Anticipation Work: Cultivating Vision in Collective Practice

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ABSTRACT
This paper joins a growing body of CSCW and HCI work addressing problems of temporality in large-scale collaborative work. Drawing on ethnographic fieldwork around large-scale infrastructure development in ecology and ocean science, and analyses of futurism in science and technology studies, we call attention to "anticipation work": the practices that cultivate and channel expectations of the future, design pathways into those imaginations, and maintain those visions in the face of a dynamic world. We advance three basic claims: first, that long term technological development and sustainability in science is guided by complex and distributed forms of futurism; second, that *all* actors (both individual and collective) orient towards the future (at both temporally close and distant scales); and third, that actors engage in complex and skilled forms of anticipation work – individual and collective, formal and informal – that guide and shape the present character and experience of collaborative life.

Author Keywords
Anticipation; time; temporality; futures; collaboration; infrastructure; ecology; oceanography; futurism.

ACM Classification Keywords
K.4.3 Computer supported collaborative work.

General Terms
Human Factors.

INTRODUCTION

> *"Imaginations of the future, like imaginations of the past, are devices for living in the present."*
>
> Sanz-Menéndez & Cabello [40]

Big data and big science have captured the attention and imagination of scientists and policymakers alike with glossy visions of innovation reaping benefits on a societal scale. Many of our deepest hopes and fears for the future manifest in new trends for data science like "quantified self," "algorithmic living" and "the internet of things" and in the generation of terabytes of data about our communication, bodies, behaviors and Earth. Previously unseen amounts of capital are invested into developing infrastructures which will support the storage and acquisition of these large data sets, whether it be billion-dollar initiatives in social media like Facebook or Twitter, in cybersecurity like those of the NSA, open government such as data.gov, or biotechnology such as 23andMe. And, as climate change, urbanization, and ocean acidification permeate both our public and scientific dialogues about the Earth, researchers and policymakers have been faced with the pressures of planning, constructing and maintaining new scientific systems that produce unprecedented stores of data to answer grand challenge questions, expanding not only the functional ability but also the imagination of science. These innovations are pointed towards the long term, at scales from years to decades to centuries. Answers to the grand challenge questions facing science today depend on whether the future lies in our understanding of a passing present quickly accumulating into one highly auditable trace of big data that represents the world around us.

At the heart of this dialog is a complex bridging between past and future, a fundamental turn to futurism and an increased need for understanding the complex work practices that support and maintain visions of technological advancement. This is a call to more squarely integrate futures – and the work we do to imagine, contest, and produce them – into our studies of sociotechnical systems.

We offer the theory of "anticipation work" as a forward-looking frame to capture practices in the present that cultivate our expectations of the future, design pathways into those imaginations, and maintain those visions in the face of a dynamic world. Anticipation work is the realized, pragmatic and attainable ways actors move toward some imagined future (ex. designing protocols for handling specimens, formalizing data standards, establishing support groups). It is a persistent and permanent feature of everyday life (much like our core theories of articulation and cooperative work), illuminating that which we wish to represent and embody. Anticipation work sensitizes the analyst toward the temporal factors at play in collaborative life and links to spheres broader than the immediate project of study.

Through these actions we can more clearly and critically see futurism in our studies of collaboration, technology

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development, and big data. Different groups mobilize resources in order to inscribe their visions into the design of systems, including social and organizational structures. While futurism often is wrapped in pledges to build, promises for tomorrow, and vaporware, anticipation work traces the real-time work and adjustments that underwrite any master narrative about the future. Anticipation work helps to us to ask questions of these efforts like: what and who are we building for? Whose voices are found in the design and what are their visions? Who is left out? What will be valued and devalued by design?

We begin by exploring the forms of future work necessarily involved in core CSCW theories of coordination and articulation work, then follow with literatures concerning temporality, futures and anticipatory governance external to CSCW scholarship. Second, we highlight three cases from field work around large-scale collaborative projects in ecology and oceanography that locate anticipation work within arenas of common CSCW concern: standardization, planning and project evolution. Lastly, we assert the ubiquity of anticipation work and discuss its relationship to broader design and policy concerns, both within and beyond the worlds of large-scale collaborative science addressed here.

