Breaking Down While Building Up: Design and Decline in Emerging Infrastructures

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ABSTRACT

This paper asks what we can learn from breaking down systems to understand the development of systems. Through ethnographic fieldwork around a large-scale infrastructure development project in the ocean sciences experiencing a scale downward and threat of further defunding, I highlight four often overlooked components of innovation and development that have important implications for the HCI community. The first debunks the mythical liquidation and restart of Western development's "fail fast, fail often" mantra by tracing the complexities of breaking down an infrastructure, highlighting that the end of a technology is entrenched in longer-lived social, political and organizational consequences. The second dives deeper into these social consequences, as formalized structures are broken down and new temporary and contingent working orders surface to fill their place. Third, I signal the critical consequences of the thoughtful practices of assessment and evaluation of both human and material resources that occur during the downturn of systems. Last, I discuss the deeply personal connections that amplify through processes of breaking down systems.

Author Keywords

Infrastructure; oceanography; sustainability; breakdown; scaling down; repair; breaking down; collaboration.

ACM Classification Keywords

H.m. [Information systems]: Miscellaneous

INTRODUCTION

In a time when "go big or go home" and "fail early, fail often" (or variations of "fail fast/better/forward") are inescapable mantras of Western technological development, there exists a conspicuous hole and opportunity borne from the missing narratives behind what happens when projects do fail and everyone does actually have to go home. While the mantras carry weight because of the truism that all

projects must die, the heralded sensibility of failure does many things in disservice to the reality of the end of systems.

Systems are built with longevity in mind, particularly at the large scale, yet many are faced with an untimely reminder of their impermanence. While we may line up new organizational strategies, servers with high enough capacities and buildings for testing and assessing our technologies, even successful undertakings rarely fulfill all of what they set out to do. There exists a pervasiveness of breaking down that isn't limited to the full end of a system but arises in more subtle forms of scaling back our ambitions or pushing things to the back burner. In this way, the confounding reality of systems is their tendency to at once be breaking down and building up. HCI has traditionally celebrated design and construction, but less is understood of the converse scenarios: decline, ruin and dismantling. This paper asks, what can the breaking down of systems tell us about innovation, design and sustainability in HCI?

The ends of systems (and subsystems) are rarely true ends and their path of breaking down should not be seen as purely perverse or negative: we find the remnants of a dismantled working group in new collaborations; libraries that were converted to laboratories remain laboratories; and legacy systems and code are reused with developers in their next endeavors. Each unit is incorporated into new networks and assemblages, placing importance on understanding these relational transformations in times of turndown.

The decomposition of one thing contributes to the creation, recovery and memory of another. When the assigned order of things falls away and is reoriented toward the afterlife of a project, we see breaking down requires the generation of new knowledge ripe with implications for the HCI community, wherein the way in which we order the world (and the categories we place over what is valuable, reusable and waste and who is able to make those assignments) is rearranged and reified with distinct consequences for future developments.

Through ethnographic fieldwork around a large-scale infrastructure development project in the ocean sciences experiencing a scale downward and threat of further defunding, I highlight four often overlooked components of innovation and development that have important

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CHI '16, May 07-12, 2016, San Jose, CA, USA
© 2016 ACM. ISBN 978-1-4503-3362-7/16/05...\$15.00
DOI: <http://dx.doi.org/10.1145/2858036.2858420>

implications for HCI. The first debunks the mythical liquidation and restart of Western development's "fail fast, fail often" mantra by tracing the complexities of breaking down an infrastructure, highlighting that the end of a technology is entrenched in longer-lived social, political and organizational consequences. The second dives deeper into these social consequences, as formalized structures are broken down and new temporary and contingent working orders surface to fill their place. Third, I signal the critical consequence of the thoughtful practices of assessment and evaluation of both human and material resources that occur during the downturn of systems. Last, I discuss the deeply personal connections that amplify through processes of breaking down systems.

BREAKING DOWN

I will employ "breaking down" as a catch-all for the active practices that dismantle an infrastructure, whether fully or partially. Breaking down is an activity not an incident. Actors often describe more nuanced forms of this work through terms like "scaling down", "descoping", or "pushing off". This paper is concerned with the overarching characteristics of breaking down: the degenerative processes that stop established trajectories, define fragments and assign their fates. This paper is concerned with setting an agenda around breaking down to turn a spotlight on non-progressivist accounts of technological development, including all forms of the declining moments toward the end of a system or subsystem's tenure: decay, ruin, destruction, etc.

This conception of breaking down is meant to broaden our community's recent appreciation for breakdown and repair by expanding upon the processes immediately called to mind by "breakdown" (broken components, failure to meet expectations, disaster unexpectedly hitting the project, loss of a significant internal resource) to include that which is spawned from external influence (such as decreased funding or diverted attention). The latter scenario is particularly salient in our field site where a great natural disaster will often mobilize the community to capture once-in-a-lifetime phenomena (e.g. a volcano opens on the seafloor off the coast of Washington [30]). Breaking down is concerned with the unraveling of systems as a thoughtful process and not simply a clean break that requires fixing. Additionally, I assert breaking down as a persistent and ubiquitous phenomena across scales in system development: an individual component of an infrastructure can be breaking down yet the whole infrastructure remains or, the entire infrastructure may be poised for dismantling.

