reducing the cost of network infrastructure by offloading connectivity to externally owned-and-operated resources, like WiFi, that exist outside the common-carrier network—but extends the potential for those who provide resources to monetize that activity on a newly massive scale through the use of blockchain.
    - "They proposed using blockchain on their mesh devices to allow people to buy and sell storage and processing power," says McInerney, "making a fully distributed datacenter very economic."
  - "This patent is the biggest event in wireless since Marconi," he continues.
    - Since 1877, when the Bell Telephone Company incorporated, the business model has remained largely unchanged—"We pay our monthly bill and get our service," says McInerney—but now "the polarity of the network" is set to reverse as the flow of money inverts.
    - That is, he predicts the evisceration of the telecom industry (which has always relied on subscription income to finace the expensive work of erecting and maintaining infrastructure).
  - Although when McInerney first heard about this patent—which was granted by the United States on October 1, 2019—it was in the context of the datacenter application, upon reading it he recognized its much broader applicability.
    - McInerney has always had an intellectual fascination with money, and recognizes that acceptance of any monetary system relies on trust: "Establishing trust, so that businesses and people can transact—locally, globally—is immensely difficult to do," he says. "All of a sudden, with this patent, we now have an edgeless fog of minibanks that inflates at the rate that the cloud inflates. We have, for the first time since [the Bank of England was formed in] 1694, a new form of money."

        - Recall that the formation of the Bank of England established, for the first time, a process for managing debt as an intangible asset—that is, money—which itself serves as the basis for not only all transactions (whether by cash, wire transfer, check, credit card, Venmo, or otherwise), but also all business models.
            - "Amazon is simply layering a server concept and a warehousing concept on a monetary base," says McInerney.
        - This patent stands to fundamentally change the relationships of commerce, and thus commerce itself—and, as he says, "It is not only the structure of the business models, which will have to change, but now we have fundamental questions about the nature and form of money itself, but what is critical is that money, regardless of its form, must be measurable and manageable."
    - The nature of banking as an institution is under threat by this patent, and, "because there is so much money at stake," McInerney does not believe that lobbying efforts by the banking industry will carry the day, with so many others striving for a piece of the economic pie, particularly given that this will not only be a U.S. phenomenon:
        - "Last week, [OmniMesh] just got the go-ahead to globalize the patent to 150 countries," says McInerney (although the very breadth of the patent might render it unenforceable).
    - That is, he predicts the evisceration of the banking industry.
- Solarization of the invisible parts of a window:
    - Lunt and Zhao's patent enables any window to continue with its customary function of enabling people inside a building to view the outside world while letting light in unabated, but now with the added benefit of generating electricity as it does so.
    - The consequence of widespread application of this new solar concentration technology would be to establish real estate owners as electricity producers.
        - "If you transformed the business model of all property developers and property managers from their classic role of renting square feet to pulling solar energy off windows, how much money is that?" poses McInerney. "You don't have to have all that efficient a conversion rate to make a stink-load of money on your building"—if only there were a means to monetize it.
    - This is where the two patents have the potential to interplay synergistically.
- The multiplicative effect of considering the two patents together:
    - McInerney's focus thus far has been on the potential of the OmniMesh patent to render every phone a bank, thus upending the banking industry, and on the potential of the window-solarization patent to establish every owner of real estate as an electricity producer.
    - Combine the notion of the pocket minibank and the literal powerhouse, and an unprecedented disruption could befall all manner of establishment industries.
        - "We now have a technology that will let us convert, on a massive scale, solar energy off windows all around the world, arbitrage that energy on the cloud, and make staggering sums for landlords and property owners," says McInerney.
            - Notably, as opposed to engaging in the "cryptononsense" of speculative trading in Bitcoin and the like, these solar-based electricity transactions would involve "real money for real things."
    - The impetus for landlords to solarize their windows might be to make a profit in a new way, but the societal consequence will be large and positive—nothing less than to move civilization away from its long-standing carbon dependency.
        - "This is the green new deal that pays for itself," says McInerney. "How much better does it get than that? That is an inflection point in the history of humanity!"
            - This new paradigm would elevate carbon-free electricity above conventional production, without even a hint of taxpayer subsidy.
        - That is, he predicts the evisceration of the electric utility industry (which, like telecom, has always relied on ratepayers to underwrite the expensive work of erecting, maintaining, and managing its infrastructure).
            - This would literally shift the balance of power, as electric utilities no longer need to generate the flow of electrons, but instead manage that flow and store excess capacity for subsequent use.
    - The petroleum industry is similarly at risk as this self-funding green new deal permanently depresses the price of oil due to low demand.
        - Historically, "the oil-and-gas-and-coal processing industry" has successfully lobbied Washington to secure its own survival, but will it be able to do likewise with equally powerful real estate interests lobbying against it?

        - "The money the property owners will make overrides all other interests, and they will not let some oil-and-gas company get in their way," says McInerney.
    - That is, he predicts the evisceration of the petroleum industry.
- Put it all together, and just these two patents could put "a lot of people, a lot of money, and a lot of capital all at massive risk."
    - "We have four of our world's biggest industries imploding, and one of our world's biggest industries exploding," says McInerney, but that is not all. It is only a matter of applying one's imagination to envision other sectors that will benefit—or go bust—in this nascent world of unleashed opportunity.
        - "I know all of you will come up with dozens of new spaces that will open, offer opportunity, and—for many of you—gigantic new careers," he says.
- Nassi pushes back on McInerney's thesis, however, noting that decentralization has already been tinkering with all of these industries, and they all remain rather healthy despite mesh networking (which Nassi first addressed with TTI/Vanguard in July 2002) and resource-sharing having been around for decades, solar panels on roofs and concentrated in solar farms similarly feeding electricity back to the grid, and the like.
    - "I'm struggling to put what you are saying into some coherent whole," says Nassi, to which McInerney answers with dollar signs:
        - "The difference here is the money. If we can unleash money in sufficient volume, mesh networks suddenly become a different reality, and already, with solar on the roof, the Germans are having very big problems with the grid," with McInerney relating concerns surrounding production beyond what their grid can manage.
    - Moreover, as solar penetration expands—whether with more solar farms, more rooftop solar, or deep adoption of solarized windows, as McInerney predicts—grid infrastructure will have to expand its tendrils to incorporate all the new producers.
        - As one TTI/Vanguard participant puts it, "The whole issue of microgridding is going to create a new variant of wires and pipes as you build out the grid."
        - Again, McInerney sees it all coming down to money: "The question of where the payments flow, and who subsidizes whom for what, is a big one. Every grid manager has struggled with how we manage this."
    - Whether considering solarization and grid management or mesh networks, McInerney remains convinced that these patents point to a definite direction of change—and, in the case of mesh, that that direction could well benefit Nassi considerably, given the mesh-networking patents he personally holds.
        - "Your early innovations could prove to be valuable," commends McInerney, "but if there's no money in mesh, it's not happening."

Transportation, Information, and the Future of Cities—Mr. Benjamin de la Peña, Seattle Department of Transportation

- Although the details of how people get around in a city are ever-evolving, the principal modes of transportation tend to settle in for the long haul, whether autos, buses, bikes, subways, light rail, etc.—oh, and don't forget the option to walk.
    - Once infrastructure is built out to accommodate a particular mode of transportation, reliance on that vehicle type becomes entrenched.
    - However, the pace of general technological innovation is making inroads into the urban transportation sector.
    - Benjamin de la Peña, formerly with the Seattle Department of Transportation, was integral to the 2017 development and publication of the "New Mobility Playbook," a functional plan that explores policies, strategies, and practical measures surrounding the city's preparations for new transportation technologies and those still over the horizon.
        - The Playbook readily acknowledges that new transportation technologies will come into being, while also recognizing that their characteristics will not be known before they emerge.
            - The city must enable its department of transportation to be able to manage innovation and the data that will accompany it, while always being mindful of potential impacts of any new technology and structuring its adoption to align with the values of the citizens, which for Seattle includes safety, equitable access, a people-first ethos regarding rights of way, and so forth.