LITERATURE REVIEW

Concerns and assumptions of a temporal kind are present but muted within even the earliest generations of collaboration scholarship. In fact, the very introduction that conceives CSCW's core theory of articulation work builds from a future-oriented frame:

> "Each project, as defined by its initiator(s), must begin with a vision-an image, an idea, a notion---of what can, might, or should be done. Because the vision does not yet constitute reality, or even necessarily a sense of how to make the vision into reality, the initiator (whether more like a dreamer or a planner) must consider ways and means of implementing the vision; otherwise disruptive problems will haunt the entire project. What is required to attain the goal? What modes of action, what types of work or sequences of tasks, what resources?" [46, p. 166]

Articulation work is motivated and defined by both a futuristic sensibility and by the temporal orderings of work between ad hoc practices and more permanent, institutionalized policies or procedures. Likewise, the theories of cooperative work and coordination mechanisms are contextualized by their temporal boundaries (short-term, long-term, perpetual), where performance and practice are impacted by the time for task and the time limitations of proceduralized work [40]. Each form of work is faced with concerns of a distinctly temporal and forward-thinking manner, yet often in our analyses of cooperative work futurism becomes thinkable only within the confines of project goals and schedules.

In recent years, this recognition has led to a growing chorus of CSCW work arguing that many of the pressing questions around collaborative life turn centrally on problems of *time*. Karasti et. al. [30] call out CSCW's strength in addressing short-term distributed collective practice, yet assert the need for analytic modes that will tackle the growing temporal scales of infrastructure built for the long term. Work concerning “the long now” [35] and “the long term” [17] emphasizes the temporal orientations of infrastructure, bringing to light the complex alignment of goals and social organization across individual, institutional and broader policy arenas that sustain development, maintenance and use. Jackson et. al. [25] argue that all distributed collective action is subject to the ebbs, flows and evolution of rhythms across organizational, infrastructural, biographical and phenomenal dimensions of work and life.

Many of these insights have emerged from a body of CSCW work around the challenges and complexities of large-scale collaboration and infrastructure development in the sciences [28], long central to CSCW research. Formative collaboration theory has arisen from the scientific spaces of the WORM genetics community (infrastructure [43]), the Department of Energy's CORE prototype (the collaboratory [50]), and the Stanford Research Institute (groupware [19]). These foundational works provide us understanding of social phenomena that we now take as given: illuminating how collaborative technologies loosen or break bounds between close and distant [34], disciplinary and interdisciplinary [44], and human and nonhuman [32].

In recent years this coupling of CSCW scholarship and sites of scientific inquiry has been legitimized and amplified by the increased funding of research efforts through the National Science Foundation and more direct integration of social science analysis into the scientific research process more broadly (e.g. Charlotte Linde, ethnographer at NASA). This in turn has produced new waves of CSCW scholarship and insight into the dynamics of large-scale collaborative work and practice: the political and economic implications of open or closed data sharing, production and curation [5, 48]; the connection of new infrastructural development to changes in the basic values, experiences and identities of scientific work [27]; the dynamics of scientific software development [24]; the role of materiality in collaborative practice [4, 38]; and opportune strategies for connecting ethnographic analysis with design and policy implications [16, 26].

Over the same period, a largely separate body of work in the fields of science and technology studies and the broader social sciences has called out the remarkable extent to which collaborative practice is influenced by the futures embedded in scientific systems. The future and how people anticipate it (on a continuum of abstract speculation to concrete prediction) is integral to understanding action. This is an idea tracing back to early works by Max Weber concerning “dual futurity,” in which all humans are oriented toward the future and guided by this orientation for action

in the present [50]. Expectation is a pathway toward which actors calibrate both private and public behaviors, and provides grounds for negotiation between actors [7]. From the personal, possible and close (ex: "I will get fired for this.") to the collective, abstract and distant (ex: "Humans will need to relocate to another planet."), the continua of anticipation structures and drives human behavior in striking ways.

The anticipatory behaviors that comprise the design, use and maintenance of systemic structures are integral to our understanding of collaborative life across scales. In their conception of the "sociotechnical imaginary," Jasanoff & Kim [29] provide a compelling empirical case in which actors at the national level derive strikingly different expectations of their (nuclear) futures, drawing distinctive demarcations between scientific interest, safety regulation and national innovation [32]. The analysis is rooted in understanding the practices of activism, licensing and litigation which, in aggregate, represent the broader (and quite different) positions of the U.S. and South Korea on nuclear containment - what was regulated and considered hazardous, whose voice was heard in litigation and policymaking, what was imported and trusted, etc. Futures and visions are not merely reflections of the world but are mindfully curated and impact how actors perceive themselves in relation others in the world [10].

While futures in Jasanoff & Kim's piece are defined and pursued, futures can just as easily be broken and lost. For example, despite being touted as the greatest achievement of applied biology, with the potential for bringing adequate food and protein to poor populations and developing nations, Collingridge's illustration in "The Social Control of Technology" [12] shows that the Green Revolution's food production did not lead to a healthier diet for those it intended to impact. The adoption and dissemination of the new infrastructure instead fell to the social realities of poor credit, high costs of produce, inadequate accumulation of land, and widespread discrimination.

