Civic Data at the Seams

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Abstract

As civic data typically involves multiple stakeholders and institutions, data work often happens across seamful spaces. We use seams as an analytical lens to examine data production in a civic data project mapping extreme heat islands to promote environmental and climate justice. Our analysis calls attention to the work of aligning multiple infrastructures as well as the temporal and political qualities of seamful arrangements. Throughout our participation in planning and executing this civic data project, our attention was consistently called to the seams during moments of breakdown. Examining the conditions of these misalignments, we argue that seams decay as underlying infrastructures shift over time through product development, personnel turnover, and institutional change. Further analyzing the responses and maintenance work needed to sustain or re-create alignment reveals how power dynamics are reinforced or asserted at the seams. Civic design interventions must attend to these temporal and political aspects of seamful spaces when working in collaboration with other city stakeholders.

CCS Concepts

• **Human-centered computing → Empirical studies in HCI**; **Computer supported cooperative work**.

Keywords

Seams, Civic Data, Community Science, Data Activism

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1 Introduction

Civic data is widely viewed as a potential lever for social action – an information resource that can support decision making, make operations more efficient, amplify marginalized voices, and legitimize causes [24]. As such, many community-based organizations, such as nonprofits, advocacy organizations, or grassroots movements, leverage data to pursue their social and political goals [3, 24, 31]. To understand and support these efforts, we partnered with a community-based organization using participatory science to map urban heat islands.

UrbanHeatATL[1] leverages multiple free or low-cost tools to produce maps of temperature records across Atlanta. The project places low-cost temperature sensors in the hands of volunteer community scientists, who walk, bike, or skate around the city to record hyper-local temperature measurements, capturing block-to-block differences in ambient heat across the city. Like other ad-hoc information systems such as homebrew databases [109], this is a system that creatively utilizes available resources to meet information needs. The project is situated precariously across multiple technical tools and social arrangements: sensors, apps, python scripts, google forms, and maps, along with the communication and coordination work needed to support and maintain them.

Throughout our participation in coordinating UrbanHeatATL, our attention was repeatedly drawn to seams, the gaps and overlaps of the multiple infrastructures we operated within [82, 107]. Data production at UrbanHeatATL requires successful coordination across multiple technical, social, and institutional infrastructures, each with their own politics, standards, and epistemologies. Successful coordination required ongoing creative work to complete tasks across heterogeneous infrastructures. Throughout our time on the project, we frequently experienced breakdowns that resulted in incomplete or missing data, challenging the ability of the UrbanHeatATL initiative to produce usable data. These breakdowns highlight the edges, differences, and changes that happen within and between critical project infrastructures. These infrastructures were brought together in a shifting set of alignments and misalignments that enabled community data production. The ways our team navigated these (mis)alignments provide insight into how

[1] https://www.wawa-online.org/

membership and power was negotiated both through and around technology in a collaborative and participatory civic data project.

Collecting observations across two years of project team meetings and working with data produced by UrbanHeatATL volunteers, we use seams as analytical viewpoint to examine data work in a civic data project. Rather than arguing for seamless or seamful design, we use seams as an analytical viewpoint that embraces the "messiness of everyday life" and highlights complexity, inconsistency, and heterogeneity present in real-world sociotechnical systems [10]. It is critical to account for these factors to understand data work, which always occurs in seamful spaces that cross infrastructures, whether those be data types, softwares, open data platforms, hardware, social structures, or institutions. It is especially important to understand seams in the context of civic data, as seams are sites where power and participation are negotiated.

Our attention to seams provides insights into temporal and political aspects of data production in a civic data project. We detail how product evolution, personnel turnover, and institutional change shifted underlying infrastructures and caused changes in established alignments and misalignments – breakdowns in intended (mis)alignment that had previously been established to enable data production in accordance with project goals. As a result, we argue that (mis)alignments decay as seamful spaces change over time. In other words, the ability to work across multiple infrastructures requires ongoing maintenance and repair work that accounts for the dynamic change in underlying infrastructures [95]. In addition, we also find examples of how UrbanHeatATL *strategically leveraged* seamful alignments and misalignments resulting from the gaps between infrastructures to control access to data and information. Our fieldwork shows how alignment is not always the given desired state, but rather that seamful alignment and misalignment are opportunities for agency and action. Based on our findings, we argue that seams, the gaps and overlaps between heterogeneous infrastructures, are places where power and membership are negotiated in civic data projects. Through our analysis, we contribute to ongoing discussions of civic data work by: (1) providing a detailed empirical account of civic data work in seamful spaces; (2) identifying the forces of infrastructural change that cause alignments in seamful spaces to decay over time; and (3) sharing a set of recommendations for establishing equitable collaborations across seamful spaces. Taken together, these contributions help us understand seams as a site of agency in civic projects. Ultimately, our analysis of seams provides insight into the temporal qualities of seams and the role seams play as power is negotiated across seamful spaces.