        - "The basic premise of the Playbook is this: We don't know what technology is going to come, but we do know what kind of city we want," says de la Peña, "so focus first on the kind of city we want, and technology has to adapt to that."
            - This philosophy is in direct opposition to the car-centric way cities throughout the United States have developed over the past century, which has led not only to debilitating traffic congestion, but also to many of the social inequalities that have come to plague cities.
    - De la Peña focuses his thoughts primarily around two of the five plays in the Playbook, namely the need to "reorganize and retool the Seattle Department of Transportation to manage innovation and data," and the need to "build new information and data infrastructure so new services can plug-and-play."
        - That is, instead of zeroing in on each new way for people to get around the city, attention would be directed toward new ways that users receive, understand, and send information, with the understanding that a well-developed information infrastructure will better integrate each new component of the transportation infrastructure.
- Of the possible leverage points a system might have, those most aligned with information acuity are:
    - "Constants, parameters, and numbers"—i.e., things that can be measured.
    - "The structure of information flows"—i.e., who does/does not have access to information.
    - "The goals of the system."
    - "The mindset or paradigm out of which the system—its goals, structure, rules, delays, parameters—arises."
- Information possesses the power to shape the system to which it pertains; therefore, applying these information-relevant leverage points requires the utmost of care to avoid causing or perpetuating injustices.
    - Example of the use of information to suppress a facet of the population: Redlining.
        - In the 1930s, the federal government's home loan program collected municipal-level data to determine high- vs. low-risk regions for lending.
            - "Guess what was the data they used to define whether a community was risky or not," poses de la Peña. "Race. The more white the community, the safer it was to lend to it; the more mixed it was, then it was riskier. Anything that was defined as 'hazardous' had nothing to do with the kinds of businesses that were, or the civic or social infrastructure of the place."
            - The consequences of redlining were severe: People in minority neighborhoods were unable to get a loan to purchase or improve a home, businesses there could not borrow to invest, and governments were not about to invest in infrastructural improvements in hazardous districts.
                - That is, "Racism was taken to an informational level," he says.
        - And the effects from decades ago carry over to today:
            - The most obvious outcome is persistently low home values.
            - Another was revealed in a recent study, which indicated that the average temperature differential between formerly redlined and nonredlined neighborhoods in the same city is about 10°F; only in nonredlined regions did cities invest in green infrastructure, whether parks, lawns, or tree-lined streets.
                - "I'm sure you can understand what this means in a warming world," says de la Peña.
    - "Level of service"—defined as the number of vehicles that can traverse a length of road in a given time—has been used as a city-shaping metric.
        - Highways, with interchanges rather than intersections, enable vehicles to cruise along at high speeds and thereby optimize level of service, but de la Peña emphasizes that slower roads—i.e., failing roads, by this metric—are safer for people.
            - "The highway system, which was supposed to be intercity, began to be rammed through cities," he says. "and guess where they rammed the highways within cities? The redlined communities. Why? Because there was poverty there."
            - The focus on a system goal of increasing transportational level of service had the direct consequence of disrupting the social infrastructure of already compromised neighborhoods and perpetuating institutional poverty and segregation—injuries that redlining had already inflicted.
    - "So what you measure and how it is propagated through the system created these kinds of problems for us," says de la Peña.
- With the New Mobility Playbook as a guiding document—and following the example of work done in Copenhagen—Seattle undertook its first-ever citywide public life survey in 2018 with a goal of discerning the "social performance of the streets."

- De la Peña explains in terms of the previously stated leverage points:
  - *Constants, parameters, and numbers*:
    - "Up until cars, streets were vibrant public spaces," reminds de la Peña, with pedestrians, horse carts, handcarts, bicycles, streetcars, and so forth, moving every which way, and doing so safely, devoid of traffic controls.
      - In contrast, in most cities, the only uses for streets are "vehicle conveyance and vehicle storage"—again because of elevating the importance of level of service and thus measuring only that.
        - Even Seattle, which is a more bike-friendly city than many in the United States, has only 12 bike/pedestrian counters, compared to more than 300 traffic sensors.
      - When measurements emphasize the components of urban life that citizens care about most, the system can align with those values.
      - Seattle's survey countered the prevailing myopia by assessing the wide range of potential uses of streets in the modern day.
        - "Are people meeting there? Are people shopping?" poses de la Peña. "Hopefully [the new information] will shift some of the dialog and the goals of the system."
  - *The structure of information flows*:
    - The pace with which a type of information moves within a system is inversely related to the power associated with that information.
      - In the context of a city, planning documents are created over any years and are then used to guide municipal actions for many more; they are powerful but slow.
      - In contrast, data changes quickly, but is only briefly influential when it is collected and disseminated in close to real: "Information about emergencies and incidents will change the way you are travelling for a particular day, because you have to avoid that particular area of traffic," says de la Peña, "but it doesn't change the whole system."
      - Between these two extremes lie reroutes (e.g., related to road work), schedules (e.g., for public transit), and routes (e.g., one-ways, signal placements, and the roadways themselves), each with an increasing degree of permanence.
    - "The first thing to do to improve the information flow is to map the information flow," he says, including considering the format of information at its point of storage and at its point of use, and to make them conform.
      - Pro tip: Don't store actionable information/data in PDF reports, which only create friction. Instead, "If you are building a new permit system, it needs to be able to spit out this kind of information, because the user on the other end needs that kind of information."
    - To elevate information that might improve the fabric of civic life, the DoT sought to expose the "hidden ecosystem of transportation information infrastructure," recognizing that "infrastructure is only infrastructure if other services can use it," says de la Peña.
      - Consider Waze: Each user is provided with a route from location to destination that provides the greatest personal benefit, without considering potential impacts on others.
        - We've all been there, as de la Peña relates: "If you hit a traffic spot, it will say, 'Turn right, then turn left,' without knowing that that road could be a purely residential street that gets filled up the moment there are ten cars there, because it is oriented not toward the system, but toward *you*."
      - In general, user-centric design helps the individual to the detriment of the broader system; other design systems to consider include those focused on counter-balancing, collective awareness, worker-centrism, relationships, the ecosystem, consequences, life-centrism, and issues beyond human-only needs.
      - Were all elements of the informational ecosystem to coordinate, the benefit would accrue to all transportation users.
    - The open-data initiative is a start to making information accessible to city residents, but too often that means releasing archival data, rather than the dynamic, real-time data on which to make actionable decisions.
      - "There is a reason governments are called bureaucracies," says de la Peña. "A lot of the work back then was about keeping files in bureaus. We're good at collecting information; we're pretty bad at actually releasing information"—or organizing and annotating information to make it understandable for those who might attempt to build a public resource atop it.