Concerns of this kind address the social and political nature that accompanies sites of CSCW scholarlship and the affective character of temporal work. Adams et. al [1] draw the abstract notion of time down to the individual experiences of it. Actors tack between futures, presents and pasts in order to characterize their status, optimize and secure their 'best possible futures' and inhabit a feeling of hopefulness despite uncertainty [1]. The everyday interactions and behaviors of individuals are guided by the positive or negative valence of futures, closely tied to the distance and speed at which those futures are approaching [35]. Adherence to or belief in a particular future can dictate an individual's likelihood to adopt or reject new sociotechnical structures [3, 37, 42]. Technological intervention does not ensure a future and the lived future will differ from the past representations of it [8].

From science and technology studies, the worlds of anticipatory governance and knowledge both emphasize the ways in which the expected consequences of an action, construction or policy may encourage a vision's proliferation or disaster – the continua of anticipation structures and drives human behavior at the individual and collective levels. "Anticipation, then, takes on a Heisenbergian dimension as a form of knowledge that not only guesses about events in the world but directs them in unintended but unavoidable ways" [23, p. 558]. Rather than anticipation being a path dependent form in which the future is inevitably a continuation of the past, anticipatory governance looks at prediction as one among a host of possibilities that shape everyday action and policymaking.

In this paper, we borrow the adjective of "anticipation" and the "work" of Strauss and Schmidt to illuminate how practices in the present define, orient and accommodate to expectations of the future that are often sidelined in our current understandings of collaborative life. This paper tackles the problem of anticipation work: the complex behaviors and practices that define, enact and maintain vision across individual and collective, and temporally close and distant scales. In the context of collaborative life, anticipation work does important things. It illuminates that all actors orient towards the future and places futurism at the center of design and long term sustainability of technological development. And, it sensitizes the analyst toward the temporal factors, emergence and change in the formal and informal performance of everyday action.

The sections that follow explore these propositions in the context of large-scale infrastructural development in ocean science and ecology. We offer three vignettes that trace how actors gather and align futures, and in doing so form regularities which support those futures (and just as often break them). We conclude with three basic arguments: first, that long term technological development and sustainability in science is guided by complex and distributed forms of futurism; second, that all actors (both individual and collective) orient towards the future (at both temporally close and distant scales); and third, that actors engage in complex and skilled forms of anticipation work – individual and collective, formal and informal – that guide and shape the present character and experience of collaborative life.

METHODS

The accounts that follow draw on more than three years of ethnographic fieldwork into patterns of computational change and large-scale infrastructure development in the American earth science research communities, with special attention to two projects – the National Ecological Observatory Network (NEON) and the Ocean Observatories Initiative (OOI) – central to current changes in their respective fields. This included more than 200 interviews with actors in both fields ranging from scientists, engineers, project managers, staff, postdocs, and policymakers. Our observational work took place across a

wide variety of sites: actual fields, ecological towers, ships, docks, construction facilities, laboratories, and formal meeting places. This included time spent with boots in mud, at meetings, collecting bugs and small fish, deploying instruments and learning the knots that fasten them.

Transcribed interviews, field notes, photos and related documents (scientific or news media articles, etc.) were collected and qualitatively coded following a grounded theory approach [13, 21]. Each investigator performed fieldwork within a single domain, then together exchanged thoughts, memos, stories and field notes. The emergent themes were then further developed into subsequent memos that guided later round field work and provided the basis for the analysis presented here.

ANTICIPATION WORK & E-INFRASTRUCTURE DEVELOPMENT

The cases that follow build on two leading examples of contemporary collaborative infrastructure development in the sciences. Our first case follows a suite of changes unfolding in American ecology in recent years, driven in part by the development of the U.S.-based National Ecological Observatory Network, or NEON. With a construction budget of $434 million and a thirty-year operation plan, NEON plans to build and distribute consistent and long-term data across more than 100 carefully selected sites that would, taken collectively, provide crucial new input to pressing scientific and public questions around the ecological impacts of climate change, land use change, and invasive species. Building on core data from satellite observation, tower and remote sensing units, and a standardized field sampling program, and a suite of computational and post-processing tools that will package network data into a series of higher level data products, NEON aims to provide the first continental scale portrait of ecological change as it unfolds at the organism, biome, and regional levels. Having successfully navigated its design and planning phases, NEON is now in the midst of a five-year construction process scheduled to culminate in full operational status by 2017 (though parts of the observatory are already collecting live data).