LITERATURE REVIEW

This publication joins a body of work that calls for taking degenerative processes more fully into account in HCI, recognizing the tight connection between valuing (as reusable, in need of repair, discardable) and the sustainability of our endeavors [5, 12, 34].

Across many subdivisions of our community we are faced with the inescapable breaking down of systems, but perhaps most pressingly within our ICTD endeavors where the stakes of rolling out new technologies are high and their aftermath has in many cases left hard lessons, confusion and detritus in their wake [23]. Even successful ICTD initiatives must work within constraints that largely prohibit the best practices of iterative design and prototyping (e.g. [2]), leaving technologies that require local bug-fixing, necessitate complex withdrawals or drive the accumulation of waste. Alongside many successes of the field, more recent scholarship has concerned the rise-to-ruin trajectory of ICTD interventions that never quite make it off the ground after they are developed (e.g. One Laptop Per Child [47], Claim Mobile [14]). As the field matures, ICTD has proven itself as a tool for delivering and analyzing technologies for those in need, yet little is known or understood about the social and material consequences of removing these technologies in those communities.

Complementing this perspective, a growing body of literature in CHI and the broader social sciences acknowledge the generative and consequential worlds of breaking down, where disassembly is just as important as assembly [22, 42]. This work begins by asking what happens when we forgo novelty and progress for decline and decay in our studies of new media and technology and then, points to the deeply social implications of coming apart and putting back together - notably, the "broken world thinking" of Jackson [28].

The repair literature serves as a counterpoint to the consumerist and wasteful character of modern Western technological development by thinking toward reuse and sustainability after failure and by recentring human practice and relations - not simply the innovation. In this way, without repair and maintenance there is no durability and only decay [43]. I argue that this dichotomy is misleading (or exists as more of a continuum), as there are cases in which component parts are neither repaired nor maintained and instead syphoned into new arrangements or discarded wholly in order to wind down endeavors and make way for new collaborative infrastructures. This phenomenon is neither decay (as all components are not left to decline) nor is it truly repair (as components are not necessarily reestablished into a recognizable system) but is a complementary phenomena that characterizes the cases I present here.

This line of repair thinking was largely initiated within the long tradition of HCI work concerning infrastructure and the challenges of large-scale development in the sciences, particularly concerning the social complexities that both uphold and undermine technologically-driven plans (notable insights can be found in [3, 24, 31, 37, 45]). In this vein, much has been written about the challenges of sustaining long-term infrastructure [18, 19, 28, 36] and the longevity and dissemination of social and material linkages borne from infrastructural work [26, 38, 41].

For all that this work has done to direct attention to the thorny problems of developing long-lived systems with their long-lived consequences, it also suggests deep holes in our understanding of the converse complex challenges of scaling downward, decaying and ending systems. This joins a choir of interest in these challenges echoing throughout the worlds of science and public policy and research policy and the critical need to produce lessons from scaling down in the face of the current research climate in which funds have been steadily pulled from our scientific and technological endeavors [8].

Recently, Science and Technology Studies has tackled the thorny issues of technology in decline, largely concerning the practices and strategies to reestablish power structures, curate a system's legacy and set valuations of "normal" and "functioning" that range outside the technological capabilities of the system. Notably, the recent conception of repair-as-normalization (as first discussed by Ureta [43] of Santiago, Chile's restructured public transport system) bears on our narratives about breaking down in three distinct ways. First, we see that actors that are breaking down a system - particularly during processes of scaling down and not coming to a complete close - have a formed state to which they are striving to have the system reach, including new criteria for evaluation, new goals, new organizational and material structures. Second, following Star & Ruhleder's canonical statement that infrastructure is only visible upon breakdown [40], the redefinition of what falls within or outside the purview and responsibility of the infrastructure emerges as visible in the practices of breaking down, sometimes within formalized governance structures but more often in its more commonplace daily work. Third, repair-as-normalization shows us what can be disciplined often becomes reincorporated into recognizable systems while more chaotic or difficult-to-contain components fall away in the process of breaking down.

STS has a strong tradition following cases that concern failure and breakdown that record more humanist accounts of technological endeavors. These cases highlight the natural inclination in times of breakdown to attribute blame. Yet, blame universally falls on a complex and largely insurmountable interlocking of plans, people and places (e.g. Three Mile Island nuclear disaster [35], the O-Rings of the Challenger space shuttle mission [44], and the rise-to-ruin of the WATERS Network [27]).

Notably, Cohn [11] traces the lived experience of the systems work which are wrapping up the final days of NASA's Cassini space mission, highlighting how systems are political in their unmaking as they are in their construction and how in times of turndown, formalized structures fail to capture that which may generate the most consequence. As the Cassini system works its way into (planned) obsolescence, the human infrastructure is centered, reorienting the relationship of humans to each other in the curation of legacy, and pointing to the

difficult consequences of unvalued work that proves critical after-the-fact.

