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The Internet of Futures Past: Values Trajectories of Networking Protocol Projects

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Abstract

The Internet was conceptualized as a technology that would be capable of bringing about a better future, but recent literature in science and technology studies and adjacent fields provides numerous examples of how this pervasive sociotechnical system has been shaped and used to dystopic ends. This article examines different future imaginaries present in Future Internet Architecture (FIA) projects funded by the National Science Foundation (NSF) from 2006 to 2016, whose goal was to incorporate social values while building new protocols to replace Transmission Control Protocol and Internet Protocol to transfer and route information across the ever-expanding Internet. I examine the findings from two of the NSF's FIA projects—Mobility First (MF) and eXpressive Internet Architecture—to understand the projects' trajectories and values directives through their funding cycle and their projections into the future. I discuss how project documentation and participant articulations fall into the following three

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distinct themes about past experience and speculation: understanding the public, negotiating resources, and carrying project values into the future. I conclude that if the future Internet is to promote positive sociotechnical relationships, its architects must recognize that complex social and political decisions pervade each step of technical work and do more to honor this fact.

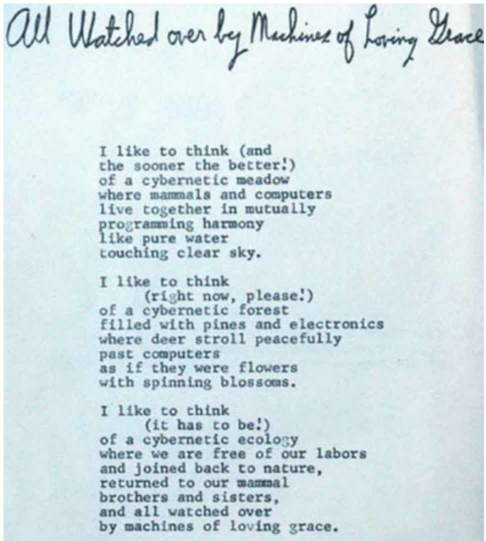
Keywords
future imaginaries, Future Internet Architectures, Values in Design, networking protocols, critical informatics

Introduction: Yesterday's Technological Tomorrows

A cybernetic meadow where humans and computers coexist harmoniously, connected in ways that seem both natural and impossible, became a common trope in the popular imagination in the 1960s. Richard Brautigan's ([1967] 2007) utopian vision pleads for a near future in which humans and computers live in harmony, where we are "free of our labors" and return to nature, "watched over by machines of loving grace." It begs for a world in which humans can transcend their bodies and physical space under the magnanimous care of machines.

Brautigan's poem, reproduced in Figure 1, was published a year before computer science pioneers J. C. R. Licklider and Bob Taylor envisioned a future that was "happier for the online individual" because networked computers would enable seamless, efficient communication organized by shared interests and goals rather than by "accidents of proximity" (Licklider and Taylor 1968, 28). In this future, "unemployment would disappear from the face of the earth forever" (Licklider and Taylor 1968, 28). In the following year, 1969, the first message was sent via the Advanced Research Projects Agency Network (ARPANET) and packet switching, queuing, and other concepts that undergird the contemporary Internet began to coalesce (Abbate 2000; Clark 2018). The future imaginaries of ubiquitous, friction-free computing influenced the sociotechnical construction of the Internet that we still see struggling toward fruition today in the form of smart cars, cities, and homes through interconnected Internet of things (IoT) devices.

This article examines how yesterday's technological tomorrows manifest today and in the recent past. Specifically, it explores different


All Watched over by Machines of Loving Grace

I like to think (and
the sooner the better!)
of a cybernetic meadow
where mammals and computers
live together in mutually
programming harmony
like pure water
touching clear sky.

I like to think
(right now, please!)
of a cybernetic forest
filled with pines and electronics
where deer stroll peacefully
past computers
as if they were flowers
with spinning blossoms.

I like to think
(it has to be!)
of a cybernetic ecology
where we are free of our labors
and joined back to nature,
returned to our mammal
brothers and sisters,
and all watched over
by machines of loving grace.

Figure 1. "All Watched Over by Machines of Loving Grace." *Source:* Brautigan ([1967] 2007).

conceptions of *the future* in Future Internet Architecture (FIA) projects funded by the National Science Foundation (NSF) from 2006 to 2016 with the goal of building values[1] into Internet routing and transfer architectures that would significantly reduce technical friction in these systems and eventually replace Transmission Control Protocol (TCP) and Internet Protocol (IP).

This study took place from 2016 to 2018, after the work with the values directives had concluded and the NSF funding had nearly been exhausted. This article focuses on the work within two projects funded by NSF's FIA program—Mobility First (MF) and eXpressive Internet Architecture (XIA). Both are interdisciplinary and interinstitutional network research projects with different approaches to building out their network protocols; MF aims to create content naming standards (CNS) to build out its protocols, while XIA intends to build out the entire networking protocol stack.

As these new networking projects were funded as part of a directive with "Future" in the title, with the stated goal of bringing about a future Internet, it seems important to examine how key players in these projects imagine the future use of their designs. Furthermore, these projects were built with distinct goals and formed with regard to values requirements. Examining how these expectations shaped the engineers' experience of work allows us to understand the trajectories present in the projects as they sought new partnerships to sustain themselves financially.