2 Related Work

The data pipeline used in this citizen science project constituted a patchwork data production system integrating multiple tools to produce temperature maps. As data production was situated within a nonprofit, it was shaped by the specific practices and challenges facing resource-constrained organizations. Through related work, we highlight the role of "homebrew databases" [109] in nonprofit information management which informed our analysis. Related work on seamfulness [107] provides a second core concept informing this work, building on previous research on collaboration in seamful spaces. Homebrew databases and seams share characteristics of fluidity [110] or ephemerality [107], a commonality that motivates our work examining long-term maintenance and breakdowns in seamful CBO data production.

2.1 Data in Civic Projects

The rise of data-driven decision making in funding and governance has increased pressure on activists and advocates working in civic spaces to engage with data. As a result, there is growing interest in HCI in understanding the challenges and potential around using data to pursue social and political goals [4, 16, 22, 94]

Considering the perceived value of data in civic spaces, data becomes an important resource for social and political action. For advocacy organizations, data often plays multiple important roles, legitimizing the work of the organizations to external stakeholders, fostering innovation around quantifying social issues, mobilizing diverse audiences, and amplifying the visibility of marginalized groups [24]. Individuals and organizations can obtain data by finding and accessing data made available by other stakeholders or producing data themselves. The open data movement has aimed to increase the availability and accessibility of data, creating more information resources to support the use of data in advocacy and decision making [51, 53]. Critics highlight issues limiting the accessibility of data portals [9, 55, 56, 60, 61, 77, 105], inconsistencies in formatting and metadata that make it difficult to synthesize data for application [9, 75, 89, 105], and an emphasis on access over information justice [52]. Nonetheless, activists leverage imperfect data, performing additional work to make open data actionable [3, 104]. Activists also produce their own data, tailored to the specific context and rooted in local knowledge [21]. Practices of data production are particularly common around environmental issues. Local-scale monitoring and conservation projects that have long been influential in developing solutions to problems like pollution, wildlife deaths, or pest outbreaks [71]. A wide variety of technological tools and platforms have been developed to support members of the public in monitoring and protecting natural resources such as air [5, 7, 47, 99], water [41], and forests [108]. While volunteer motivation and data quality are often highlighted as key concerns in these projects, Gabrys argues that environmental monitoring projects can utilize data that is "just good enough" to demand further action from regulators [36]. The recognition of multiple stakeholders in civic decision making around environmental challenges highlights the need for HCI research to address not only the isolated practices of data production, but how multiple stakeholders engage in civic issues around data. Recent work has highlighted how multiple stakeholders, from activists to municipal government, leverage climate data in plural and sometimes contradictory ways [16, 35]. Critically, this growing body of work highlights the local, relational, and plural qualities of climate data, arguing that "data are perhaps best understood...as a set of relations" [94]. This project aims to understand data as a set of relations that shape and are shaped by choices community partners made as they navigated the edges of multiple infrastructures to produce civic data. We contribute a detailed account of sociotechnical systems producing civic data, building on ongoing discussions on the role of data in local civics and particularly in understanding data in CBOs.

The Community Based Organization (CBO) is an essential site with a particular context that plays an important role in shaping civic data work. Advocacy and activist work is often pursued by CBOs, making it critical to understand the role of CBOs in civic data. For CBOs, data promises to improve decision making, increase effectiveness of programs, amplify marginalized voices, activate stakeholders, legitimize the organization and the organization's mission, generate innovative ways of understanding key issues, and support cases made to funders [11, 24, 32, 57]. HCI researchers have engaged with CBOs working with a wide variety of data including volunteer contacts and hours [107], case management [12, 39], program usage [6, 112], and data about key issues related to their mission [35, 58, 64, 80].