        - For instance, the Seattle DoT has had dozens of maps available to view through its website, but none rendered reasonably on a smartphone, much less was importable into the most widely used mapping apps.
    - It is time to stop treating data merely as a tool; it should be recognized as the asset it can be.
        - In the household context, a tool might be one of the several kitchen knives or screwdrivers; you know how many you own.
        - When considered as an asset, you track where each is located, who last touched it, its current condition, when it was last serviced, and the cost to replace it if needed; moreover, a permissioning system would enable access to use or maintenance only to authorized family members.
        - "We need to learn to treat data as an asset, so that there is a line of responsibility, understanding of what is important about all of these things, and a line of sight to all of these costs," says de la Peña.
        - One important asset in the transportation system is the network of road signs; de la Peña cautions that, as human drivers begin to share the road with autonomous vehicles, it takes surprisingly little visual perturbation to trick a driverless car into seeing a road sign as something it isn't (e.g., a yield sign as instead a 45 mph sign).
    - To concretize the scope of needs users might have of the transportation system—and how to address those needs—de la Peña's team created a set of ten personas:
        - Terézia and her children, who walk from home to take public transit;
        - Juanita, who delivers groceries on her scooter;
        - Warren, the tech employee who needs to know locations/times to catch the company vanpool;
        - Ali, who worries about traffic delays that could affect the commute to work;
        - Nida, a tourist who wishes to walk safely and pleasantly to interesting sites;
        - visually impaired Sarah, who needs to know how to transfer from one bus to another to complete her journey;
        - wheelchair-bound Omondi and her aide Jean, who need to navigate to the light rail stop via a wheelchair-safe route (i.e., relatively flat and with curb cuts and crosswalks);
        - young Mitul, who has a flat tire and needs to call his parents;
        - Tony, who just finished a cab ride but forgot his credit card;
        - Hyun, who seeks a shared bike that is available nearby.
    - The needs of each are different, as will be the particulars of the information that will best assist.
        - "What information do they need the moment they need it?" asks de la Peña. "We were not going to create another app; that was just the most ridiculous thing to do. What we needed was an information regime so that we could serve up this information to whatever layer they choose to get that information from."
            - That is, certainly the physical infrastructure matters to transportation, but so too does the informational infrastructure.
- *The goals of the system and the mindset or paradigm out of which the system—its goals, structure, rules, delays, parameters—arises*:
    - The informational infrastructure will only meet the goals of the city if it builds on the values its population holds dear.
        - Seattle, as a community and as a government, cleaves to the overarching goals for its transportation system of equity, safety, mobility, sustainability, livability, and excellence.
            - De la Peña notes that it took a nine-month-long process to arrive at this set of goals.
                - "We looked at the history and asked, 'What are the usual things we have said we are responsible for through all the old processes?,' and we brought it to as many people on our staff as we could, and asked, 'Which of these things are important to you?' Then we drafted it, and brought it back to people [for review]. We knew that not everyone was going to be completely satisfied, but everyone needed to be heard."
        - Chief among these are what de la Peña describes as informational imperatives: accelerate decarbonization, advance equity, protect privacy, and level the playing field economically.
            - To the last point, "Uber has said it wants to be the Amazon of transportation," says de la Peña. "Great—that might lead to more efficient services—but what if the next day [the company] folds? What happens to the city and the ability of people to get around?"
            - Still, the private sector can be a vital partner to public-sector activities.

        - Example: The private sector makes cars, but the public sector permits those cars, not to mention licensing their drivers, before they use the public infrastructure.
- De la Peña invites readers to visit his newsletter Makeshift Mobility, which tracks innovations in informal transportation.
    - In addition to his own publication, de la Peña recommends works by a variety of thinkers in this space:
        - Authors Steward Brand and James Gleick, both of whom have spoken in the past to TTI/Vanguard, as well as Donella Meadows and Douglass Allen.
        - Less formal writers Cassie Robinson, Rachel Coldicutt, Morgan Herlocker, Kevin Webb, and Bianca Wylie.

Epidemiology and Informatics, Dr. Dominic Suciu, G-Genomics

- The spread of the novel coronavirus might sometimes be referred to it as an invasion, but in reality, viruses were here long before people, or for that matter bats or even bacteria.
    - Virus-like life forms date back billions of years to the primordial soup, and the rest of life has evolved in response, including the development of virus-protection mechanisms that are integral to cellular and organismic survival (e.g., DNA-cleaving restriction enzymes, the CRISPR process, the cell nucleus, microRNA), some of which are at the heart of today's greatest advancements in biomedicine.
    - This is not to say that higher life forms and viruses have settled into a comfortable relationship.
        - "Cellular life forms came into a world in which there were viruses, and there has been a constant battle between us and them ever since," says machine learning G-Genomics-based bioinformatics researcher Dominic Suciu.
    - As COVID-19 ramps up into pandemic territory, Suciu provides insight into respiratory viruses in general, this new pathogen in particular, how viruses mutate from manageable to pandemic inducing, and actions that would mitigate the consequences of whatever the next debilitating novel virus might be.
        - He also offers a brief immunology primer and reveals the challenges of vaccine development.
    - At the time of Suciu's talk, reports were of 80K known global infections and 3000 deaths, with the Seattle area gaining notoriety as the U.S. epicenter of the outbreak; global numbers had more than doubled at the time of this writing and will have continued to escalate dramatically by the time you read this, with drastic measures being taken to control the disease's spread.
        - "Maybe I should have brought a sickle!" he quips morbidly.
    - More seriously, "My talk is going to tell you about what we should have been doing over the past ten years, what we should be doing in the future, and what we have to do now that we are in the middle of a pandemic," says Suciu.
- Respiratory viruses:
    - The common cold—that miserable feeling that stuffs up your nose or ears, makes one run and the others pop, causes you to cough and feel generally lousy—is caused by any of seven families of viruses, with each of those families encompassing thousands of distinct genomic sequences, amounting to more than 1M sequences in all.
        - However, the genomes of fewer than 600 have been determined through sequencing.
    - Of these seven families, Orthomyxoviridae (839K sequences; 11 sequenced genomes) and Coronaviridae (33K sequences; 52 sequenced genomes) are those responsible for pandemic outbreaks, whereas the remainder are largely responsible for mere seasonal annoyances.
- The importance of acquiring genomic sequences of viruses:
    - The genetic particulars of members of a family of respiratory viruses can differ considerably.
    - Looking at coronaviruses for their obvious timeliness, the genome of the virus that is now known to cause COVID-19 bears a striking resemblance to that isolated from a bat in China in mid-2019, dubbed Bat Cov RaTG13, with marked differences from the virus that caused the 2003 SARS epidemic or diverse strains sequenced from other bats.
        - Bats often serve as viral reservoirs, where pathogens lurk and evolve, causing no harm to their hosts before crossing over to the human population with less sanguine results.
    - Today's sequencing methods made it possible to acquire full knowledge of the novel coronavirus in just days, whereas puzzling out the SARS genome consumed several weeks and great ingenuity in 2003.

- "Now we have next-gen sequencing and have the ability to sequence millions of reads in a single run," says Suciu. "You don't have to know what you're looking for; you just put it in the machine and do it."
- "What do we do with sequencing data?" poses Suciu. "During a pandemic, we would use the sequencing data to develop vaccines and drugs, and during normal times what we would be doing is, hopefully, predicting these things before they come."
  - (More on vaccine development below.)
- Mutation is a natural genetic phenomenon and is particularly active in viruses.
  - The benefit of actively sequencing new strains of coronavirus is to trace the viral lineage throughout an outbreak.
    - "If you look at the sequence that patients have, you can create a picture of who got it first," says Suciu. "In Washington, they found that WA-2 is a direct descendant of WA-1. If you see a completely different sequence showing up in Washington, you will know that it might have come from somewhere else, and if you have sequencing data from around the world, you will probably know where it came from and what the chain of transmission was"—with policy implications and obvious benefits for epidemiology.
- But sequencing data also has much to offer during the long lulls between epidemics.
  - "During nonpandemic years, the sequence undergoes neutral mutations that don't really effect the [virus'] function," says Suciu, "but it diversifies the sequence space, allowing [the virus] to cast a very wide net to look for new forms to emerge as a new strain."
    - Many mutations have little effect, occurring in portions of the viral structure that do not appreciably alter its function or transmission.
      - "But, if you make enough of those [mutations], all of a sudden you make a brand new structure that might become relevant," says Suciu. "That's why, if you look from one pandemic to another, you see big changes in sequence and new structures that you didn't see before. Most importantly, they jump and take over the entire [viral] population."
  - "[A virus] uses those passive years when it is living in the animal population to create the diversity necessary to create entirely new forms that become the next pandemic," he says. "It is very hard to monitor that space.
  - The only way to gain the upper hand on the next debilitating virus is to continually sample animal populations.
  - Thus, it was not merely fortuitous that Chinese researchers had recently sampled and sequenced the close, bat-based viral relative of COVID-19; they had been following best practices of going out into the wild to add to the library of potential pathogens.
    - "This is what you are supposed to do when you don't have a pandemic," says Suciu. "Every five years or so there is a pandemic or minipandemic with a sequence that is dominant for a while, but the reservoir has the sequence of the next pandemic, and it is evolving over time."
  - But Suciu recommends taking the virus-sampling ball and running with it, suggesting the collection of anonymized, pooled samples of pathogens and sequencing them in batches.
    - "It needs to be massive, anonymized, and continual," he says. "You do not know what you are looking for."
      - Yet, there is a good guess where to find it: hospitals.
        - "Sick people tend to go to hospitals," says Suciu, who believes that HIPAA laws unnecessarily complicate collection and testing of patient samples. "You should not need consent to take a patient's sample that he gave to the clinic anyway and use it for whatever you want, so long as it doesn't break the privacy of the individual patient."
      - He suggests regular collection and sequencing of "really disgusting samples, such as everyone's snot for a week"—imagine the pathogenic riches to be mined!
        - "This would give you a view of what is actually flowing through the population over time, backwards," says Suciu. "This should be global."
      - In fact, Suciu did just this kind of work when at clinical diagnostic lab firm CombiMatrix, where machines would attract urban mosquitos, pool their blood, and discover the ambient bloodborne pathogens; researcher Eric Schadt got around the patient privacy challenges by collecting sewage samples and studied quite an array of enteroviruses.
        - "I guess there's no consent when you flush a toilet," says Suciu.
    - Witnessing the emergence of new viral features makes it possible to foresee the next dangerous pathogen.
      - "With a chain over time, you can see how this evolution is taking place," he says.