The research and findings presented in this article are part of a larger study of how issues of temporality are treated in all three FIA projects—XIA, MF, and Named Data Networking (NDN; Paris 2018a, 2018b, forthcoming). While science and technology studies (STS) scholar Katie Shilton (2015, 2018; Shilton et al. 2013, 2014) and I have already published on values within NDN, this article focuses on the lesser-known projects MF and XIA, as they are organized, directed, and built in ways that are radically different from NDN.

From 2016 to 2018, I conducted, audio-recorded, and transcribed interviews with ten respondents from both XIA and MF and iteratively analyzed more than fifty documents pertaining to various aspects of the projects using a grounded theory approach (Timmermans and Tavory 2012). As I engaged in this research, I coded my document analysis notes and transcripts in accordance with the focus of that project—articulations of temporality in technical projects. While that was the focus of the larger study, this article contains the findings around a theme that emerged—*the future* and how project principals articulate it in terms of the past. Here, I organized these findings into the following three subthemes of past experience and speculation: understanding the public, negotiating resources, and carrying values forward. The first theme, "understanding the public," was derived from how principals and engineers describe pro-social aspects of sociotechnical arrangements—for example, whether they talk about meeting market demand or meaningful engagements with social problems, structures, and hierarchies. The second theme, "negotiating resources," focuses on how funding is sought and how this activity shapes project directives. Both these subthemes help tell the story of the third subtheme, which concerns how the people building these new Internet projects envision values and "carry values forward" through the trajectory of the NSF funding cycle.

I conclude that the trajectories of values directives in XIA and MF mirror those of architecture projects of the past that envisioned a technical tomorrow that continuously falls short of the utopian future they initially advocate. Before describing the literature and findings that lead to this conclusion, it is important to mention that infrastructure is messy, as Susan Leigh Star and Karen Ruhleder (1994) famously stated. The next section begins to unravel how messiness plays into the process of building the FIA projects, as it describes how values directives from the NSF shaped each project's stated focus and how the projects came to define themselves.

Future Internets: XIA, MF, and the Values in Design (VID) Council

In 2010, when the NSF was funding the FIA projects, a few problems with the Internet loomed on the horizon. First, as social media surged in popularity, the public was largely oblivious to the fact that data generated from interaction with these platforms could be monetized and assigned value (boyd and Ellison 2007). Second, content streaming was becoming more widespread following the advent of platforms like YouTube, Netflix, and Amazon Video, among others, and the growing popularity of IoT devices extended the promise that cities, homes, schools, and cars could become wired and made "smart"; however, the widespread use of these data-heavy applications using traditional TCP/IP routing and addressing of traffic created bottlenecks (Burroughs and Rugg 2014). Finally, net neutrality, which had been debated in preceding years, became a more prominent issue as the Federal Communications Commission (2010) began leaning toward a policy position that the Internet could be considered a public utility. In this context, the NSF suggested developing solutions for the future Internet that would not only solve these technical issues but also attempt to address the already persistent social problems of Internet privacy, security, and openness. This section focuses first on how NSF FIA projects were directed to incorporate values into their designs and how the individual projects differentiated themselves as they took up this directive.

FIA and VID Partnership

The NSF first mobilized the VID Council, an interdisciplinary team of expert social scientists and policy analysts from major research institutions focused on the social, economic, and political aspects of technology to guide the work of the FIA projects. NSF expected that the VID/FIA partnership would lead to the collaborative design and deployment of networks that met the needs of society (Fisher 2007).

This VID/FIA collaboration incorporated tactics of "anticipatory ethics" in technology design, in which ethics advocates become involved in the technical projects early in the design process to guide the development of a given technology (Shilton 2015, 2). The VID/FIA project held ten meetings from 2010 to 2014, with topics ranging from FIA project overviews to comparing FIAs, privacy, security, deployment scenarios, and evaluation. The VID Council members at the meetings offered prompts or questions for the FIA teams that coalesced around the meeting topic. They further posed real-world scenarios as provocations to prompt the engineers to describe in simple terms how they understood and built values into their designs, which the Council members could then give feedback on as the projects took shape.

While that was the expectation, the experience of the partnership both converged with and departed from this stated goal in significant ways. In an overview of the NDN's participation in the VID/FIA collaboration, Shilton (2015) highlights that while the impetus for anticipatory design was clearly important to both technicians and ethicists, cross-disciplinary translation issues made meaningful engagement with anticipatory ethics in the collaboration difficult. However, the partnership fueled excellent reflective work that has resulted from the VID Council (Friedman and Hendry 2012; Knobel and Bowker 2011; Nissenbaum, Stark, and Zeiwitz 2013; Shilton et al. 2014). A report by VID Council members at the conclusion of its involvement with the FIA projects highlighted ongoing issues with the partnership. Beyond the cross-disciplinary translation issues mentioned by Shilton (2015), the VID/FIA partnership faced "diverging assumptions about the directions and capacities of the research" (p. 4) and "barriers to and difficulties presented by a lack of prolonged engagement" (p. 6).

There has been relatively little documentation of what the engineers involved gleaned from the partnership. Hence, this article focuses on their perspectives. My conversations with the FIA principals revealed that various interesting solutions that they had developed resulted from their experience with the VID Council, as well as from the FIA respondents' own projections for the ethical development of their projects into the future (Paris 2018a, 2018b, forthcoming). The next section describes the settings of XIA and MF, two of three FIA projects that made it to the final round of NSF funding.