Though most CBOs are engaging in some form of data work, working with data presents many challenges, especially to organizations with limited resources. Many nonprofit organizations have few staff with formal research training, lack access to affordable technical assistance, and face limits in terms of staff time, funding, and access to technical tools designed to support their work [13, 32, 67, 70, 97, 110, 111, 117]. Considering the increasing pressure to engage with data and the limited capacity to manage it, many CBOs produce more data than they use [93, 97]. As a result, CBO data can be characterized by fragmentation and data drift, creating a 'cycle of disempowerment' for nonprofits [14].

CBOs adapt to these circumstances with workarounds that creatively meet information needs but sometimes end up creating additional, potentially burdensome data work. For example, organizations might adopt suboptimal but low-cost ICTs, that nonetheless entail unforeseen burdens from poor usability or low functionality [117]. Another common practice is the development of ad-hoc information management systems that are assembled to meet information needs [2, 3, 36, 103]. The "homebrew databases" that emerge work across multiple systems and mediums, including personal office applications, printed paper copies, and custom technical tools [109]. These systems are continually reconfigured as volunteer managers respond to diverse and fluid information needs and seek information management systems that reduce overhead, a process which ultimately creates more data maintenance work [109]. Tran et al. describe the messiness of these ICTs and reconfiguring practices as *tinkering*, a care practice that allowed the organization to adapt information management systems as needed to provide care [101].

Considering both the challenges and opportunities for CBO data practices, we build on the description of homebrew databases [109], by providing an in-depth analysis of the breakdown and maintenance of a single homebrew database used in an action citizen science project [118]. Particularly attending to the observation that these databases are re-configured, re-assembled, and tinkered with over time [102, 109], we add to existing work by examining different forms of break-down that necessitated active maintenance as components of the assemblage failed over a five year period. Finally, we build on previous work on homebrew databases by examining how membership was negotiated through and around these data pipelines by identifying homebrew databases as seamful spaces.

2.2 Seams and Seamfulness

The language of seams originated in conversations around ubiquitous computing, and have since spread to broader use in HCI. Weiser was the first to explicitly articulate seamlessness in *The Computer for the 21st Century*, which detailed a vision of future computing with ubiquitous devices that users seamlessly transition between [113]. In this line of thinking, seams are a design challenge which may be overcome to create a continuous, holistic user experience [40, 63, 74]. Seamfulness, on the other hand, challenges the implicit value of seamlessness, embracing a design approach that emphasizes configurability, appropriation, complexity, and heterogeneity [48]. Chalmers, for example, argues that seamlessness is not a requirement for ubiquitous or wearable computing systems, and leverages seams instead as a generative feature to draw on in design work [15]. Rather than opposing approaches to design, the seamful-seamless debate can be viewed as an articulation of complementary approaches that ultimately encourage different forms of user agency, prompting instead to ask how we might design "beautiful seams" [48, 114, 115].

Growing out of Chalmers' ideas of seamfulness focused on the boundaries of technical infrastructures, the language of seams has also been applied to sociotechnical systems as an analytical viewpoint that emphasizes complexity, inconsistency, and heterogeneity by embracing the "messiness of everyday life" [28, 29]. In this analytic mode, Vertesi adopts a language of seams to describe how planetary science teams used readily available tools to creatively work across multiple, heterogeneous infrastructures to "achieve fleeting, nonstable, even ephemeral moments of alignment" [107]. Seamfulness has also been adopted to describe social media use in disaster response [23], mobile and remote work [33, 65], and civic dashboard development [78]. Attending to seams draws attention to multiple overlapping infrastructures, each with their own politics, standards, and epistemologies, and the creative work that actors perform to align them [107]. For example, Vertesi describes how a distributed science team accessed power through an on-site generator converting European power grid to the American standard and achieved co-presence by stitching together multiple conference lines, video feed, networked software, and document sharing tools. Through these examples, we see various ways that overlapping heterogeneous infrastructures created seamful spaces which were carefully and creatively navigated by actors within those spaces to create fleeting moments of alignment in "in ways concordant with membership" [107]. We also see team members pushed to the margins when alignment is not achieved. Vertesi describes one such moment when a scientist lost carefully crafted visual materials in a conversion from Mac to PC, ultimately impacting the scientist's status and their ability to influence discussion [107]. This example draws attention to the ways power and membership are negotiated in seamful spaces.