Following this work, Cohn [12] describes the invisible forms of labor that accompany infrastructural decay, as a system drifts or ages (in contrast with rupturing) to the end of its life in purposeful, active ways. Cohn offers "convivial decay" (or "repair-into-decay") in which actors acknowledge and accept the geriatric nature of a system and position themselves to bow out gracefully, characterizing what will degrade and how.

Much like the architectural ruins of DeSilvey [15], the many accounts featured above demonstrate a hunger for breakdown and repair that transcends any simple dichotomy between birth and death, and speaks to the urgent need to conceive of infrastructure otherwise. In doing so we may come up against forces that attempt to formalize, categorize and control. The world of architecture teaches us that, because most ruined forms are indeterminate, such structuring forces tend to be temporary and contingent [15]. Explored further within the Discussion, architecture has much to teach the HCI community about this converse side of development, having long theorized the connection between ruin (verb, to break down either actively or through the passage of time) and ruins (noun, that which decays and can be restored) and exploring how these distinctions may force a reconsideration of traditional forms of ordering and assessing a space (or an infrastructure in our case) [9, 16].

I am employing the term breaking down to situate my work as symbiotic to the breakdown and repair literature and to answer more recent calls to go "beyond repair" [43]. Acknowledging that the world may well be in a constant state of breaking, I look to *how* it is breaking and *where* the thoughtful and intentional practices of breaking down lie. As Sims & Henke [39] argue, there exists slippage away from an original mission as resources and standards change, and as components succeed or fail to meet stated goals. In this slippage, actors identify (and often change) metrics of success and failure for both the current state and the future state of the system. Following this, rather than looking to restore breakdown to a normalized state or convivially decay, I employ breaking down to indicate interventions that do not necessarily reform into something recognizable as the system it once belonged, where metrics of success tend to be moving targets. While often humans and things are revalued after they are repaired (and thusly reoriented back into a recognizable system), the active form of breaking down I describe allows valuation to occur before success or failure in that regard and encompasses that which does not again become disciplined and may fall out of view as waste or as a pure invisibility.

The following vignettes explore three facets of breaking down unaddressed by previous work within the HCI community then extends into a discussion of how this can impact future systems-building and analytical work. I

conclude by signaling the need for continued exploration into degenerative scenarios of design, development and collaborative life to support sustainable systems.

METHODS

The following is drawn from two and a half years of ethnographic fieldwork into patterns of change and collaboration in large-scale longterm infrastructure in the ocean sciences in and around the Ocean Observatories Initiative (OOI). This included over 70 hours of interviews (averaging between 1 and 2 hours) with 63 participants affiliated in some way with the OOI across roles such as scientist, staff, administration, advisor, developer and project manager. Participants were selected by their affiliation with the OOI or on recommendation by other participants. Observational work took place intermittently between Fall 2013 and Summer 2015 at oceanographic field sites on ships, docks, laboratories and meeting rooms. Data was collected through audio recording interviews, drawing and photographing facilities and equipment, and through the collection of formalized documentation from the initiative and its governing body, the Consortium of Ocean Leadership (COL), including brochures, posters, publications and videos. Transcribed interviews, field notes, videos and related documentation were qualitatively coded using a grounded theory approach [13, 21] where themes of breaking down, tenure, turnover and life-after-OOI emerged as prominent. Additional interviews were then conducted to fill in the narratives of these themes which are detailed below.

THE DOWNWELLING OF OCEAN INFRASTRUCTURE

The OOI was conceived in a time of a perceived boom for the sciences, particularly for those research initiatives that may bear on hot button issues like climate change, urbanization and ocean acidification. The vision of the OOI is a network of instruments laid across the ocean floor, in its waves and above its atmosphere able to capture data in real-time for over 25 years and answer grand challenge science questions about the earth. Sensors, network cables, satellites, seafloor-walking robots, buoys, gliders and video cameras coalesce under one cyberinfrastructure, developed by the collaboration of five major oceanographic institutions. Participants describe the OOI as a “FitBit for the oceans” where the big-data gathering will visualize trends that prescribe healthy oceans. With the knowledge gained from its data, the OOI is poised to transform not only the world of ocean science but public policy worldwide around sustainable practices and energy consumption.

The inauguration of the OOI’s construction mobilized hundreds of scientists, technicians, administrators and policymakers - moving their families and their offices; erecting new warehouses, docks, and laboratories to build and test instruments; and putting in place new

organizational structures and reporting systems to hone, track and assess progress.

However, the realities of the financial collapse, the Gulf Oil Spill and Fukushima, amongst an array of unprecedented-scale hurricanes and tsunamis have presented diminishing budgets for research-related activities in the field. In large part because of this, the grand vision of the OOI system is not fulfilling its original dream: recent reports from the National Academies have placed our largest investments (not solely the OOI) under a microscope, complemented by a series of publications in *Nature* and *Science* [48, 49] and other major outlets both academic and popular that question the method, impact and governance of large-scale systems in the U.S.