XIA

XIA works to develop a networking schema to route data through the Internet's least congested points. The project has been led by a lone principal investigator in the Department of Computer Science, Computer, and Electrical Engineering at Carnegie Mellon University (CMU) and developed with his associates at CMU, Boston University, and the University of Wisconsin. The work of XIA is now carried out by forty faculty, working primarily in the Department of Computer Science and adjacent departments at CMU (XIA 2018b). In XIA's protocol schema, each entity—host, content, and service—has a unique identifier (XID) to be called upon in various networking processes. The purpose of the XID is to build an Internet that is more scalable than the current TCP/IP Internet, which XIA principals characterize as very rigid and not flexible enough to easily withstand large fluctuations in traffic (XIA 2018b). The primary use cases that the principals envision and build for are streaming content and automated vehicles (Gupta 2016; XIA 2018b). XIA is conceived as an entire architecture to replace IP, in which TCP would run over XIA's protocol. This has proven to be a huge research issue because networking protocols are *path dependent*—even a small change to one part of the larger standardized architecture, or IP stack, requires reconceptualizing and rebuilding the entire protocol stack built of increasingly complex and codependent layers of architecture (Gupta 2016; XIA 2018c).

MF

MF envisions that the shift driven by the increasingly mobile- and application-driven Internet will gradually demand a new "more flexible, but more secure Internet in which mobile devices and applications, along with updates in service and trust, drive the architecture" (MF 2018). As with XIA's focus on scalability as a motivating concern, MF is dedicated to enhancing network mobility, creating networks that can support the easy physical movement of users, whether those are people or applications, without breakdowns in network connectivity (MF 2018; Raychaudhuri, Nagaraja, and Venkataramani 2012). To this end, MF takes a different technical approach. Instead of XIA's tripartite identification scheme, MF develops complex naming systems for different scenarios, each of which comprises different constellations of entities (MF 2018; Raychaudhuri, Nagaraja, and Venkataramani 2012). The primary investigator (PI) of MF is a professor of computer science who runs the project from Rutgers University's Wireless Internet Lab. The PI manages the work of six other co-PIs at the University of Massachusetts–Amherst, Massachusetts Institute of Technology, University of Michigan, Duke University, University of Wisconsin, and the University of Nebraska (MF 2018). To further ground the findings and discussion, I now present some visions of the future that align with, portend, and exceed in critical ways the FIA developers' and engineers' assumptions about a future world in which their designs exist.

Background: Facing the Future

Concepts of the future play into trajectories of technological development in various ways. Analysts from numerous fields have taken different approaches to understand the implications of how technologists imagine, describe, and design for future needs, social contexts, and political-economic landscapes.

In an article explaining the impetus for ubiquitous computing, a more recent version of Brautigan's cybernetic meadow that served as inspiration for the development of smart environments and IoT, STS scholars Paul Dourish and Genevieve Bell (2014) suggested that speculative fiction can be a useful tool for probing technological development because its narratives provide examples of technological imaginaries bound by epistemological and ethical assumptions. They note that within technological development endeavors, in-project narratives about the future expose political agendas that manifest in articulations of certain functionalities, failures, and technological solutions, while at the same time obscuring others.

The technoutopian imaginaries of Brautigan, Licklider, and Taylor, discussed above, are joined by others, from the LSD- and technoevangelist Timothy Leary to Internet libertarian John Perry Barlow, who guided policy around the nascent Internet. These "visionaries" argued that advances in technology guided by market ideology would bring utopia by ending the hegemony of burdensome physical and social identities that had recently been the focal point of social movements around women's reproductive rights, civil rights, and American imperialism (Daniels 1997; Nelson 2002). These writers all enjoyed a privileged position within the racial, gendered, and socioeconomic structures of the United States in the late 1960s to early 1970s. As they preached the utopian benefits of transcending physical space and identity, their social advantages enabled them to ignore the difficult realities of racial, gender, and class-based discrimination that shaped sociotechnical policy at the time. Their advocacy for a colorblind, class-averse, market-based utopia guided policy decisions for the Internet as it grew into a free-market engine and amplified extant social structures of power and inequity.

Critical race and digital studies (CRDS) theorists, including Alondra Nelson (2002), Jessie Daniels (1997), Lisa Nakamura (2002), Ruha Benjamin (2019), and Charlton McIlwain (2019), among others, have explained the different ways that these twentieth-century libertarian imaginaries of an identity-free and bodiless sociotechnical future shaped the Internet. Dominant technologies were funded, built, and marketed to reify extant power dynamics in accordance with a meritocratic, colorblind, neoliberal ideology, resulting in an unequal distribution of benefits and harms (Daniels 1997; Bonilla-Silva 2003; Nakamura 2002). The liberatory technological imaginaries, needs, and use practices of people placed at disadvantage by official and unofficial policies were minimized, discredited, and thwarted in technology construction (McIlwain 2019; Nakamura 2002; Benjamin 2019; Nelson 2002). The Internet, framed as a value-free neutral zone, decided on by the best and most deserving technologists and policy makers, came to favor global capitalism, with the needs of people already facing social inequality coming second to the generation of wealth. We see this continuing today as technologies are used to surveil and disenfranchise working-class communities (Eubanks 2018), to extend racist stereotypes (Noble 2018), and to further enrich those who are already powerful, while the most vulnerable pay the price (Noble 2018; McIlwain 2019; Benjamin 2019).