- Immunology and vaccine development:
  - The first line of attack in an immunological response are antigen presentation cells, which come in two forms:
    - One envelopes a putative extracellular microscopic invader in an acid-laden lysosome, where it becomes chopped up; proteins from the major histocompatibility group (MHC) enter the lysosome and migrate the antigenic components to its surface, where T cells either confirm them as "self" or condemn them as "nonself," triggering the development of antigen-specific antibodies.
    - "The second half of antigen presentation is the cell monitoring itself," says Suciu. "It's introspective."
      - Every cell has the capability of similarly encapsulating protein fragments within it, migrating the lysosome to the cell's surface, and enlisting cytotoxic T cells—killer T cells—to kill the cell if the T cell recognizes antigenic protein fragments.
    - An antibody or cytotoxic T cell can only respond to its specific antigen, but there is no a priori way to know which antigen a virus will present among the many it might code for.
    - "The reason vaccine development is so difficult and is so hard to predict is because you don't know which piece of viral protein is presented, you don't know which molecule—of dozens in each individual, and each individual has a different combination of them—will be doing the presenting, and you also don't know the shape of the T cell molecule that shows up and whether it will actually recognize anything," says Suciu. "This is not something that you can turn a switch on and get it to work."
      - In contrast, the firm Moderna Therapeutics seeks to generate immunity by bypassing direct detection of the virus-produced protein fragments; instead it "feeds the mRNA directly into the patient, the patient's cells produce the protein, and that might give you a sense of what might elicit a response in a more natural way."
- Suciu presents an analysis framework to gain maximal benefit from global pathogen monitoring:
  - Prediction—Observation of pathogenic mutations provides a heads-up before an outbreak.
  - Vaccine and diagnostics development—Observation of new viral features/proteins enables the development of assays or even vaccines prior to the disease jumping from the animal reservoir to the human population.
    - "If it does emerge, you know right away that you already have assays developed, and they are not that expensive to make," says Suciu.
    - A library of known antigens establishes a foundation for vaccine development: "This gets you to be ready with vaccines for relevant viruses when a new form comes out," he says.
  - Structure determination—In light of the growing corpus of data that connects sequences to structures, deep neural network models are increasingly successful at predicting the 3-D structure of a protein from the genomic sequence that codes for it.
    - "Having the sequence is not enough; it is also important to know what the structure is."
  - Iterate by using the output of structure determination to seed prediction.
- Steps to take to minimize pain during the COVID-19 pandemic:
  - In conjunction with the healthcare apparatus, governmental and industry leaders must take the helm to stop the pandemic, in part by keeping the economy going and not swamping the hospital system (which, in the United States, is shorter on per capita beds than most developed countries).
  - Leadership is necessary to protect the most vulnerable members of the population—the aged and immunocompromised.
    - At the time of Suciu's talk, there had been minimal guidance; at the time of this writing, national emergencies had become the norm, lockdowns were proliferating, the seriousness of the pandemic had been largely accepted, even by early naysayers.
    - "If you have any influence, caution is not a bad thing to be using at this point," he says. "If we had been monitoring, we would have been responding better to this pandemic."
- The greatest unmet need:
  - Suciu believes that the availability of simple, low-cost assays is vital to fighting viral outbreaks in particular and global health more generally.
    - "The future of global health doesn't cost $1000 per assay or even $50 per assay," he says. "The future of global health costs 5¢ per assay, but developing cheap assays like that requires an enormous amount of technology—a high-tech low-tech approach."
      - For instance, chips in home glucose monitors cost mere pennies, but "require a big vision."

        - "A lot of times the technology you need are throwaways from the semiconductor industry," says Suciu, "things that can be repurposed to do what you never would have designed it to do in the first place."
            - When at CombiMatrix, he repurposed decades-old chip technology—from a factory that was otherwise going out of business—to do DNA synthesis on an array.
    - Perhaps the pain of the COVID-19 pandemic will convince players in the biotech industry that enabling the resources to avoid future catastrophes is the right thing to do, or maybe they will recognize that even a tiny profit on a product volume that scales with the global population makes economic sense; either way, global health depends on the availability of cheap testing.
        - "The means are there, but the will is not there," he laments. "People want to see how much money they can make per assay, while the real money—and it's huge—is the volume."
    - Technologies developed for situations like the one we face today can also be repurposed to quell other public health calamities, notably the spread of antibiotic-resistant bacteria, both within the developing world and from there to developed nations.
        - Under-resourced clinics and hospitals might have stores of broad-spectrum antibiotics, but not tests to distinguish which medicine is best in a given circumstance; this leads to overprescribing and, in turn, the emergence of resistant strains, which pose a global threat.
        - And, speaking of the developing world, the Southern Hemisphere is poised for a heavy blow as COVID-19 plays itself out in the North and begins to hit less-resourced nations during their cooler months.
- Comparison of the contagion of new coronavirus and influenza:
    - Human receptors differ for various pathogens: receptors for most forms of influenza occur in the lungs, but for this coronavirus they are situated in the mouth—on the tongue and roof of the mouth—increasing the virus' contagion.
        - "It's all about how the virus gets into you," says Suciu. "When you are walking into a room in which there are viral particles, what is the efficiency of those actually entering your body? This is why it is so important to wash your hands and not get stuff in your mouth."
    - Were influenzas' receptors also in the mouth, the flu would spread more quickly and cause greater damage than it already does.

The Storm before the Calm: Beyond the Coming Crisis of the 2020s—Dr. George Friedman, Geopolitical Futures

- George Friedman, founder of Geopolitical Futures and author, most recently, of *The Storm before the Calm: America's Discord, the Coming Crisis of the 2020s, and the Triumph Beyond*, dissects the very notion of the United States of America as a nation, determining that it is—and always has been—a construction, forged from the deliberations of the Founders, who carefully tuned it to run resiliently.
    - That is not to say that it wouldn't need maintenance nor even occasional overhauls.
    - By studying the nation's history, Friedman has identified two seemingly natural periodicities of this machine:
        - 80-year institutional cycle, with three periods to date, each thus far circumscribed through war:
            - The first period began with the end of the Revolutionary War and the drafting of the Constitution in the mid-1780s and ended with the Civil War in 1865.
            - The second period proceeded through the end of WWII in 1945.
            - The third period is due to end within the coming decade.
        - 50-year socioeconomic cycle, with five periods to date, each thus far defined in terms of pivotal Presidents:
            - The first period began with George Washington (led the country from the Revolution, 1776) and ended with the conclusion of John Quincy Adams's term (1829).
            - The second period began with Andrew Jackson (1829) and ended with Ulysses S. Grant (1877).
            - The third period began with Rutherford B. Hayes (1877) and ended with Herbert Hoover (1933).
            - The fourth period began with Franklin D. Roosevelt (1933) and ended with Jimmy Carter (1981).
            - The current, fifth, period began with Ronald Reagan (1981) and is due to reach its natural conclusion with whomever is elected President in 2028.