In fact, over time, this scrutiny coupled with internal stressors have resulted in the removal of a significant number of components of the OOI’s infrastructure, to a degree where there is a much talk of defunding it altogether before it even breaks out of being in the “construction” phase and into “operations”. As the infrastructure diminishes on its way to “live”, staving off what architecture calls a “rise to ruin”, participants and the oceanographic community at large have expressed fear of OOI in a “shambolic state” [47] of “what is left, even?” (participant quotation). Budgets keep decreasing as costs of construction keep exceeding expectations and, contingencies are being eaten up.

Following this, there has been a significant amount of reorganization which has only meant more costs and surprises. As an analyst, I watch as the people who were once interviewed and observed, who believed they would be part of this project for its 5-year construction and then some part of its 25-year run, are now looking for work elsewhere (or have found it already), and the buildings built specifically for OOI become repurposed for other departments and initiatives. Participants express worries of the detritus that will be left if people don’t figure out what to do with the physical infrastructure laid on the ocean floor that has no technical infrastructure pulling data out of it. They also express worries of the future of their careers, their institutions and their ideas. This backdrop lends itself to a rather confounding reality for the OOI in that it has been breaking pieces of itself down since its earliest days of being built up.

To be clear, the OOI is not over nor is it considered a failure, but some large portions of it have been closed and reopened elsewhere, reorganized and reoriented around new goals. As the climate around the OOI shifted and schedules or funding changed, along did the initiative’s priorities where some things elevated to critical status and others (often bluer sky ideas) fell out of sight or were actively removed from plans. The following cases are shallow dives into the complex practices and sociomaterial configurations of these sites intended to draw out components of breaking down that both go beyond repair and strengthen the

arguments of repair work with consequence for HCI research moving forward.

It is important to note here the structure of the OOI where the five (5) “implementing organizations” at OOI are each housed at their own institution and are in charge of their own specialization under the expansive umbrella of the infrastructure: (1) cyberinfrastructure that connects instruments to data streams and statistical engines, (2) visualizations that make sense of those data streams and abstracted values and makes these available and comprehensible online (deemed the “education” leg of the initiative), (3) the observatory on the East Coast, (4) the observatory on the West Coast, (5) the global arrays in the Irminger Sea and Argentine Basin.

These cases are best served as a first person narrative, rehashing my experience of learning what may be the most expansive example of breaking down to date in the OOI and then witnessing its consequences.

Case 1 - The Library: What Remains to Do the Breaking Down

In March of 2013 I visited the site of the cyberinfrastructure group for the first time. The university library had recently been converted into a facility specifically for the OOI. The modern site was bustling with engineers and scientists working toward the development of the infrastructure. In my field notes I wrote:

When I first walked in here, the modern converted library looked like a movie scene of scientific discovery as if Tom Cruise himself was about to burst in and draw his fingers along the glass walls with interactive projections of mathematical models (a la Minority Report). The space was bustling with excitable energy ready to take on the frontiers of ocean research. People were everywhere, the mid-level “walls” between “offices” felt like an inviting space where neighbors could chat and easily gather. Over these walls colleagues are organizing lunches, yelling about bad haircuts, and giving each other hard times for missing last night’s happy hour.

This new building is just one of the many instantiations of new facilities that I would see built for the OOI. Over the course of the next two years, the scene within this converted library has significantly changed. In a later visit the PI of the cyberinfrastructure group gave me a desk to work at between interviews and meetings. As I walked through the halls, I saw that many of the interviewees that I had such lively conversations with were let go (though I came to learn that while unpaid, some are still active because they believe in the vision of OOI). Many of the part-time and junior affiliates have quickly risen to full-time positions of power that they may have not necessarily desired upon their arrival to the OOI – moving from something that looked almost like a service position that spoke to their core values now into a more administrative role that deals with the bureaucracies of big science management, with interim titles like Project Manager and Operations Manager. My field notes read quite differently on this trip:

It’s quiet in here. Really quiet. He hasn’t popped his head over the low wall yet to introduce himself but my neighbor certainly knows that the person who used to sit here was fired two months ago. I, and my fast keyboard typing, are likely a bit mysterious to him. I know I have only one neighbor because I can hear the tip-tap of only his computer keys and I know he’s a male because I was told who the only females left standing are, and I know their desks aren’t this adjacent one. These modern constructions around me once felt like the scientific frontier, but they now feel like the panopticon, like a place of high surveillance. And, being audited, it IS surveilled and reduced to spreadsheets that don’t capture the empty nameplates and old library smell that creeps back in when you turn a corner just right. What I once saw as progress now looks like some broken world that Steve Jackson [25] might write about.

That week I had two interviewees cry during our chat. One shed a single tear when my very first question of “So, tell me what you do.” was immediately met with, “Working eighty hours a week for four years. I have estranged my family.” I came to understand this is eighty hours with no overtime. His work became ostensibly valued at about \$8/hour or less and, more than that, no one has stopped him from doing so, so his colleagues have verified his worth at \$8/hour. Participants justify this scenario as necessity in a continuously tightening environment where the vision has stayed yet the number of people and resources have dwindled.