Even in the most "policy-aware" contexts guiding computing and Internet history, the concepts of "society" and "user needs" are rather flat—focusing on governance issues of security and market-based economics rather than a politically contested and contextually contingent set of practices already engaged in systems of power. Early Internet architects knew that building a system to be used by people would require policy, as articulated by Sandra Braman (2017) in her analyses of early ARPANET requests for comments, and by David Clark in his recent book on *Designing an Internet* (2018), and his co-authored "Tussle in Cyberspace" (2005). But to this end, these works describe how architects and policy makers deployed technocratic solutions to manage, control, or accommodate competing demands or "tussles" among various stakeholders as if the architecture itself was and would be a "neutral" arbiter of these struggles. The particular privileges held by those making complex decisions about technology made it difficult to understand or account for the interests and concerns of those swathes of society affected by but not included in policy-making around technology. As the early Internet grew into what it is today, we see how "technology is a society made durable" (Latour 1990) as the ways these technologies were designed ensured that they would mirror and reify the existing structures of power and inequity well into the future.

STS scholars Michel Callon, Sheila Jasanoff, and Sang-Hyun Kim have explored how future sociotechnical imaginaries manifest in decision- and policy-making that influences how technological projects come to exist over time, compete and strive for primacy in the field, and determine new standards to mark key parts of this struggle for existence. Callon's (1980) comparison of the sociotechnical aspects of scientific innovations with electric vehicles in France in the 1970s demonstrates how scientific or technical projects struggle toward existence. As projects begin, they struggle in various ways—to adhere to pre-existing policies, to compete for and/or manipulate market demand, and then to shape policies that are hospitable to their continued trajectories. In Callon's account, projects compete for market and political dominance from the moment they are developed. However, only a few win out, and these set the terms for all others in the field. Jasanoff and Kim (2013) describe similar processes in energy technologies from the 1970s to 2010, showing how different policy contexts are constructed in different countries with regard to risk–benefit calculations that account for varying imaginaries of public and private responsibility and how extant energy policies guide these sociotechnical imaginaries.

With respect to the central issue of market ideology referenced in the work of scholars of STS and CRDS, along with the visions of tech evangelists, fields concerned with marketing strategies and business decisions consider the future in relation to market dominance. Accounting for market futures entails the practice of consumer expectation management—an effort to define the product and to position it positively with consumers, so that, in many cases, consumers' expectations of the product, or field of products, are defined before they have a chance to interact with it. Wroe Alderson and Miles Martin (1965) discussed expectations as one "primitive" (p. 121) that defined behavior and transactions in market systems. They suggested that expectations are dependent on information and values and that managing expectations might be most easily done by managing information.

The STS and CRDS work discussed above shows that technological projects, especially those funded by nation-states, are built to support the status quo of the nation-state and the power of those who already hold enormous privilege. State policy provides the directives for the projects' emergence and construction, and, in turn, these projects determine the field of competition, consumer expectations, and, to some extent, what technologies are possible. The article at hand does not detail the initial emergence of the FIA projects[2]; instead, it explains how those leading and working within the distinct projects have attempted to set new standards, negotiated with funders, and established ethical and social directives. All of the decisions guiding these activities were shaped by the experiences and expectations of the project leaders and engineers. Now that I have established this frame for analyzing participants' articulations about the future as translations of how they view the trajectories of science, technology, and society based on their own experience, I present the findings and analysis.

Findings: Futures Past

As I spoke with the FIA teams about their project structures, overarching project and subproject goals, day-to-day work, and strategies for solving technical problems, the theme of the future emerged repeatedly although it was rarely articulated explicitly. However, as the FIA projects literally have the word *future* embedded in their brief from the NSF, are all still at the prototype stage, and have not met their original goals or timelines, it is unsurprising that respondents speculated frequently if obliquely on the project's trajectory. A common thread through all their responses is that technological development is engaged in a kind of translational work in which project narratives privilege technical considerations over social and cultural ones.

Understanding Publics

The principal theme that emerged from the analysis of the applications running on XIA and MF was the differing ways in which the leaders and engineers situated their work socially. On the one hand, project leaders and engineers claimed to have a clear picture of the public's concerns in relation to their projects; on the other hand, they felt compelled to make conjectures about the best ways to make the public care about the technologies and affordances they were designing. Yet neither of the projects actually included public consultation or testing to confirm these conjectures.

MF and XIA perceive their protocols to have similar benefits. XIA's PI recognized the market value of focusing on applications but also emphasized how XIA's application portfolio is diverse (personal communication, October 30, 2017; Paris 2018b, 160). MF, on the other hand, is less focused on applications and more on standardizing the protocol.

While application development is important to XIA, the project focuses more heavily on the refinement of its addressing schema. XIA's PI had a clear eye on the project's relation to the public and how that relationship determines XIA's success. However, he pointed out that optimization was a specific *non*-goal for most public-facing applications built on XIA (personal communication, October 30, 2017, Paris 2018b, 160). As XIA requires large identifiers to be carried with the data, which makes addressing complicated, the goal with applications is to provide an example of simple uses of XIA architecture for novel scenarios or scenarios that exist but have few, if any, good and efficient solutions (Paris 2018b, 153). XIA's PI envisions XIA research in the future not with regard to a whole infrastructure but as beneficial in limited and specific scenarios (personal communication, October 30, 2017; Paris 2018b, 151).