In comparable ways to NEON in ecology, our second site, the Ocean Observatories Initiative (OOI), is breaking down traditional configurations of oceanography that are deeply repositioning the way scientists are relating to their work, their colleagues, their field and their lives outside of science. OOI is an unprecedented undertaking in the field of oceanography worldwide. It is the first observatory of its kind, touted as "the instrumented ocean:" a form of data-centric infrastructure predicated around distributed sensors and sample collection wired continuously to the ocean basin, sea-floor-walking robots, buoys, and gliders - each transmitting data to two dedicated satellites above for open and real-time access to big ocean data for at least 25 years. Scaling upward in both size and in longevity, the OOI is an evolving portrait of the ocean, relaxing many of the constraints of temporality built into more monolithic systems and introducing both immediate access and long-term archives. Not only is OOI operating at multiple temporal scales, but it also mutates as it progresses: adding new connections, instrumentation, geographies and data types as new questions are asked of it. At once long term and malleable, the observatory is not static, nor bounded by a concrete set of potential operations and uses. This is not just a day-by-day change in the form and function of the data network, but also decade-by-decade.

These developments are of deep CSCW interest in their own right: NEON and the OOI each attempt to build, in part through computational means, a form and scale of collaboration that would change the nature of ecological and oceanographic work and organization, with deep implications for practice, training, and policy, but also the core vocational identities that shape and define research as a way of life [26, 27]. But they are also of interest for the significant changes they spell for the basic temporal practice and orientations of their fields. As the following examples make clear, such reorientations initiate and rely on new cascades of anticipation work through which individual and collective futures are imagined, produced, and negotiated.

Case #1: Standards as Anticipation Work

Our first case involves the work of standards and protocol development that dominates current NEON development efforts. As stressed to us repeatedly by informants, standards are central to everything NEON seeks to accomplish. Standards are needed to ensure the comparability of data across space and time, ensuring that measures taken by sensors or field technicians in one time and place can be meaningfully correlated with those emerging from parallel activities in other times, groups, and places. Standards operate as a hedge against human and infrastructural variability, producing consistencies in method and practice across the vast human, natural and temporal scales that NEON is called upon to span. Taken in the abstract, standards are needed to separate the often subtle and complex signals of ecological change from the noise of field variability. More concretely, they establish the line between random collections of bugs in jars (or numbers in spreadsheets) and an integrated and comparable body of data and evidence from which complex scientific work and public decision can proceed.

In practice this proves challenging to achieve, for a wide variety of reasons. Some stem from the range and heterogeneity of field conditions that NEON protocols are required to address (rivers that freeze in the winter or dry up in the summer; soil conditions ranging from rich to non-existent; land cover conditions that lend themselves well to satellite and remote sensing analysis vs. those ill-suited to such methods; etc.). Others connect to the highly distributed nature of NEON field operations, and the need to ensure consistency across a large and dispersed staff of varying

backgrounds and research experiences. Others connect to the embedded histories of work by specific sites and investigators, and the widespread hope that NEON will build continuities, not ruptures, with this past. At the most profound level, NEON faces the challenge of standardizing a radically *un*standardized field (or more precisely: a field that has struggled to converge on method and technique above the level of the individual site or PI research program). As one staff scientist explained to us,

> "Because of the breadth of those sampling activities, plants, insects, mammals, aquatic environments and so on, you're sourcing information from a variety of different communities. And even within each of those communities, there are no standard methods of practice. One PI and another PI will differ quite strenuously about the right way to do it, and so there is no standard within the community of practice."

To map and constrain this variability, staff scientists charged with developing the NEON instruments and field protocols engage in elaborate practices of consultation, codification, and field-testing. Coordinators of the various NEON science areas (microbial, plant and insect ecology; soil science; remote sensing; etc.) work closely with area specialists and advisory boards to arrive at standards workable and defensible across the range of disciplines and field conditions connected to NEON operations. As the network moves closer to operations, staff scientists also work increasingly closely with the growing field operations staff to ensure that protocol descriptions are clear, unambiguously described, and implementable across the range of regional sites that constitute the network. This includes processes of 'cold-testing' in which protocol descriptions are handed to field technicians 'raw' to see if the rules and procedures described can be accurately and consistently deciphered from description. It also includes elaborate training exercises in which regional managers and field staff – most with generalist science training, but none with disciplinary expertise across the comparatively vast range of procedures NEON field teams will be called on to perform – are trained in the methods and underlying science questions guiding NEON data collection efforts. These exercises are meant to build consistencies across organizational and geographic variance: ensuring that teams operating in the x and y regions, for example, are sampling air, soil, water and organisms in ways that preserve the integrity and comparability of data across teams and sites. But they are also meant to build consistencies *across time*, guarding against differential interpretation, the accretion of unstructured workarounds, and other forms of protocol 'drift' in ways that ensure that data points produced in 2017 hold the same general meaning as those produced under the potentially radically different conditions of 2047. This work is rendered additionally complicated by the fact that the scientific, natural, and technological worlds NEON is meant to respond to are themselves in flux, in ways that must *also* be accommodated moving forward. In this way, NEON (like other longterm research projects, c.f. [9]) must fix without freezing a complex landscape of change, managing the boundary between constancy and change in ways that protect the 'liveness' and relevance of the project without sacrificing the integrity of its core data products as they shift and evolve through time [9]. The sum total of these efforts, performed through a multiplicity of mundane actions that characterize the ordinary work of NEON in its day-to-day operations, constitutes anticipation work of a particularly skilled and complex sort.