- What is common to both the institutional and socioeconomic cycles is that their conclusions are brought about through turmoil, whether the culmination of a horrific war or a leader unable to match policies to a mounting crisis, followed by one with a novel approach that shifts the economic calculus.
  - The termination of either cycle does not portend a serene decade to come, and the confluence of the two cycles compounds the havoc; the turbulence of Donald Trump's presidency—and the forces that led to his election—are the opening acts of the impending transition.
  - However, history tells us that on the backside of this turmoil, once the shape of new institutional and socioeconomic fundamentals become apparent, American life should be prosperous and smooth—at least until the next period starts to play itself out.
- Friedman describes the long road that brought him to this way of parsing history and delves into the implications.

- In 1975, Friedman was teaching political philosophy at Dickenson College by day and designing war games at the U.S. Army War College, when he found himself in a bar with some of his military colleagues bemoaning the state of the nation, which had suffered, among other things, two assassinations, social upheaval with full-on domestic military response, and the resignation of its disgraced President—all over the course of the prior five years.
  - One of the Lt. Colonels said, "We have never seen anything like this: The republic is in decline, and we have reached a point of absolute dissolution that we can't survive!"
  - Although hardly happy about the state of affairs, Friedman approached his colleague's despairing assertion from an intelligence perspective by considering whether anything similar might have occurred in the nation's past.
    - After some reflection, he became aware of a historical pattern:
      - Every 50 years from the dawn of the nation, an unlikely man found himself in the Oval Office—Jackson, Hayes, Roosevelt, and Reagan, each presidency surprising for its own reasons—yet, each implementing a novel approach to the challenges of its time to propel the nation into a period of prosperity.
        - When it comes to Presidents, contends Friedman, "the great struggle is among those want to go someplace you can't go, those who want to back up, or those who are totally lost. The totally lost are the ones to look at, because they are the only ones in touch with reality. Reagan was totally lost, Roosevelt was totally lost, and Hayes didn't even know where he was. There is an interesting process that takes place, where you have to start wiping the slate clean."
      - "Sitting there in 1975, I said, 'Well, it sucks to be alive, but it's not as bad as the Great Depression, and it's certainly not as bad as the Civil War, and it's not as bad as Andrew Jackson, although the characters are the same—we have a bunch of weird people running around," says Friedman.
  - He set his ruminations aside for four decades, until in the runup to the 2016 election a conversational partner resurfaced that old refrain, "It's never been this bad! We've never seen anything like this! There's no way that, with this lack of civility, we can possibly survive!"
    - But America had been this bad, American's had seen this before, and the nation indeed survived.
  - This led Friedman to three observations: "One, everyone believes that the time they live in is the best or the worst. Two, it never is. Three, there are cycles working that I don't understand, but I have to."
- Friedman invokes the invented nature of the United States to explain the reasonableness—in fact, he believes, the inevitability—of its cycles.
  - "Every part of the United States was invented," he says:
    - The federal government, which was invented at the Constitutional Convention, is wholly artificial.
    - The people were invented through waves of immigration—and forced internal migration for the Native populations—"creating massive factionalism," he says.
    - The geography was invented, with the Erie Canal connecting the Midwest to East Coast ports and thereby international trade, and with the bridging of the Mississippi River and construction of railroads, which opened up all points West to exploration, exploitation, and settlement.
  - "We are a machine," says Friedman. "We take our bearings from the Enlightenment, which believed in the machine kind of as an alternative to God. The United States was the first regime founded on the principal of the Enlightenment. We saw the republic as a technological experiment."
    - As per the laws of physics, "machines accumulate energy and rise, then dissipate energy as fall, and with a machine, there has to be regularity of that cycle," he says.

- Although not explicitly planned by the Founders, the 80-year institutional cycle and 50-year socioeconomic cycle are the natural outgrowths of this notion of nation-as-machine.
  - "We can see that at certain points we will despair of our condition, and at other points we will be giddy; it is the nature of the machine."
- The cycles:
  - Institutional cycle:
    - At the outset, the Constitutional Convention established the fact of states and a federal government, but it took the Civil War to define the division of control.
      - The outcome was that the federal government, going forward, would hold sway.
    - Eighty years later, with WWII, the federal government took over society at a large scale, "completely changing what we understood the United States to be," says Friedman.
      - For instance, it appropriated private production to meet the sudden manufacturing needs of wartime, and it allocated manpower to the war effort.
      - The outcome was that the federal government, going forward, would play a deep role in the economy and society, with "the experts who won WWII [being] the ones who would govern in the future," he says.
        - Experts in science made the atomic bomb a reality; experts in manufacturing and engineering built warplanes, ships, and tanks at a previously unimaginable rate; and experts in management mobilized society to make it all possible.
        - Following the war, the new paradigm of government-by-expertise continued—and the nation prospered.
    - Now, here we are, 80 years on from WWII, and the technocracy that emerged from the last turning of the national machine's crank is being challenged by the citizenry.
      - "If you build a government based on expertise, the great danger is that it becomes incoherent," says Friedman.
        - By definition, an expert has great knowledge in a narrow regime, but the integrated needs of society require coordination across interests.
          - For instance, a healthcare law involves point-of-care medicine, incentives for pharmaceutical development, supply chain management, risk management, financial structures, and much more.
          - "The coordination of, literally, thousands of experts writing [legislation] gives very little opportunity for someone to stand back and say, 'Does this make sense? Does this work? Does this achieve our goals?'" he says.
      - Too often, the needs of an individual citizen bumps up against the regulatory structure established by the technocracy.
        - Friedman experienced this himself when, upon turning 65, he preferred his existing health coverage to Medicare.
          - His pre-birthday literature stated that he was eligible for Medicare, but not that he was required to accept it.
          - When he went to the Medicare office to opt out, Friedman was surprised to learn that he would be hit with a perpetual fine for not having participated from age 65.
          - The office worker sympathized with him but had no power to grant him an exception.
        - "The problem is the idiosyncratic event," says Friedman, which is something that the nation's Founders anticipated with the First Amendment, which lays out that "Congress will make no law…prohibiting…the right…of the people…to petition the government for a redress of grievances"—that is, citizens have the right to request an exception.
        - But, as with Friedman's Medicare experience, petitions no longer reach the ear of a decision maker with authority: "The technocracy has created no access point for the citizen to petition the government," he says. "The power rests in the document—16K pages in the case of healthcare."
      - The upshot is large-scale governmental irrationality: "The rationality of the expert, distributed as it is, becomes irrationality," he says. "The right of the citizen to petition the government has been lost."
      - In part, this is what created the Obama–Trump voter, believes Friedman: "The growing concept of the 'deep state' that Trump speaks about is not as fantastical as it appears. The problem is that we have embedded in our lives an entity of enormous power that cannot be reasoned with, and there is a feeling of helplessness that people get from this institutional reality."