While XIA is interested primarily in building out an infrastructure and secondarily in demonstrating benefits to the public, the postdoctoral MF developer highlighted how exhibiting MF's benefits is not straightforward. In designing the name space for MF's CNS, to be used in emergency situations, he grappled with design, because, as he put it, "How do we do expect those MF networks to be deployed? Only when they are deployed can we see how people are using it. Only after that can we see problems and decide how we're going to improve it" (personal communication, February 28, 2018, Paris 2018b, 160). He did not think that user testing—let alone large-scale deployment—would happen soon, but he related that as long as users can use the same hardware and service providers to access the content they want, few care about changes in protocols. Furthermore, he stated,

> I don't expect Mobility First to be deployed outside the lab for at least 10 years, to be very honest. But what I can tell you is that some design concepts of Mobility First have been adopted by a lot of standards [bodies], companies, and organizations. For example, the GNRS [Global Name Resolution Service, MF's unique content authentication service] is being used to some degree. And there is one new group using MF in IETF [Internet Engineering Task Force]. (personal communication, February 28, 2018; Paris 2018b, 154)

MF's PI also pointed out that they have been working on developing standards (personal communication, September 19, 2017; March 1, 2018). In particular, MF is focused on the standardization of this global name service (GNS), which can help optimize IP or other new protocols like software-defined networking (SDN). However, he emphasized that a protocol is not a standalone item that can be deployed into the network without an understanding of and carefully designing for integration with the existing network (personal communication, March 1, 2018).

Small incremental changes are planned for MF and XIA at the protocol and intraprotocol level, respectively, which will, for most users, imperceptibly shift the present into the future. The data will be identified in both MF and XIA, stored, and routed in-network. The identification of data would theoretically make it easier to subvert net neutrality in concerted ways as the identification schema betrays the data's provenance and to and from where it travels.

Through the course of their NSF funding cycles, both projects seemed to have settled on how their protocols—or components of them—can provide the best navigational system for the future Internet. Principals of both XIA and MF seemed to agree that what is most important is that their respective protocols allow applications to operate in ways that are more efficient for user demands. However, their work has proceeded without any rigorous consultation with users or the public; instead, each project consulted internal tech policy experts. (The degree to which the projects meaningfully engaged with external social and policy experts of the VID Council is detailed below in the subsection, "Carrying Values Forward.") Considering the work and time dedicated to fleshing out their respective protocols, this omission of public feedback is striking. It is also interesting that there is no clear agreement on what the larger, public-facing goals of each protocol should be both across the projects and within each project as they reach outward for funding.

Negotiating Funding

Funding directives often shape the trajectory of conceptualization, development, and deployment of technology, which is also true of MF and XIA. The mobility, scalability, and in-network storage of XIA are distinct advantages of its protocols (personal communication, September 19, 2017; October 30, 2017; December 4, 2017; January 9, 2018; Paris 2018b, 21, 22). The XIA PI noted that this functionality was a key factor in winning XIA's collaboration with the Defense Advanced Research Projects Agency's (DARPA) Secure Handhelds Assured Resilient networks at the tactical Edge (SHARE) program:

> It turns out that in certain environments [in-network content storing] is really very important, not only in the web, but also in a military context. It was something that we could accommodate, even though that wasn't our goal specifically. In some sense, we knew there are a whole bunch of things we'd like to support, but none of them are really [our target] except for mobility and security. (personal communication, October 30, 2017; Paris 2018b, 160)

Given his informal non-disclosure agreement with DARPA, a military research agency, the XIA PI could not say much more on the topic, including whether, as he implied, a specific SHARE application is being built using concepts from XIA. However, this quotation shows that XIA's in-network storage of information secured by the XID makes XIA a good collaborator for DARPA's SHARE program, which aims to "demonstrate secure exchange of information at multiple levels of classification over unsecured military and commercial networks (e.g., Wi-Fi and cellular) using a heterogeneous mix of devices from tactical radios, to laptops, to handheld devices" (DARPA 2017). DARPA's stated goals indicate what types of applications may be under development. Use in a military capacity is one way that standards evolve and gain public and institutional buy-in. This has been the trajectory for nearly all technical standards and devices in use today, from packet switching to Global Positioning Systems (Abbate 2000; Kumar and Moore 2002).

The PIs from MF and XIA admitted to multiple, extensive partnerships with the Chinese networking giant Huawei. The mention of partnering with Huawei might, in some circles, raise concern; since 2010, Huawei has continually been in the headlines for perceived security threats and developing technologies that foster espionage for the Chinese government (Ping 2019). However, others suggest that the drama surrounding Huawei's security threats must be understood in the context of the contemporary geopolitical stage in which US ethnocentrism shapes Western discourse on tech issues (Lex Team 2013). For example, Cisco has been very vocal about Huawei's threats to competition and has lobbied to bring suits against the company (Wagnaff, Crew, and Finkle 2013), resulting in a ban on Huawei's technology in the United States (Finley 2019).