Case #2 - The Phone Call: The Values and Connections that Elevate and Diminish When Breaking Down

Almost two years later, as I walked through the hallways of the education group between interviews, grimacing at the lightly falling snow so late in the season that flutters through each passing window, a door opens to a conference room and out emerges an earlier interviewee shaking his head. He laughs nervously at my catching his reaction and rushes through a synopsis of a tense phone call he has just concluded between the high level project managers at the cyberinfrastructure and education groups and the program officers within NSF and COL. The cyberinfrastructure project lead had just learned that someone at the education group’s institution was hired to do forensics on the cyberinfrastructure group. Understandably, the project manager of the cyberinfrastructure called in a paranoid panic: why is the education group trying to get in on the “inner sanctum” at cyberinfrastructure and why did the program officers at NSF all know this would occur yet cyberinfrastructure was “left in the dark” about an audit? Just how long had this been going on? [Almost two months.] What did they find and, ultimately, what is going to happen next? The interviewee lamented the “shady” feelings that he feared these actions had aroused in those at cyberinfrastructure but then tightened his discussion with me around the technological work that *must* be accomplished - instruments *must* have drivers that pull data from them cleanly, in real-time and with scientific accuracy; the data streams *must* coalesce in ways that are

manageable by the developers to feed visualizations; the data *must* be accessible at different resolutions (hourly, daily, single site, multi-sited, etc.); there *must* be redundancies so that the system does not have lag if there is a breakage somewhere in the stream; and there *must* be an understanding of what is already built, what can be built and what has to drop out of the pipeline. The PI at cyberinfrastructure did not receive the answers he was looking for that day and not for many months ahead.

These must-haves echo the longitudinal orientation of the OOI, which at 25 years defines the system's prowess but it also defines a maintenance regime that staves off "the end" into a far future that may never come to be. In no small part the avoidance of death in the rhetoric around and within the OOI was intended to deter some of the doubt from its ever-scrutinized community. One participant said of the NSF and program managers that "maybe they did not want to put that negative vision into our minds so they largely avoided the 'what happens if...' scenario and only focused on the Plan. In times of uncertainty all that can happen on the ground is to keep trucking and hoping that we will be able to see the project through."

By the warming of the next season, cyberinfrastructure was confronted with many indications (yet no concrete word) that it would be disbanded. Participants knew that the budgets would run dry by July and had no assurance that any would be replenished. As they moved into July, a series of meetings were held in which the management at cyberinfrastructure suggested the employees look for other jobs, and soon thereafter the decision was made to avoid potentially moving their accounts into negative territory, thusly stopping the current course of construction. The final termination was described as "abrupt", "intense", "out of left field" and "difficult" and the process to clear out the library of its personnel and material resources swiftly clocked in under a month from announcement to final day.

The funding mechanism that supports OOI, called the Major Research Equipment and Facilities Competition (MREFC), defines a systems engineering approach to development that requires a significant amount of bureaucratic process. Up until this point, all implementing organizations had been provided an almost script-like series of schedules, budgets and tasks and a significant amount of paperwork to track not only their daily progress but their hourly progress. Milestones were separated into "inchstones" and accomplished through a series of Work Breakdown Structures, Integrated Master Schedules, Earned Value Management forms, and Engineering Change Requests. When the news was delivered to the team, suddenly everyone went off script. No Plan was provided to break down cyberinfrastructure and there was not a contingency that provided any guidance.

Many of cyberinfrastructure's employees moved elsewhere and found jobs across both industry and academia. Some were left without a place to land on the very last day of

cyberinfrastructure's OOI funding but most were able to reorient around the quick close of a project that was originally poised to support them for at least one more calendar year in construction - and up to 25 in operations and maintenance.

Each external company that was providing services and resources to cyberinfrastructure had to be alerted that they would no longer be working with them. All of the cyberinfrastructure software was ported (happily) into a large account on Github under a BSD license. All of the services that were running to support real-time reporting from construction (from the wiki pages to the pages that fill all of OOI's history, technical and otherwise, and all of the code documentation) were wrapped up and efforts had to be made to transfer each to the appropriate parties. All of the software that scheduled meetings and kept records of constructions as well as all of the licenses and leases needed to be transferred to their new owners (largely NSF and COL). Significant time was spent by all parties to find jobs for themselves and help to find jobs for their colleagues, write recommendations, talk to people on the phone from the companies that were hired and reconcile the significant budget deficits at the institution for previously unpaid parts of the construction.

What will occupy the library next is now a topic of university management: the library is currently a host to ghosts and one groundskeeper: a program manager (who was an operations manager when we were first introduced) who has been working more than full time to shoulder the conversion of physical resources to their rightful new homes including computers, laptops, displays and computing equipment that were substantial in size. He communicates daily with the contracts staff at the university who also took on overtime to transition with alacrity and minimum friction with those that remain with OOI at other implementing organizations.

CASE #3 - The Champion: Breaking Down an Identity

As pieces began to fall far behind schedule at the cyberinfrastructure group, NSF had to pull back funding from each of the implementing organizations to help support and fill the gaps. Faced with layoffs, resource removal and relocation and redistribution of laboratory space, the West Coast observatory affiliates worked countless hours to complete their portion of the system despite the deepening constraints. As affiliates of the OOI began to drop in the percentages of time on the project or drop away fully (both by choice and not), there was a feeling that the last people to see this project through to operations would be its champion and a skeleton crew of other "power players" (PIs, project managers, domain experts for deploying instruments, etc.).