        - Even while establishing a more representative and less corrupt government structure, the advent of the primary system in the United States—which shifted the power of nominating candidates from party bosses to the electorate—also abolished a ready avenue for citizens to petition their government.
            - No longer could a person promise their vote—and the votes of their friends and family members—to a party boss in exchange for granting a petition, leaving citizens with no recourse.
        - "This is the crisis we are facing now," says Friedman. "There is a general feeling that, if you need something from the government—and the poorest are the ones that are most likely to need something from the government—they can't do anything about it because the regulations were written by experts."
    - This feeling of social disempowerment, believes Friedman, will likely initiate the next turn of the institutional cycle.
- Socioeconomic cycle:
    - Friedman fast-forwards to the fourth period in this cycle, with Franklin Roosevelt being elected while the nation was in the throes of the Great Depression, with the massive plants of the Industrial Revolution idle due to lack of customers.
        - When the industrial working class lost their jobs, the crisis only deepened as unemployment neared 25%.
            - To break the cycle, Roosevelt established the New Deal that began the process of creating jobs for people, who could then spend on goods made in the reinvigorated factories.
            - In the end, it took WWII to create an unprecedented demand for goods, which was the ultimate engine that pulled the nation out of the Depression.
                - "Out of the war came the idea that consumers should be able to moderate their consumption by having credit," says Friedman. "This was not an idea that had been there before."
        - Thus, bank-issued credit cards—and the high consumption they enabled—became the key innovation emerging from the fourth period of the socioeconomic cycle.
        - But high consumption has its limits in a healthy economic system.
            - By the 1970s, overconsumption had come to limit money available for investment, and something had to give.
                - "I bought my house in the 1970s for 18% interest, and that was considered pretty good," says Friedman. "Inflation in the United States was 12%, and unemployment was also 10%. It was a terrible time."
    - The solution to the problem was to further enrich the wealthy, who could use those funds for investment instead of consumption.
        - "This violated every moral principle that could be imagined from the Roosevelt period," says Friedman, "but voodoo economics worked."
        - He therefore credits Reagan with enabling the investment that would fuel the microchip economy that led to the boom times of the dot-com bubble.
            - "The vast investments that became available would not have been available in the 1970s. There wasn't that much money in the system," says Friedman.
        - "Ronald Reagan shifted the moral foundation of the system away from the supremacy of the consumer to the priority of the investor," he says.
    - This leads to a new problem, as the socioeconomic cycle readies for a shift from its fifth to sixth period: "There is so much money, but almost nothing to invest in," says Friedman.
        - Accompanying this situation are interest rates so low that Baby Boomers cannot afford to retire.
        - And hard times have not only fallen upon senior citizens: Wages of members of what would once have been deemed the industrial middle class have fallen so low that they cannot afford to become homeowners.
        - "The condition now of the working class of the industrial Midwest is like that of the blacks in the 1960s and 1970s," he says. "Single mothers dominate, and drug addiction is endemic. This class feels, rightfully, that they are held in lower regard by the technocracy."
    - Arguably, Trump now occupies the White House because of this disconnect between white workingclass people and the technocracy as embodied in 2016 by Hillary Clinton, who went so far as to label them *deplorables*.

- "All those Midwestern states that flipped suddenly at the end were responding to what they saw as a personal attack," he says.
- The battle is now playing out between the technocracy—striving to hold onto its sense of order—and a declining middle class.
  - But the divide is defined by more than just income and education; it also plays out on the very geography of the nation, with the technocracy concentrated along the coasts and those who feel downtrodden in this way living the middle and southern reaches of the country.
    - "Between the Rockies and the Appalachians, only three states voted for Clinton," says Friedman.
  - This geographical component is truly troubling, because it divides us as a people: "There are many people that I have met who have never met someone who actually likes Donald Trump," he says. "Given that almost half the country likes him, that is a pretty remarkable thing. But then I've met people in Hayes County, Texas, where I live, who have never met anybody who didn't like Donald Trump."
- "We are at a cyclical point where we should be seeing a great deal of turbulence," he says; this is occurring right on schedule. "Over the next decade, the whole matter will have to be straightened out—and will be straightened out, because one thing we know about our cycles is that they moderate themselves."

- Friedman believes that technology will play a leading role in the resolution of the duel at the center of the dual-cycle transition.
  - "In our society, technology drives economic development, social development, and political development," he says.
    - Examples from history:
      - Electrification of cities—Throngs of people had to move for factory jobs, "and having moved to cities, nighttime was a nightmare. The invention of electricity had the effect of making cities bearable."
      - Internal combustion engine—Significant penetration of car ownership stimulated the dispersal of the population and the growth of suburbia.
      - Business innovation—"That era began in 1915, when Henry Ford opened his first major factory, but he produced the most important thing, which was not cars," says Friedman. "Everyone knew how to make cars, but he invented the dealership—the idea that a local should own a dealership and also provide service, because cars break down. [Ford] made a great deal of money from cars, but even more from the dealerships that had to pay him."
        - In yet another example of a 50-year period, Friedman notes that by 1965 the automobile had become a commodity item and was no longer altering society with fundamental technical inroads.
      - Microchip—This core technology of the information age has shaped the fabric of society in similarly elemental ways, but now in its 50s the semiconductor industry is also mature.
        - "The microchip has transformed our relationship to each other and our relationship to information," says Friedman, even while questioning the limits of the benefits of technology.
        - "The crisis of our time is compounded by the fact that the microchip's [further] additions to the economy don't warrant the kinds of investment needed, so we wind up with an overhang of money desperately searching for new technology and not finding it," he says.
  - The periodicities of the machine of the United States therefore dictate that a new transformative technology is right around the corner, and that at least some of the giants of today's tech world will fade away and become a shadow of their former corporate selves.
    - "When you see Apple creaking just a little bit, think of GM," says Friedman. "When you see federal antitrust regulators talking to Facebook and Twitter, take a look at Standard Oil, which was broken up by the trust busters."
    - If he were to bet, Friedman would put his money on something from the biotechnology sector as the next game-changer.
      - "The problem we have now is that life expectancy is expanding," he says. Among the consequences is that, with relatively low reproduction rates among Millennials, Boomers will have to remain productive further into what would otherwise be their retirement years to avoid taking down the economy.

        - "In about 20 years, the majority of voters will be old people, and they will be voting their interests instead of the interests of the young people, but we cannot afford a society so skewed toward the elderly, because the cost of healthcare will break the system."
        - Productivity is a nonstarter for a person debilitated by Alzheimer's, Parkinson's, or other debilitating diseases of old age; instead, such folks are—through no fault of their own—a net drain on the economy.
        - Just as the automobile and electricity solved social problems of their time, today's underlying social problem is the longevity of the infirm.
    - "The ability to cure people who are getting old of those diseases that make them unproductive is the towering issue of our time," says Friedman.
        - Many countries limit extraordinary health interventions for the aged, but in the United States care is not partitioned in that manner.
        - The solution is not to do away with the elderly altogether, but rather to enable them to remain productive through health-enhancing technologies.
        - Friedman has hope for near-term progress, in significant part because of the investment DARPA is making in this domain.
            - "I look to DARPA to find out what future medical technology looks like," he says.
- "There is a cyclical pattern that is intersecting with a major economic crisis, which is intersecting with a major institutional crisis," says Friedman. "That makes it all look a lot worse, but at the same time it makes it easier to solve, because it will all be solving each other and changing each other."
    - Just as past catastrophic times in American history preceded its boom times, so too will the current period presage something great to come.
        - "This is a normal process that is undertaken," he says. "The strangeness of our political leaders is the sort of strangeness that you would expect from a political system that is a loss for what to do next. It is not a problem with Donald Trump—although that is an interesting problem by itself—but a problem that the system is failing, is in a down cycle, and has to bounce up."

Stable Electron Beam-Based Additive Manufacturing—Mr. Peter Hansford, Wayland Additive

- Powder bed fusion additive manufacturing enables precision production of metallic parts in complex geometries for tooling (carbide alloys), heat sinks (copper), aerospace (titanium), nuclear (tungsten), and many more applications (materials).
    - "Powder bed fusion is powdered metal that is being fused or melted together by either a laser or an electron beam," says Peter Hansford of Wayland Additive; however, each of the two prevailing technologies—selective laser sintering (SLS) and electron-beam melting (EBM)—have deficiencies that variously limit the size of parts, generate stress points, waste raw material, and do not permit real-time monitoring during the manufacturing run.
    - Hansford offers a better alternative: a variant of electron-beam additive manufacturing that removes the charge that accumulates at the growth surface, and thereby avoids smoke events common to EBM, while also negating the need to suffer the inefficiencies of SLS caused by its hot–cold cycling and slow beam movement.
    - Wayland dubs its proprietary approach NeuBeam (derived from neutral beam), despite using a current—the electron beam—to melt the metal powder; the ability to draw away the charge buildup in the not-yet-melted powder confers a suite of advantages over existing technologies.
    - Hansford describes the processes, benefits, and drawbacks of SLS and EBM, and explains how NeuBeam retains the benefits of each, diminishes their drawbacks, and introduces monitoring opportunities to give operators both control over the process and confidence in their output.
- Selective laser sintering—the pros and cons:
    - The laser beam fires on the metal powder, creating a plasma at the target point, melting the metal to fuse it.
        - "But, if you have ever seen a laser fired into powder, you would have seen a volcano effect as [the laser] moves around," says Hansford. "That is creating what is called spatter—oxidized particles—which falls back down to the powder."
            - To counteract this contamination, today's SLS machines flow inert gas above the surface of the powder to blow the spatter out of range of the build area.
            - Constraints on the distance the gas can disperse the spatter limits the size of a part an SLS machine can make.