Both MF and XIA have promising paths toward the future. A variety of technological options are available in the field of future Internet projects, but the sense within the projects is that only one is likely to emerge and set the standard for the others to follow. This dynamic seems to be driving the growing sense of competition between the FIA projects and their corresponding anxieties about obtaining continued funding, as well as the technical and value compromises that new funders may require. While the projects are technically similar, their activities, goals, and organizational structures are different. It is currently unclear whether there will be a single "winner" or whether MF and XIA will differentiate themselves sufficiently for components of the projects to find homes in other areas, from standards organizations to the tech industry (Paris 2018b).

Carrying Values Forward

The operationalization of the term "values" is a critical part of this analysis because the term seems to have different valences for different participants of the FIA/VID partnership. The VID Council noticed a mismatch in the ways that FIA projects operationalized value-laden terms like *efficiency* and *democratic* in their sponsored workshops (Nissenbaum, Stark, and Zeiwitz 2013). As noted previously, respondents from both FIA projects and protocols articulated that they prioritize the values of privacy and efficiency. For XIA, privacy is the primary value (XIA 2018b; personal communication, October 30, 2017; February 28, 2018), while MF states that efficiency is their main value although it is cited as a critical benefit in both projects. However, both "privacy" and "efficiency" can be operationalized as value-laden terms in various ways when thinking about sociotechnical systems in general and with these FIA projects in particular.

Project respondents' articulation of values may be significantly associated with how the NSF-enforced engagement with the VID Council brought some of these issues to light. The VID Council encouraged both XIA and MF to examine privacy and security issues. XIA's primary policy expert from CMU's Department of Engineering and Public Policy noted that he was brought into the project as a result of the NSF grant. While he observed that he only associated the phrase "values in design" with his mandatory engagement with the VID Council driven by the NSF funding, he asserted that,

> *Values and design* as a concept was certainly discussed more at NSF meetings. The NSF asking questions of PIs causes them to discuss these issues. But I am not certain if it would have gone in a different way otherwise .... Things like privacy implications or competition implications are things that I would have raised with or without [encouragement from the VID Council]. (emphasis added, personal communication, December 4, 2017; Paris 2018b, 52)

He noted that he rarely attended the VID Council meetings but had a general sense of what happened at them and explained that they had little bearing on the work he did with the XIA project. From this and other statements from the PI, we glean that while the XIA PI and a few others attended the VID Council meetings, XIA also had an internal team focusing on policy issues and other concepts like "privacy" that often fall under the broad banner of values in design (personal communication, October 30, 2017; Paris 2018b).

Similar to bringing in the policy expert, the XIA project sought collaboration with human–computer interaction (HCI) researchers at CMU. This was not mandated by the NSF funding but was a step that XIA took to address more fully the issue of assessing social impacts (personal communication, October 30, 2017; Paris 2018b; XIA 2018a). One problem that the XIA team uncovered was that for both applications and platforms running on top of networking protocols, privacy issues change as often as terms of service are updated. It is difficult even for experts and professionals in this arena to stay abreast of what data are being tracked, monitored, and sold by any given website or platform. As such, the XIA team, with direction from the HCI researchers from CMU, partnered with secondary educators in Pittsburgh public schools to better understand how this problem manifests in use cases.

From this engagement, the XIA team developed a tool kit for high school students (XIA 2018a) because there is no required computer science training and little technical Internet literacy education in high schools, despite the fact that people of all age ranges—especially teenagers—spend substantial time on the Internet (personal communication, October 30, 2018; par). While not mandated in any way by the NSF funding or XIA's involvement with the VID Council, the XIA team, led by HCI researchers, hoped to explore privacy issues by developing a technical literacy exercise with high school students (personal communication, October 30, 2017; Paris 2018b, 55-56).

The XIA PI noted that the solution is not simply encouraging students to be concerned with privacy or use tools to protect their privacy online, as these tools change. How corporations and regulators view privacy also changes as do various other factors that influence the notion of online privacy. Because of this, the PI suggested that Internet privacy education should be grounded in an understanding of how Internet architecture works (personal communication, October 30, 2017; Paris 2018b 56). He described a project that enlisted the aid of two high school teachers who helped students understand what messages are passed through the network to transfer a packet:

> The thing that I really, really loved was the first thing that they came up with all by themselves was this notion that they emulated the network . . . by having boxes that represented routers and the messages were printed around the classroom. If students wanted to pass something from one person to another, they would have pieces of paper that would be the messages or the packets or some other physical objects. (personal communication, October 30, 2017; Paris 2018b, 56)

The intention behind this project was to help students see that to exchange information over the Internet, they need an address, and then the network figures out which path to take. According to the XIA PI, the interaction also helped the XIA team explain concretely to the students what some of the components of Internet infrastructure are and what they do.

While the VID Council found that cross-disciplinary language was a problem, XIA attempted to take it a step further. This in-project example of an anticipatory ethics undertaking that addressed the translation between science, technology, and society was largely successful, according to an XIA practitioner (personal communication, October 30, 2017; January 9, 2018). However, more interesting to the study at hand is what the emphasis on the high school tool kit project says about XIA's vision of the technological future in which it is designed to intervene. Conceived and implemented by XIA, the project was developed to prove the utility of including computer science and technical literacy in public education, under the assumption that it will continue to be important for future users not only to know how to use the Internet but also to be able to adapt to changing Internet topologies and emergent social issues. The impetus behind this push may also be that academic engineering departments would prefer not to have to teach basic technical competencies to their students. While XIA's intervention in public secondary education seems to reflect an unselfish interest in producing a well-rounded populace able to stay informed of technological advances and possible threats to privacy, it might also indicate XIA's vision of a future where this knowledge is crucial to economic survival.