The example above indicates a core form of anticipation work, as played out under the distinctive conditions of new collaborative network formation in the sciences. Standards work represents a powerful bid to anticipate, shape and gather future action across a wide variety of actors and contexts, building new regularities of action that will sustain (if successful) the core integrative interests of NEON. To do so, it must also manage and curtail deviations from the standard, the subtle forms of customization, drift and workarounds that may constitute perfectly reasonable responses to local conditions, but undermine the integrity of the whole. But the same strategies are required to respond artfully to the futures that *can't* be fully anticipated and controlled: changes in biomes and landscapes that bring new phenomena to the center of scientific attention, changes in the technological landscape, and changes in the core questions and interests that science and the public may call on ecological research to answer. NEON must bend and answer to these futures too.

Case #2: Moving from Construction to Operations

During the period of our fieldwork (2010 to the present) NEON passed or approached two central milestones. The first was the successful completion of its pre-construction planning phase, a process running in various forms for more than a decade and completed with approval of the final NEON science and operations plans, its incorporation into the FY 2012-2013 presidential budget request, and the subsequent Congressional appropriation of the first round of NEON construction funding. The second concerns the transition from construction to full-scale operations – a milestone that will formally conclude with the completion of facilities construction scheduled for 2017, but which NEON as an organization (and individual groups and actors within NEON) has been increasingly orienting towards as the project moves forward.

The move from planning to construction marked major changes, both to NEON as a project and NEON Inc., the legally constituted entity formed to plan and build the proposed network. During the period of our fieldwork NEON staff grew from a team of 12 operating out of temporary space near the Boulder airport to a group of more than 120 occupying a sizable office building in central Boulder. This growth has included the introduction or significant expansion of new disciplinary types and roles, including project management, systems engineering, environmental permitting, civil engineering, human

resources, and other functions tied to the growing scale and construction orientation of NEON. The same period has seen a related shift in organizational structure and culture: from a relatively flat and fluid model (which some informants likened to a 'start-up' culture) to a more complex, hierarchical, and internally differentiated model marked by the complex division of labor within and between groups, systems of managerial accountability, and a more professional culture of project management imposed in part by the requirements of Congressional accountability and borrowed in part from project management and systems engineering methodologies developed in the worlds of large-scale physics, astronomy, space contracting, and the defense industries. For some (especially those coming from past histories in engineering and industry) this was perceived as a natural and welcome change. For others (especially those coming from ecology's own organizational roots in small-scale lab and field traditions) these changes were received more ambivalently.

The move to operations spells a further set of changes, which NEON as a whole and individual actors within NEON are now working to anticipate, unpack, and respond to. As alluded to above, an important element of this is the rise of a large and distributed field operations staff. Rendered obscure under earlier descriptions of the project (which cast field operations under the oblique but impressive sounding title of 'Fundamental Sentinel Units'), field operations will eventually come to constitute the bulk of NEON staff and the largest single budget item for the network going forward. Conversely, as the network enters operation, the role and size of the science and engineering teams is likely to shift, from active design of the protocols, instrument suites, computational tools and data products that will define NEON science, towards more of a trouble-shooting and maintenance role, dealing with problems and breakdowns as they occur. NEON itself as an organization is likely to become more stable, predictable, and in the words of more than one informant, "boring."