- Through repeated cycles of heating and cooling during manufacturing, the resulting part is riddled with stress points.
  - "You are immediately making parts very hot, then they cool down rapidly," he says. "Those parts become very stressed. You will see on laser systems that you have to have a very thick base—and the bigger the part, the thicker the base you need to have—and then you tie that part down to the base when you are building the part. Then you have to heat-treat the part afterward to relax it, otherwise it just bends like a banana."
  - Purveyors of SLS machines incorporate a heated platform to limit the effects of alternating heating and cooling, but the benefit is only imparted to the initial layers of the build.
- Electron-beam melting—the pros and cons:
  - The technology underlying electron-beam additive manufacturing is much more efficient than SLS at transferring the energy of the beam into the powder.
  - In contrast to surface-level laser sintering, the electron beam, operating in a vacuum environment, penetrates into the powder bed for improved melting, however this has a negative side effect, as well.
  - Under the effect of the beam, powder particles ionize and then repel one another, creating what is dubbed a smoke event.
    - In a smoke event, electrochemical surface oxidation occurs as charge builds up on the topmost coat of the powder.
      - "If we were to leave it like that, in a very short period the powder would be flying all over the inside of the machine," says Hansford.
      - To overcome this, conventional EBM semi-sinters the powder around the part's region of growth to "tack the particles together, making them conductive, and takes the charge away."
      - While solving one problem, it causes two others:
        - First, the semi-sintered powder is difficult to remove and has a tendency to clog fine internal geometries of a part, such as cooling channels.
          - "Normally [with an electron-beam process] you have to blast the powder out," says Hansford. "If you're working with titanium and have to blast titanium around, it becomes pretty explosive, so most of the titanium parts made on electron-beam are very coarse powder—large particle size—to allow them to do this blasting without too much risk, and it also helps the presintering powder not to repel."
        - Second, the semi-sintering process requires the introduction of heat, which dictates the manufacturing temperature, rather than being able to tune the temperature as best suits the desired metallurgical properties for the part.
  - On the upside, EBM is a hot process, without the intermittent cooling that stresses the metal: "We're creating hot parts that are relaxed and therefore they don't need support structures," says Hansford.
  - Moreover, the electron beam moves two-orders-of-magnitude faster than the laser beam; a fast beam imparts more energy to its target.
    - "An electron beam can move 1000 m/s; a laser is, if you're lucky, 10–14 m/s," he says. "You have a very fast beam, it has a lot of energy in it, and it is very productive compared to lasers."
      - Even the simultaneous use of several lasers cannot not hold a torch to the application of an electron beam.
- The NeuBeam solution:
  - "What we did is take that charge away in the fact that we made the system neutral," says Hansford, who does not otherwise elaborate on what is presumably Wayland's secret sauce.
    - "The powder remains free—[not semi-sintered]—it is not charged up, and it is not repelling itself," he says. "We do a hot process, but we are just keeping the part itself hot and using the powder around that part to insulate it."
      - This combination of characteristics excites parts manufacturers who shifted from SLS to EBM, but who sorely miss the free-flowing powder of the laser-based process.
      - Even better, NeuBeam's residual powder is reusable, rather than contaminated, as per SLS.
  - NeuBeam offers several advantages:
    - Process flexibility
      - The process is temperature-tolerant, rather than being locked into the temperature required for EBM's presintering.
      - The process is transparent, enabling control over material properties: "We have given you the tools to change parameters," says Hansford, where the effect of each tweaked parameter can

be independently observed, for instance in mechanical properties of the part or its grain structure.
    - The process is designed for production.
    - The process is amenable to the use of all manner of metal powders and a wide range of powder particle sizes.
    - The process facilitates design freedom; for instance, the geometry of a part can be used to dictate build-time support structures that best match production criteria.
    - Postprocessing is simpler with NeuBeam than with either SLS or conventional EBM.
- System stability
    - Not only is the NeuBeam system more stable than either SLS or EBM, but also important parameters are overt to the user, including a full map of instantaneous power imparted to each point on the build bed: “With electron-beam you can measure current,” says Hansford. “You know exactly what is going on.”
    - “We have created a very stable system with a large operating window for large parts,” he says, accommodating parts as large as $(450\ mm)^3$, “while the larger build volumes on laser systems today are using small parts, and multiples of those small parts, rather than large parts, because the stresses on those large parts are too great.”
        - “We are able to do large parts because we have the capability to do large parts without stress,” says Hansford.
    - The Wayland solution includes auditability provisions, tracing every part produced back to its production run and machine settings.
    - Machine calibration is easy by design.
- Better metallurgy
    - With knowledge of energy input and all parameter settings, users can tune each build to optimize grain size, maximize density, minimize material stress, maximize powder recycling (due to low oxygen pickup), and more.
        - “They can manage the microstructure and tune the part’s metallurgy as they want it for that particular application, which is really important for production,” says Hansford.
            - This is effected by using the beam to moderate the postmelt cooling rate in what he terms a “local simmer scan.”
        - “You need to be recycling the powder, but know that it is within specification and meets the criteria of the application.”
- Process monitoring controls
    - The need:
        - The conventional procedure to monitor production quality is to destructively test perhaps five percent of parts.
        - “If I print 20 parts today on a system, I get 20 parts out, I cut one up, and I analyze what that is,” says Hansford. “If this is for production, I can’t cut them all up, so I have 19 that I assume are very similar to this one part, but that is not really good enough.”
    - Monitoring entails a trio of sensing systems:
        - A temperature sensor in the form of a near-infrared CMOS camera calibrated for 600–1500°C measures absolute temperatures, cooling rates , and phase changes.
            - “We can give you temperatures in degrees-C for every point on the bed,” says Hansford, which he says is key for resolving problems should they occur.
        - A structured-light system consists of a synchronized visible-light CMOS camera and light projector that emits a range of fringe patterns on the build area; the instantaneous build height across the powder bed is calculated from the captured imagery, permitting the detection and real-time mitigation of any out-of-plane irregularities.
            - “You have the scanning of the electron beam, you have the pictures from the infrared, and you have the structured light all happening and calibrated on top of each other,” says Hansford.
            - Correcting errors in the midst of a build remains a highly manual process, but the Wayland team is working to incorporate machine learning to recognize the onset of part swelling to initiate early mitigation in real time to recapture the part’s integrity.
        - A backscattered electron detector—"an electron microscope, in effect”—distinguishes among material types according to phase interactions with nuclei of different elements, while also detecting the degree of localized ionization in the vicinity of the meltpool.

- Summary list of NeuBeam's capabilities: high productivity, large build volume, thermal management, rapid material development, microstructure management, good surface finish, ability to use either coarse or fine powder, high powder recycling rate, easy part recovery/finishing, large hot parts without stresses, and support-free parts.
    - NeuBeam eliminates many of the post-processing steps required of SLS and EBM, notably the need for powder cake breakout, heat treatment, and wire cutting to separate the part from the base.
  - Dominating the applications for this additive-manufacturing technology is the space of high-wear, high-heat-resistant parts, such as engine components, tools for the food industry, drill parts with internal cooling channels, and metal-cutting tools of all sorts.
- Wayland Additive—the business:
  - This UK-based startup spun out of an engineering firm that had an internal need for a better manufacturing process for its high-precision metal parts.
    - "It was just 18 months—a very fast incubation period—from a blank piece of paper to creating a machine that worked and was stable," says Hansford, "and then we sat as a project within this engineering firm looking for an out.
  - After devising a funding stream, Wayland spun out in August 2019, such that, over the past three-and-a-half years of concerted effort, the team successfully developed technology and processes in preparation to have a commercial-class machine ready by November 2020, with shipping expected in 2021.
    - "We expect to be working closely with our customers," says Hansford. "Our aim is to produce six systems for 2021 and work closely with the companies that we are currently engaged with on projects to develop applications and materials for them. However, in the past couple of weeks, we have been thinking that we may provide a facility that gives them some access to the technology to prove out in the short term—maybe on a yearly basis—so that they can have a lower entry figure. They can get into this technology first, try it out, and then scale up from there."
    - Wayland currently focuses on customers in the aerospace industry.
      - "That's where the interest is, for large parts for aircraft," he says. "They are also struggling with getting production consistency in the field"—an area in which NeuBeam's process-monitoring system offers great promise.
  - The company's team consists of 17 people, most from the semiconductor industry with experience in electron-beam applications.
    - "In that industry, electron-beam is used for lithography to inscribe on chips with [nanometer-scale] accuracy," says Hansford. "But in the additive world, the electron-beam source came from the welding background. That is, [expertise] spanned the two ends of the scale."