Despite the XIA team's articulation that the secondary education intervention that resulted from the VID partnership was a positive values project, XIA practitioners at various levels articulated that they did not regard the VID Council's input as particularly important or useful to their work. There was an overriding sentiment that engineers and internal policy experts know better than sociologists and external policy experts about how to incorporate important values into their work, as voiced by one of XIA's top policy experts (personal communication, December 4, 2017). Of his involvement with the FIA/VID partnership, he observed, "In this realm, I think privacy and security and how they [translate across geopolitical borders] were much more on everybody's mind than these so-called values issues [raised by the VID Council]" (personal communication, December 4, 2017; Paris 2018b, 53).

As this statement from the XIA policy expert shows, even if the term "privacy" was agreed upon by both FIA and VID participants, this word has different valences across geopolitical boundaries and, for XIA at least, thinking through the technical issues of privacy in different countries had primacy over other considerations of privacy. Overall, however, the XIA team seemed rather uninterested in the idea that privacy may mean very different things even within the borders of one country, such as in the United States, where formal and informal policies place large swathes of the population at an enormous but varied informational disadvantage; the socioeconomic and racial disparities in government and corporate surveillance, for example, can palpably affect certain people's lives.

Efficiency is a guiding value in both XIA and MF, but it manifests in different ways, which suggests that the projects may also have different visions of the sociotechnical future. The MF developer, for example, linked the CNS application's efficiency to the wider social benefits of rapid response and community resource allocation in emergencies rather than market priorities (personal communication, March 1, 2018). Indeed, MF seemed to be better attuned to the fact that values shape how technology intervenes in ethical questions—in this case, the focus on developing messaging systems for natural disasters shows awareness of how technology can be used to address the likely onslaught of climate disaster in the face of structural inequality. MF's intervention indicated that it understands that social structure shapes technology use and that the allocation of resources is a critical juncture where technology can improve existing ways of solving civic problems. This may account for MF's interest in developing standards with the National Institute for Standards in Technology (NIST) and the Internet Engineering Task Force (IETF) rather than developing the tech industry or military allies.

XIA, however, has more strongly emphasized efficiency in the form of interface speed and low latency, which aligns with its ambitions for establishing industry ties. We see this, for example, in how XIA orients its solutions toward the driverless car market (personal communication, February 28, 2018; Paris 2018b, 88-98). While XIA's engagement with sociotechnical values might have had more robust outward-facing interventions than MF's, XIA's focus on industry seems to disregard the complexity of the social and political dimensions of its technical project decisions. MF's engagement with values is apparent in the ways it focuses on standards development, and it seems to be slightly more deliberate than XIA in attending to what it understands as pressing civic issues. Both projects have taken their original directive from the NSF to incorporate values into their designs and practices and promote protocols to undergird the "Future Internet" in different ways. However, despite claims that they want to see a different future for the Internet, generally, the FIA projects seem to be following the same paths that Internet projects have traveled in the past.

Discussion: Envisioning the Future

The issue at the heart of this article is how experience influences the extrapolation of or speculation about the future in the FIA design process. One persistent issue throughout the study has been the projects' efforts to reduce the "friction" associated with the contemporary Internet to produce more "friction-free" technology tools and experiences, not unlike the futures envisioned by Brautigan and others back in the late 1960s, in the form of enabling IoT and easy mobile connections. However, the description of the projects in this study has shown that infrastructure is a project-contingent, messy, and overlapping process of intertwining social and technical complexity, which unfurls slowly, as Star and Ruhleder (1994) argue.

The networking architecture that these projects are working toward represents a huge investment of time and resources, and it specifies, determines, or constrains the requirements for every bit of technology to be built on top of it. In terms of technology design and implementation feasibility, changing the architecture every two or three years is unthinkable. The projects manage expectations by articulating fuzzy visions (Alderson & Martin 1965) of what they are doing and how they are doing it, keeping open possibilities for partnerships with funding agencies, standards bodies, and corporate entities. Projects that seek funder buy-in must engage in expectation management and reframe their projects as long-term investments as they find that it takes longer than anticipated to complete their proposed goals. However, as these projects branch outward for funding their political character becomes clearer. As Callon (1980) suggested, the promise of technological innovation might lead to the "emergence of new political actors who, by fighting to impose their technical choices, are inevitably led to define the needs to be satisfied, the forms of social organization to promote, and the action to be undertaken" (p. 358).

From Callon's perspective, it might be a stretch to think that FIA projects themselves have become policy actors, but it can be argued that the policy actors are the organizations the FIAs have approached for funding, such as corporate entities like Huawei or government defense agencies. If these kinds of actors are enlisted in the projects to help complete the remaining architecture, their first priorities would likely be to profit and secure defense advantages. However, to the extent that the FIA projects themselves can maintain control over the design and direction of the new architecture, the idea that they might guide standards bodies like NIST and IETF suggests the hope that the values they have struggled to articulate might still develop and shape future work.