Through the period of our fieldwork, many of our informants were actively thinking towards a life in post-construction NEON. Some spoke with regret about the sense of growth, excitement and collective endeavor that has accompanied NEON in its ramp-up phase, and expressed concern that NEON in its steady state would become a less dynamic (albeit less chaotic and demanding) work environment. Others viewed the shift to operations more positively, and saw in it an opportunity to rebalance a series of commitments – family, outside interests, the development of one's own research program – that had been challenged or compromised under the intensity of the NEON development phase. Several of the NEON staff we spoke with were actively contemplating a life post-NEON altogether, and were taking steps (or tying to) to ensure their relevance and legibility to post-NEON job markets. This included efforts to maintain or restore individual research and publishing programs in ways that might support post-NEON transitions back into academic job markets. This connected in turn to a larger and sometimes contentious discussion within NEON around how the autonomous research programs of its PhD scientists (perhaps especially early career scientists) should be credited and supported. Several of our informants spoke of the 'google' or '80/20' model that had been floated within the organization, in which 80% of staff scientist time was to be devoted to NEON business, with the other 20% spent on individual research projects or simply "keeping a hand in" the science. (In practice, as at Google, this model has proved hard to achieve; several of our respondents noted that the sheer volume of required NEON work meant that 'their' 20% amounted to a voluntary add-on from personal time on top of an already 60-80 hour work week). Periodic discussions broke out around the nature of the NEON 'career ladder', including questions around how and whether things like external academic publication ought to be figured within the review and promotional policies of the organization. Still others sought to establish and valorize a new kind of scientific role within ecology, emphasizing the managerial skills, training, and experiences that former NEON employees might bring to other research operations.

In all these ways, actors within NEON have begun to orient to an operational future. For some, this means an accommodation (sometimes a happy one) to an adjusted role in science, as the organization as a whole and their role within it changes shape, texture and function once again. For others, this means leaving NEON altogether – and setting in motion the plans, steps, and processes needed to make that transition effective.

Case #3: Diversity, Inclusion, and Biographical Adjustment

If anticipation work shows up in more formal guise in planning and procedural activities like those associated with standards and protocol development at NEON, it is also found in the mundane and everyday interactions that drive and define what are sometimes personal or alternative sets of values, hopes and ambitions associated with collective projects. To emphasize this point we turn to a set of oceanographers pursuing a vision (which echoes that of early internet manifestos [2]) in which the new infrastructure of the OOI and big data will level the playing field for the doing of science across the currently unequal distribution of race, gender, class and geography in the field. These participants each described how data-intensive science could open new worlds of research that might not differentiate between male and female bodies in the way that traditional forms of ship-based work have in the past. While women were confronted with many barriers to entry on ships and particularly submarines even into the last decade [11], participants noted the shifting tides of gender awareness and the potential for open data and infrastructure to support discovery without the physical and social barriers of sexuality, strength, or more subtle forms of sexism that

once deterred engagement. Much like that of Donna Haraway's cyborg fiction [24], these participants are building their vision where all genders have the capacity to assert power through the ocean's coming big data resources.

This appears at first glance an unlikely future, as data-intensive ocean science sits at the corner of two particularly gendered STEM disciplines - oceanography and computer science. One participant stressed direct mentoring and caring for young women in this path to help them navigate and engage the science in meaningful and sustainable ways, while acknowledging the often subtle forms of discouragement that may arise. Another participant engaged the communication director of her institution to ensure that public-facing OOI documents and websites include imagery that references a more diverse array of genders, ages and ethnicities. She detailed her arguments over the cover photo of a recent expedition press release: under the headline was a photo of the two established, older white male founders. The participant strongly asserted that this photo reifies the diversity concerns for engagement that permeate the field, and suggested instead that the header include a mosaic of the people and roles who were invested in the project. Still another participant detailed her efforts to connect with women, both advanced and early career, through regular lunch outings, coffee breaks and trips to the bar. She detailed the ways in which this everyday social organizational work is critical to feelings of inclusion and may garner open communication for women as they traverse this space, setting an example for generations of mentors to come.

Much of this work was done with the recognition that these scientists will not see equality during their tenures, and was rather driven by a need to shepherd in and open opportunities for the next generation. One participant noted that while the number of women within her institution dramatically increased with the introduction of the OOI on campus, the number of men increased at a similar rate, leaving the statistical balance of gender untouched. But, the mere presence of additional female scientists – and the anticipation of more to come – inspired the participant to mobilize a collective initiative for female inclusion, support and sustainability in the ocean sciences. These efforts were then paralleled across institutions within the OOI and linked to similar efforts in the broader oceanographic community, forming a network of allies, generating awareness and initiating actionable items to build toward more equal futures. This resulted in formalized diversity initiatives by members of the OOI, a number of papers published about their efforts and visions, and work with the universities to address concerns and change institutional supports.