The Three-Hour Prefab Home and the Future of Urban Housing—Mr. Steve Glenn, Plant Prefab

- As anyone who has ever built a home knows all too well, it is a drawn-out, expensive, and often frustration-laden process.
  - With Plant Prefab, Steve Glenn is on a mission to remove the friction and quickly get people into beautiful, stylish, energy-efficient homes they love, and to do so painlessly, economically, and with minimal waste of building materials.
  - He begins with an effort to elevate the reputation of the prefab building model to its rightful status by presenting examples of architecturally significant homes that were either prefabricated or designed to be so in future iterations.
  - Glenn then provides a virtual tour of his Rialto, California, factory where modules are built and finished to the buyer's specifications before being shipped to the prepped building site where they are assembled in mere hours.
  - Plant Prefab customers not only have great control over the features of their new home, but are encouraged to incorporate sustainable components like solar water heating for factory-installed radiant flooring, low-flow plumbing fixtures, and LED lighting.
  - Although the company has constructed its share of high-end homes on sizable lots, Glenn sees his approach as being particularly well suited for urban infill, where construction space is constrained and on-site work would prove acutely disruptive for neighbors.
  - When considered from the global scale, prefabrication is a growing trend, with Japanese home builders having embraced factory-based builds and with the German prefab industry incorporating extensive roboticization.

- "Our focus, as a company," says Glenn, "is to make the process of creating custom, high-quality projects better."
- What is prefab?
  - There exists a continuum of off- vs. on-site construction methods:
    - Manufactured (aka mobile) homes: These are constructed entirely off-site; commonly, finishing is of marginal quality for these low-budget homes, which by federal code are not permitted to be installed permanently on a foundation.
    - Modular homes: The modules are constructed off site, but when assembled on site must conform to the same local building codes as a conventional residence.
    - Panelized construction: Entire panels—walls and roofs, including structured insulated panels (SIPs)—are built in the factory, brought to the worksite and erected there, with all finishing work done on site.
      - "You still have to do electrical, plumbing, cladding, millwork, tiles, etc., on site," says Glenn.
    - Kit home: Precut elements are brought to the worksite, where all construction and assembly takes place.
- Modernism and prefabrication
  - Beginning as early as the 1920s, modernist architects—including Walter Gropius, Frank Lloyd Wright, Raphael Soriano, and Pierre Koenig—designed and built modular-style homes, although there typically did not exist an off-site factory for module construction.
  - Just as these architectural pillars understood, one size does not fit all when it comes to homebuilding; lot sizes/shapes, setback requirements, building height, and so forth vary by neighborhood, necessitating the ability to customize any home design.
    - Moreover, the lot's view opportunities, access orientation, lot topography, and so forth dictate gross characteristics of a home's design, not to mention customer preference for finishings, fixtures, roof style and pitch, and so much more.
    - A winning combination: flexible design tools and modular construction.
  - The benefits of factory-based modularization and prefabrication are many:
    - Designed-in personalization and sustainable architectural/design elements.
    - Conforming the home design to the lot in question.
    - Extending the building season:
      - Quicker construction with concurrent fabrication of modules;
      - Minimizing weather dependency;
      - Site prep transpires in parallel with module construction.
    - Guaranteed high-quality construction without the hassles of labor shortages, cost overruns, and extensive material waste so common with general contractor-built homes.
    - In-short, prefabrication sidesteps many of the high costs associated with homebuilding: little weather dependency, on-target materials acquisition, a stable labor force, and customization for odd lot sizes, shapes, or requirements.
- Plant Prefab
  - The 62K-square-foot facility in Rialto constitutes the hive of Plant Prefab's operations.
    - Inside the huge warehouse one finds modules in various states of construction: wood or steel framing being erected; wiring or plumbing being installed in walls; doors, windows, drywall, or exterior cladding being affixed; kitchen or bathroom fixtures, countertops, appliances, cabinetry, or smarthome componentry being crafted into place; and so forth.
      - Amazon has invested in Plant Prefab, clearly anticipating deep Alexa integration.
    - Each module is completed in the warehouse then shipped to the building site, where a handful of modules could take as little as three hours for full assembly and on-site finishing, and a 16-unit dormitory might take a single full day.
      - Compare this with the many months of post-foundation work that a site-built home requires.
    - With skilled builders living and working near the Rialto factory, where the cost of living is appreciably lower than in Los Angeles proper, Glenn can provide a living wage to workers while saving customers money.
    - At the same time, he can ensure quality control and consistency of product.
      - "There are many general contractors out there who are not so great," says Glenn.
  - Glenn's own Ray Kappe-designed Santa Monica home was the first output of the factory; anyone familiar with Kappe's work would not question its architectural authenticity, despite the nonconventional production process.
    - It was the first architect-designed home to be granted LEED platinum status.

- Aside from the cost of land, Plant Prefab homes average about $250/sq-ft for completed modules, with shipping amounting to $10–$15 per truck-mile per module; crane rental, site prep, landscaping, and so forth add additional costs—in all, lower than one would anticipate paying for an urban infill home in Los Angeles.
- Available designs range from 3000+ sq-ft five-bedroom homes to 450 sq-ft accessory dwelling units (ADUs); from university dormitories to multibed dwellings for the unhoused; and from rental "auto camps" in Yosemite to temporary quarters for California fire victims.
- Currently, most of Glenn's customers are either individuals building a home for personal use or developers engaging in a small- or medium-sized project (e.g., a 24-home development in Squaw Valley).
- The greatest urban growth opportunity at present is in small multifamily housing (fewer than 10 units); this is a great fit for Plant Prefab.
- Similarly, the market for small infill units (ADUs) is growing—another viable opportunity.

- Technology
  - A customer's first step is to select a model from the LivingHome gallery.
    - It is expected that, for any build, some site-level customization will be necessary.
  - Of course, each customer will have innumerable decisions to make: preferred flooring, cladding, stairway material/style, appliances, cabinetry, drawer handles, smarthome tech, and all the rest, but selections can be made through a web-based interface that visually reconfigures the home on-screen with each choice.
  - Alternatively, a customer can work directly with Plant's design team for a fully custom plan.
  - The use of panelized construction techniques and computer-aided design ensures efficient construction.
    - For instance, heating tubes are embedded in flooring; duct work is built into wall panels; and roof panels are complete with moisture membrane and sandwiched insulation.
      - A subsidiary outcome of modeling the home's mechanical systems is a precise bill of materials for each build, resulting in nearly zero waste:
        - Every item is barcoded and comes with specific instructions for the factory's tradesworkers to follow.
    - To conform to California requirements for transported components, each module is built to the most stringent building standard, ensuring that structural elements are "straight, flush, and square" to a degree unequalled by site-built construction.
  - Architects are lining up to be included in the Plant Prefab portfolio; not only Kappe, but also Yves Behar, Kieran Timberlake, Doug Burdge, Brooks + Scarpa, and WeeHouse are all onboard.
- Sustainable design 101
  - With a deep commitment to sustainable building practices, Plant Prefab homes all strive to fulfill a netzero design ethos: zero energy, zero water, zero emissions, zero carbon, zero waste, and zero ignorance.