At present, project principals generally discount the influence or danger that these funders and outside partners might pose to the projects' stated utopian goals for the future. In many ways, the NSF FIA projects have extended the original model of government-funded Internet development that began with ARPANET and continued with the World Wide Web between the 1960s and 1990s. As the FIA projects partner with organizations like the Department of Defense and various standards bodies, they follow a model that has, in their eyes, worked relatively well. Yet, ultimately, the FIA projects' aspirations to fundamentally change the Internet by attempting to design and build new infrastructure without radically altering the organizational or economic structures of technological development are in danger of reproducing or calcifying the problems of the past.

In its effort to update Internet architecture for future needs, the NSF pumped substantial funding into the FIA projects, coupled with a requirement that projects explicitly articulate and consider incorporating the values that the VID Council brought to the design process. The NSF envisioned that the FIA funding cycle would yield protocols that would realize a previously unfulfilled utopian vision of the technological future. However, the technological future being built largely reifies the diagnoses of Nelson (2002), Daniels (1997), and McIlwain (2019) of the IP-based Internet as uninterested in the social and political structures of inequity in which these technologies are built and used and, consequently, as incapable of bringing about a better technological future. Through investigation, it becomes clear that, much like the technoutopian evangelists' visions and speculative futures of the late 1960s, the goal with these projects is to reduce the friction and tensions between computing, human life, and economics with no understanding that technology is not a neutral instrument but a political mechanism that reifies that status quo unless conscious and concerted efforts are made to break that cycle. While the FIA/VID partnership may have imparted a more nuanced and critical mode of technological conceptualization and design that would account for and address power and inequity, there is little evidence that it imparted anything beyond reinforcing notions of technocratic neutrality.

The project participants from both MF and XIA have tended to frame the failures of the current IP-based Internet—inefficient traffic and unsecure communications—as their basis for knowing what the public needs and wants. But a crucial part they seem to miss as they gauge the public would be to interrogate what costs are borne by whom and which of those costs drive change. Participants suggested that one drawback of the current Internet may be that the public will eventually reject authoritarian governments' control over and attempts to manage the public sphere and thus may begin to search more actively for alternatives to IP that promise greater security and autonomy but remain quiet about tech companies' complicity in the same types of sociotechnical constraints (personal communication, January 9, 2018; September 19, 2017). In the time since this study, the public has witnessed ongoing problems with tech companies, such as massive security breaches, complete neglect of user privacy, obfuscation of platform participation with law enforcement and governmental surveillance, and tech companies' unwillingness to take responsibility for making profits from rampant political disinformation and hate speech, all of which constitute cracks that may become significant ruptures.

The shortcomings of the current Internet as cited by FIA researchers and engineers—namely, that people want to use it in ways it was not originally designed for—continue to be a great source of opportunity and justification for the FIA projects. The smooth and frictionless streaming content has become a crucial criterion for user experience, especially as many sectors' activities have been pushed online in the face of the COVID-19 pandemic. At the same time, the public is increasingly critical of smart cities and IoT precisely because of their capacity to surveil people and reap massive profits for large tech companies who exploit users and public infrastructure and give back relatively little. We are at a point when we need new solutions for sociotechnical problems that have long been simmering for large proportions of the global population. Unfortunately, these solutions seem far off. The FIA projects carry vast potential in this arena, but they do not seem prepared to meaningfully address current sociotechnical needs.

Conclusion: The Internet of Futures Past

Understanding the expectations and experiences of various actors involved in developing FIA helps us understand how the present follows yesterday's visions of technological tomorrows. These FIA projects were conceptualized in the mid-2000s and funded in 2010. The future of these projects is now the present. The 2010 goal was to bring a future Internet that meets the needs of society by allowing easy and efficient data mobility and scalability, making, for example, driverless cars and smart cities possible. However, this imaginary uncritically sees these technical goals as positive and neglects how these technologies are and will be used in tandem with extant social and political inequalities. Part of the reason these political and social inequalities are maintained is because new technologies require buy-in and support from technological, governmental, and industry actors who benefit from these inequities. Today's ongoing social, cultural, and informational crises expose these inequities and make it clear that building technologies to better meet the needs of society requires interrogating and reimagining ensembles of support for technological projects. This article joins recent works in STS (Benjamin 2019; Eubanks 2018; Irani 2019; Murphy 2017; Dunbar-Hester 2019; Ames 2019; Amrute 2016) in explicitly calling out how uncritical adherence to old narratives of tech development reinforces existing patterns of power and inequity, and pushing for new visions and practices that might make way for a better future.

In the case of the FIAs, working toward this goal might have included fostering a bottom-up approach that considers how to construct, use, and govern a networking protocol extricated from corporate and national security interests. More broadly, as information infrastructure is built, architects should take into account *whose* knowledge and input is valued and devalued in the construction, what uses of technology are and are not useful and to whom, and how technical, economic, and political values are configured within these systems. If we are truly interested in bringing about a better future, technologists and scholars must center on the needs and concerns of users in a concerted way to bring about technological relationships that address existing structures of power and inequity.

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Notes

1. The author had no part in the Values in Design Council described in this article, nor any of the National Science Foundation values directives.
2. The emergence of the Future Internet Architecture projects is discussed in chapter 2 "History of the Future Internet" (Paris 2018b).

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