The OOI example above calls attention to forms of local, mundane, and value-based anticipation work that may feed into collective action in unique and powerful ways. These practices advocate and reflect the open, communal and democratic virtues desired to build into the future of a more inclusive ocean science community. Actors within the OOI are working to identify and pursue a distinctly cultural vision of the future that may stem (but not without work) from the possibilities raised by new infrastructures and the forms of work and organization they support. Through this example, we see that actors define their own positions and then strategize with regard to their expectations of the future [14]. Anticipation work flows outside of the bounds of the OOI and has legs in the universities, the governing bodies and the field more broadly. Actors reorient their personal plans and trajectories in light of the evolving shape and expectation of the project. The example sheds light on the core frames of anticipation work in building an envisioned future through mobilizing resources, aligning political and scientific interests, and evangelizing imagined worlds.

DISCUSSION

As the above accounts have shown, collaborative life is constituted in ways that are temporally driven, framing what our futures might in time inhabit. Our empirical examples show how much of the present work of our participants is oriented to a sense of building and maintaining futures, from establishing social support networks within data-intensive oceanography to the adherence to formalized protocols that dictate engagement in the operations of the ecological observatories.

A substrate of this work materializes from "ordinary futurisms'; the mundane, local, and sometimes highly personal accommodations to the future that always accompany the more formalized and/or speculative dimensions that are often called out in the planning and futurism literatures. The temporal orientation of these vignettes enmeshes actors (individuals and collectives) into a broader narrative connecting local and immediate action with larger spheres of influence in important and remarkable ways.

We have shown how standardization is employed to hedge against human and infrastructural vulnerability (including protocols, rules, procedures) and build consistencies across time. We have mapped NEON’s impending transition from construction to operations and the forms of work underway to prepare for, absorb, or depart from that future. Lastly, our example of the OOI presents a spectrum of formal and informal working orders that reorient biographical trajectories for diversity and equality across the field.

But such examples only scratch the surface of the multiple forms of anticipation work at play in the ongoing development of the OOI and NEON: writing grants which make use of the infrastructures, learning a programming language on the side of construction activities to prepare for the data-intensive science that is to come, or even gaining public momentum for a research venture through a photography exhibition at the Smithsonian around a particularly beautiful deep sea creature; in all these ways,

OOI, NEON, and the diverse array of individual actors that constitute both, are engaged in futurism of a very specific and consequential sort.

Beyond its grounding in the specific cases at hand, we believe the notion of anticipation work complements our understanding of collaborative life and practice in at least five important ways.

First, anticipation work builds common futures around which distributed actions can be coordinated and calibrated. Actors are actively engaged in the production and maintenance of social (sociotechnical) imaginaries. Our participants coalesce through formalized grant proposals or new protocols for operations and development, in what de Laat & Laredo [15] describe as "from predictive to procedural." The formalized practices that reconcile the complexities of NEON guide collective action through what others have theorized more deeply within customization, categorization, standardization, and regulation frames [e.g. 6, 20]. Though standardization work is often viewed merely as a bureaucratic device, it often finds its footing in the everyday anticipations of individual graduate students, administrators and researchers.

Anticipation work (and the futures that work is building toward) can become procedural, but unification can also materialize through purposeful, yet casual interactions with colleagues and in interactions via mentorship and group support. This symbiosis may converge or conflict with the formalized plans and goals of a project, like those of the NEON affiliates prepared for the re-balance of work and life post-operations. Much like plans themselves, anticipations are not determinate and can contradict or complement across actors within a sociotechnical system. As with our example of establishing research activities amidst construction obligations in NEON, anticipation work is an important mechanism by which individual futures get (re)calibrated to the formal and evolving shape of collective plans. The mindful practices of anticipation work not only develop order but are ordered themselves, ranging from the first order issues that ensure the following day will follow smoothly to a broad ideal type less easily attained.

Second, anticipation work asserts normative claims: the nature of a proper life in science, the values of a community, the forms of knowledge and infrastructure that are of greatest importance, or the kinds of technical resources that will persist into future generations. In many ways, the frame of anticipation work illuminates not only the styles of work and practice that are currently in fashion (e.g. high postmodernist construction) but may provide insight into the long term trends that will persist into future generations (e.g. big and open data, a distributed collaborative culture). The form of work that builds our infrastructures carries into the ways expected and appropriate behavior is defined, how values are enforced, and how dependencies are drawn. Taken together with the first point, we see that sometimes mundane anticipations shape not only the ways in which actors align themselves to, work towards, or rationalize their own stakes in the planned future of a project but also how such working, aligning, or rationalizing shapes the planned future itself.