While OOI grew to include over a hundred affiliates during its wind up of construction, it grew at the helm of one figurehead who, with a network of devoted colleagues,

amassed supporters by snowball for almost 15 years until the OOI materialized (under a different name) within the NSF and COL. The champion very much built his identity both academically and personally around the OOI, touting and tuning the idea for an instrumented ocean through interpersonal talks, conference talks, TED talks and talks on Capital Hill. Participants on the ground looked to him as the paradigm of the entire initiative, at once the OOI was entrenched in his identity and the identity of the OOI was entrenched in him.

While the road through construction was not without its bumps, the champion and his team set out to complete the West Coast observatory on schedule and on budget (after many iterations of both extending schedules and tightening budgets). Following a successful 85 days at sea installing instruments on the seafloor, the champion and his team arrived back on the shores to disappointing news: he was asked to step away from the OOI. The word was sent to him not by NSF nor COL but by very high level senior administrators at his university. His passion, performativity and leadership were crucial to OOI's development yet as the project wound down from construction toward operations, he was let go, his role was removed entirely and he was not reoriented for the next phase.

Prior to the development of OOI, his team's vision was to instrument the seafloor to have a constant presence able to capture natural events happening as they wind up and explode. He is now pushing the vision of the next two decades at Axial Seamount, a location central to the OOI's West Coast observatory and the only observatory situated on an active volcano, hosting more than 30 instruments connected to the shore through fiber optic cable. Through my last round of field work during April of 2015 there was much discussion about the exciting data coming in from OOI demonstrating that Axial is inflating much faster than expected: up to 1000 little earthquakes a day, indicative that the floor is cracking and an eruption is imminent. OOI's infrastructure has the ability to capture a rare natural occurrence that is theorized to be at the root of devastating weather-related events like tsunamis and provide understanding of fundamental scientific questions about life without sunlight and tectonic spreading. Because the infrastructure is not yet live and the champion is no longer affiliated with the OOI, there have been hardships accessing the data and during my interviews participants hoped that some kind of deal could be struck with NSF to release at least the seismic data (suggested by many to go into the Incorporated Research Institutions for Seismology database).

On May 1st I received emails from my participants alerting me of a great event. After weeks of interpersonal struggle reconciling the cognitive dissonance that was left without the champion at its helm (and after years of scaling down and being met with largely negative feedback from the community and from the NSF), affiliates of the OOI were

more than eager to have something to brag about. I quickly searched Google for news and was surprised to see the champion front and center, the subject of many articles and interviews [17, 30]. Conspicuously absent from this new coverage was a mention of OOI.

DISCUSSION

We see that the myth of failing fast does a disservice to technological systems, whose complexity requires particularly keen attention in times of breaking down: namely, a need to perform the critical work of packaging for potential reuse, preserving legacy and adequately assigning and distributing intellectual property and licensing. But, these examples also unearth the perhaps even more pressing disservice of the failing fast mythologies to the deeply human consequences of breaking down which are glossed over in favor of innovation. These consequences are often uncomfortable and difficult to confront, pushing HCI not only out of its comfort zone of socially embedding features and affordances, but into narratives that are both difficult to confront as an analyst and as a person.

The first case of the uninhabited library is meant to provoke a deep regard for breaking down as entrenched in human narratives and longer-lived social, political and organizational consequences - new hairlines will peek out over those low walls of the library space, personnel will bring their knowledge and lessons of OOI into new collaborations, the data from the observatory will provide impetus for new ship-based research investments at Axial Mount, machinery is redistributed and will define the computational capacities of their next set of algorithms and images. The second case dives deeper into these social consequences, as formalized structures are broken down and new temporary and contingent working orders surface to fill their place. The third case signals the critical consequences of the thoughtful practices of assessment and evaluation of both human and material resources that occur during the downturn of systems and the deeply personal connections and identification that amplify through processes of breaking down systems.

The previous cases distinguish themselves from the worlds of breakdown, repair and decay that have previously found footing within the HCI and CSCW communities. Breaking down often discards as much as it recycles and these participants are not faced with the luxury of gracefully bowing out as the system ages in any kind of predictably degenerative way. The following discussion builds on the previous cases to open the dialog around breaking down for HCI and ends with some new questions that may bear on future research in the community.

Breaking Down as Generative of a New Kind of Knowledge

When discussing the experiences of OOI with its affiliates, there is a strong feeling that they are looking back at a past that leads to a future we do not live in. This phenomenon is

echoed by Cohn [11] via Barbara Adams' "living change" where changes (like rusting, aging and decaying) are constant and difficult to see moment-to-moment yet through long looks into the past or the future we can envision them. Through our cases we see that breaking down is a highly reflective and introspective set of practices. In the process of breaking down, we see actors seek and evaluate around normalization (and therefore also designations of abnormalities) and engage in practices of reordering or re-disciplining to corral these categories, akin to repair-as-normalization put forth by [43]. Cohn [11] describes this as things drift ("things aren't quite what they used to be") or "wake" ("the unforeseen repercussions and consequences of a decision") (p. 13) and in those flows actors often attempt to bridge their story into a coherence that will carry forward into the next generation of work and innovation [32]. The design orientations of HCI can benefit greatly from understanding the creation of this coherence (evoking Charlotte Linde [32]) in managing systems, particularly at the large-scale, that take more fully into account issues of human (not just material, technical, environmental) sustainability.

The reflection inherent in breaking down unearths connections that are simply not visible during boom times, connections that are often abstracted out into the broader social and political flows surrounding the system. This provides an opportunity as analysts to uncover the participants' lessons-learned in taking this new perspective: these are critical pieces of information that either would not exist or would result in diametrically different answers to the same questions asked during the progressivist building-up phases of development. Within any development process it is typical to be deeply invested into a role that encloses the immediate world around the individual, particularly in very distributed large-scale projects such as the OOI. Breaking down provides actors the ability to see outside of their everyday (and often siloed) perspective and to take a bird's eye view that guides them into their next project.

For example, often participants echoed the sentiment that "Washington doesn't speak the language of systems engineering" put in place by its own NSF MREFC funding mechanism. Multiple interviewees compared OOI's continual difficulties to be on schedule and on budget to other government-funded infrastructural projects: the out-of-date hardware, the cloudy understanding of its user base, and the unstandardized metrics for success or failure [19]. One participant began looking across government projects for answers on how to move forward after the fall of the cyberinfrastructure group, eloquently connecting the distributed nature of the observatories (as different from the central instrument of 'successful' government projects) and the coding paradigm that supports it. Quoting at length:

"... the management approaches that were used in industry aren't understood well in Washington when it comes to software and cyberinfrastructure projects. Here we proposed to use a spiral development process. It's the kind of thing where you start with a

large set of requirements and ideas of how the software will work and then through almost continuous reviews for the following year you sit down and look at where the software stands at that particular point and then realistically reduce some of the requirements so that you can complete the thing on budget and on schedule but it does mean removing requirements as time goes on in order to finish up. There is really no alternative since you have never built something like that before! Most things in Washington are built using what is called a waterfall approach in which you have a set of requirements that you build, like an aircraft and basically you plan the details of the development and construction through the whole time period having a lot of experience in the past with building similar kinds of aircraft... So one lesson learned is that it really does need and require the agency that's doing the funding to understand well the sound software side of things and not just concentrate on the hardware things... I was taken by the paucity of success (of government software)."

This participant continued to tack back and forth comparing government and industry modes of development in an effort to demonstrate how lessons were learned in the quick process of breaking down the cyberinfrastructure group and in his orienting toward the next project. Participants often discuss their desire to mimic the arrangements of startups where the cost of failure should be less, or of the agile startup frameworks where failure is developed into the methodology of development. Participants acknowledge this is often drawn from a superficial understanding of what occurs in these "fail fast" projects and does not bridge seamlessly from the highly-accounted-for government-funded world of development to the industry world. Yet, this acknowledgment importantly signals how the fail fast ethos has begun to permeate cyberinfrastructure projects - an ethos that has been more recently discussed in the mainstream as problematic and as a disservice to the realities of even Silicon Valley [10].

The previous quotation directs attention to some of this envy of industry, but also in doing so it highlights two important realities of breaking down: (1) the need to cut back and break down as part and parcel of the development process as well as (2) the social and organizational worlds that encircle seemingly straightforward technical decision-making. The participant's hand was forced to unearth lessons-learned in planning toward the next project. He detailed how these insights will be taken to his next project, which will again be large-scale and longterm and building off of software components of the OOI platform (to which he owns the intellectual property) but with a single focal observatory - decidedly not distributed - using the spiral method of development detailed above.

Breaking Down as Transient and Contingent Working Orders

In the world of architecture, decay and ruin are often attributed to new working orders described as "opportunistic reassembly" that forces engagement with the oddities and idiosyncrasies of collaborative space [15]. When the formalized supports and constraints are forced into question, new or removed hierarchies and hybrid

collections of actors will form to debate and experiment in search of new ways of thinking (p. 10). What we learn from architecture is that the removal of formal practices moves actors to critique normative practices, which both comes with a sense of freedom and possibility as well as a negativity (danger, deprivation, fear, anxiety, and void) [15]. This reinvention of self and of space makes way for the creative creation of new orders, such as that of our previous discussion example.

The cases of breaking down detailed in this paper demonstrate our actors' difficulty to locate discrete and obvious purposes and tasks once the formalized Plan was removed and instead found themselves within a chaotic and overwhelming assemblage of many working orders requiring some form of reconciliation. Many participants detailed how they worked like "a chicken with their head cut off" on multiple streams of features and documentation, largely selected for reasons of legacy and forensics. Often participants described their work as an attempt at self-preservation: the system may be dying but "I will do this so that managers will see how valuable my work was." Bennett [4] describes this personal productivity reorientated to the ruin and devastation as a notion of "enchantment and re-enchantment," curated by an attraction to possible futures that the actors may inhabit. On one hand breaking down is a violence while on the other it is a pleasure. In these anticipatory and contingent moments, actors will incorporate what they value (materially, socially, academically, technologically, etc.) into assemblages that delink and relink into new structures.