Third, anticipation work is crucial to temporal alignment at scales from the individual and close to collective and distant. Anticipation work gives us the ability to place the practices of standardization and planning against a broader backdrop of historically-embedded and future-oriented narratives across biographical, organizational, infrastructure and phenomenal temporal scales: rhythms and events called out by Jackson et. al. [25] and Steinhardt & Jackson [45]. Actors organize their behavior in the present in real-time to reconcile the multiplicity of temporalities, some of which are currently in motion and others that are being newly engendered. Through the lens of anticipation work we draw out the active temporal work and strategic practices that align and reconcile the predictable and unpredictable nature of collaborative life.

Fourth, anticipation work is key in scaling between local and institutional forms, addressing a longstanding tension of performing CSCW work most recently called out by Ribes [36]. "We should travel across the scales mirroring the footsteps of our informants', and when we do so we will discover that scaling is the sometimes mundane, but often esoteric, work of actors." [36, p. 169]. Anticipation work follows this bridge from local practice to institutions. Expectations and their ends are often met by factors external to the individual, forcing our attention outside of the practice of one and into the larger ecology within which that individual is embedded. Anticipation work calls out an under-theorized set of practices that cross over the boundaries of a single project and align individuals at local level with institutions, planning and policies at a larger scale. Anticipation work makes visible the actors within our empirical cases as actively engaged in practices for managing the size of the project, both in the number of human and nonhuman resources as well as in their long term temporal scales.

Fifth, anticipation work breaks from risk and uncertainty in important ways. Local circumstances often break the expected trajectory of a formality or imaginary, forcing a recalibration of work practice to reclaim order [47]. It may be paradoxical to say, but the future is not fact: the one inevitability in social systems is error. Broken or irreconcilable visions can unfold as a scandal (e.g. natural disaster derails the construction of ecological sensing unit) or fall silently and passively into the background (e.g. the debilitated morale of an individual scientist takes the attention of a colleague away from their formalized goals).

Often this thinking leads us directly to limits and contingency: a series of questions subsumed under "risk"

and "uncertainty." However, this framing diminishes the purposive actions and temporal forms that direct and give meaning to practices. Our empirical example sheds light on more than what some participants noted as "Squirrel Away Funds" or "Extraordinary Maintenance" risk measures. Anticipation work captures both the formalized and the ordinary adjustments that hedge investment into a role, a project or a lifestyle. To paraphrase sociologist, Howie Becker, "in any interaction everyone always has a side bet." But what other names can we give to this futures work that is not fully predictive, that makes claims on a future it can't easily control, and is prone to producing effects even (perhaps especially!) when it's wrong?

Finally, while we may plan and hedge, the realities of the collaborative world span further than its formalized project plans and into a world full of improvisation, opportunistic change, and adaptation. We are reminded of the beautiful synthesis of John Dewey and Thelonious Monk by Nathanial Klemp et. al. [31]:

> "From Dewey's earliest work on perception (1896) and even logic (1893), he always insisted that activities are organized in time, at a particular time often at just the right time, and always with a simultaneous concern for both the future and the past." [3, p. 4-5]

For our three cases, we see that improvisation and adaptation are an integral part of anticipation work where a harmony at the collective level can result in new standards and routines that carry forward through the collaboration. As in the quotation, a sense of the past (e.g. the absence of standardization in ecology or the limitations of gender expression in oceanography) is important to any respective imagination of the future and to the jointly planned and improvised trajectory that constructs them as reality.

CONCLUSION

The paper above has argued that long term technological development and sustainability in science are guided by complex and distributed forms of futurism. All actors (both individual and collective) orient towards the future (at both temporally close and distant scales) and engage in complex and skilled forms of anticipation work – individual and collective, formal and informal – that guide and shape the present character and experience of collaborative life. These insights have important application in the world of large-scale collaboration and infrastructure development in the sciences but, they also speak to the dynamics of collaborative life and experience more generally, including in spheres well outside of the worlds of science studied here.

CSCW has long and strong traditions for analyzing and understanding collaborative practice in the present and has more recently begun building a body of work concerning time, rhythm and temporality in collaborative systems. This is a call to extend these trends and more squarely integrate futurism into our studies of sociotechnical systems. We offer "anticipation work" to bring to the fore the often invisible and forward-thinking practices of preparation and positioning that drive, unite and calibrate individual and collective action. Anticipation work illuminates the immediate actions that are building the near future, and centers these practices within dynamic spheres of collaborative life. It is a critical frame which forces the analyst to acknowledge the voices that are built into infrastructures and those voices that protest or hedge, and to be mindful of whose future is being built.

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