Multitemporality and the Long Lived Consequences of Breaking Down

In many ways, actors involved in breaking down are fixated on time: at once suspended between something long-lived and impermanent. It is primarily concerned with practices that define durations and how long something is let to live (or let to live as improbable, real or blue sky). Once faced with the pressing need to scale down, there occurs a valuation of what is worthy of carrying on, what will remain in legacy, what will simply be intentionally forgotten and others who will be forgotten without thoughtfulness. These practices are often undone and informal, breaking scripts for how to contribute in the infrastructure previously written by formalized Plans. Some of the most tractable challenges in the downturn of systems are captured by Jackson [28] as the "worst excesses of leftover habit and power." From the previous cases coupled with the building body of repair literature we learn that these narratives of breaking down live within routines and mundane activities often overlooked in favor of the recognizable progressivist path of innovation and development. In breaking down, mundane interpersonal structures weigh heavily on how and how fast we keep and discard because these informal properties arise as more legible and present. As progressivist imaginaries come

undone, new meanings and identities unfold, substantially shaped by those routines of previous working orders and by those people who visibly engage in work around them.

These orientations toward time may surface or indicate the long-lived consequences borne from breaking down. This sentiment is evocative of the anticipation work [41] and the sociotechnical projectory [33], where the ongoing mundane practices that occur in the everyday reveal the intended social relations that will persist past any constrained metric of time (the end of the project, the end of a job, etc). Each of these is oriented toward their own timelines and "anticipatory regimes" which bind actors to the way they code the present and calibrate toward what comes next [1]. Following this, Cohn [12] asserts the varying rates of obsolescence inherent in a system in decline - from the system's code to its constituents' careers. These more intimate sociotechnical transfigurations point to the multiple factors of time that orient a world breaking down.

Breaking Down as Care

Possibly the most striking and unanticipated theme borne from my field work with the Ocean Observatories Initiative has been the deep interpersonal connections that are tested, upheld and negotiated as the technological and organizational components come apart around them. While retaining the deep relationality to technological artifacts that runs throughout the repair literature, these human-centric narratives of kindness and care encircle our innovations and both elevate and undermine collaborative developments. These narratives emphasize a need for understanding human sustainability alongside longterm technical and material support.

This brings us to the ethics of care, which acknowledges our involvement in perpetuating normative narratives and instead attempts to demonstrate the multitude of connections that make the world possible. Suddenly a seemingly technological problem (such as a failed driver for an instrument) becomes a deeply intimate one (the developer for that driver stepped down citing anxiety and depression and an inability to complete the coding). Our cases of breaking down demonstrate that we live and maintain our existence in the world by wrangling together a multitude of connections in a sustainable, but not necessarily cohesive way. There is much curatorial work involved in breaking down that attempts to take responsibility for stabilizing a space outside of a formalized Plan and in doing so must also tame the affective components of collaborative life in decline: self-destruction, futility, regret, corruption and repression.

There is an equally important aspect of building technologies that is about the human labor that goes into it, the long hours and tense familial ties impacted by a potentially problematic connection to the infrastructure upheld by organizational flows (or lack thereof). We see the actors of the OOI often put the project before the personal

and in times of breaking down often the personal before the project - writing recommendations, searching for funds for themselves and their close collaborators, salvaging their work, tidying their own paper trails to leave a positive reputation behind them. We need to rationalize our labor which is often done by thinking about its relation to innovation, not personal boundaries. That labor is not just about social, political, and organizational factors but it also about how innovating is a problem of infrastructure, reconstructing what a technology means to us and how we live around it.

CONCLUSION

This paper argues for breaking down as an under-recognized form of collaborative work, critical and ubiquitous to development. Breaking down is not legato (like the pathways terms like planning, building, construction tend to invoke) but a more frenetic staccato: where there are often many fires and many scales down rather than a single point of breakdown, failure or death. As architects Stephen Cairns and Jane Jacob describe, “seen in this way, a building is a flow, not form; it is creative, not merely a creation” [9]. Breaking down is a creative ongoing negotiation between longevity and impermanence, intervention and non-intervention, chaos and arrest. Actors will engage in many preservation practices as individuals and as collaborative groups (developing documentation, distributing kudos and blame, designing new narratives as though they are linear and causal). Tracing these narratives unearths new areas of understanding, ambiguity, overlap and disjuncture within a system.

ACKNOWLEDGMENTS

Thank you to the participants who provided hours of their time to this study and to Steve Jackson, Ingrid Erickson, Amanda Menking, Ranjit Singh, Samir Passi, Lara Houston, Ishtiaque Ahmed and the participants of 2015 NSF Knowledge Infrastructures RCN, particularly David Ribes and Pernille Bjørn, for their recommendations and a wealth of discussions about the ideas in this piece. Supported under NSF #0847175.

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