One gap that has been previously identified in seams literature is the lack of work around temporal seamfulness [48]. One notable exception is Thomer and Rayburn's analysis of data management by museum curators. Because no single platform alone supported the full information needs of museum curators, actors bridged multiple systems and worked to keep them "stitched together" into a broader workflow. Patchwork data systems in this context are

characterized as "intergenerational," passing from one workplace group to another within the institution. These "intergenerational databases" contain marks of previous workers, for example traces of past data structures or formats [98]. Whereas Vertesi highlights the ephemerality of seamful spaces, providing examples of momentary alignments that are regularly recreated, Thomer and Rayburn characterize seams as long-lasting, though not permanent. Though these alignments might last for years, they note that "just as a quilt wears over time, databases need updating, reconfiguring, and reworking" which requires creative workarounds that allow the system to continue running [98].

We build on this work by providing a situated example of patchwork database practices in a five year cross-institutional citizen science project. This project utilized a combination of free or low cost and custom tools stitched together in a semi-permanent patchwork data system that passed "intergenerationally" as member turnover shifted the project team over time. Unlike museum curators, this patchwork data system involved not only the project team, but also community scientists, non-expert students or community members that performed alignment work to submit environmental data. Borrowing Vertesi's view on seams as an issue of group membership, we show how seams provide insight into how the group navigated project membership across a seamful space over the course of a long-term citizen science effort.

3 Background: Tackling Urban Heat Islands

Amid a global pandemic and a civil rights turmoil in 2020, a diverse set of stakeholders came together to tackle urban heat islands in Atlanta. Through ongoing conversations with community members, a cross-institutional collaboration emerged involving multiple local universities and nonprofits hoping to address urban heat islands through community science. The goal was to engage the public in mapping urban heat islands. The original project website describes it's ultimate mission "to use this data, collected by community members, to further environmental and climate justice" [2] by taking action on urban heat islands.

Urban areas are hotter than surrounding rural environments due to building materials that retain heat, human activities that produce heat, a lack of natural cooling resources like trees and other greenspaces, and effects of structures on wind patterns [37, 83]. Because of longstanding histories of structural racism in the U.S. that have shaped the built environment, urban heat islands disproportionately impact low-income neighborhoods and communities where people of color live [45, 68]. The impacts of urban heat islands reach far beyond the discomfort of a hot day; urban heat islands impact chronic health conditions [44, 88, 91], create economic burden as families pay to cool their homes [66, 100], and can negatively impact community health [20, 87]. These patterns create an intersecting problem of environmental justice, widening existing health, economic, and social inequities. An environmental justice approach to urban heat islands includes recognizing that the harms of extreme heat are inequitably distributed across the city, meaningfully involving community members in knowledge production and decision making, and implementing measures that proactively mitigate the unjust impacts of urban heat islands.

Organizing around urban heat islands as a local civic issue, UrbanHeatATL brought together a diverse group of stakeholders committed to community-centered science and environmental justice. Initial conversations brought together two professors and environmental scientists from different institutions. One professor was a climate scientist at an R1 research institution; the other was situated within a leading liberal arts college and HBCU and served as the co-founder and executive director of a nonprofit promoting environmental stewardship, environmental education, and environmental justice. A partnership with the Mayor's Office of Sustainability and Resilience provided a direct route to impact for data submitted by volunteers to inform city-level decision making. As the project continued to take shape, other collaborators came on board, including multiple professors from the R1 university specializing in public policy and remote sensing, a rotating cast of student interns from both universities, and additional nonprofits focused on sustainability or environmental justice in the state.

The UrbanHeatATL project puts low-cost temperature sensors in the hands of volunteer community scientists, who carry the temperature sensor as they walk, bike, or skate around the city. The temperature sensors are produced by PocketLab [3], a company that makes off-the-shelf sensors designed to be used in the K-12 classroom. Community scientists attend a training session where they learn about urban heat islands and practice using the sensor. After attending the training, volunteers can "adopt" the sensor, which they can then use to collect outdoor temperature data at their discretion. We will describe this process in more detail in section 6.

Originally, the project was primarily funded by a seed grant provided by one of the universities involved with the project. For the first two years (2021 and 2022), the project was fairly well-resourced, with many students brought on to support with data processing and communications aspects of the project. However, from late 2022-2023, the infrastructure of the project largely deteriorated in the context of restructured departments, shifting funding, and staff turnover. When the first author joined the project team in Spring 2024, our nonprofit partners were the only remaining original collaborators actively engaged with the project. Only one of the original core collaborators is still regularly consulted and most of the team involved in day to day operations in summer 2024 had not been involved in the first phase of the project. As a result, the project had experienced almost complete personnel turnover in the past five years, lost many of the resources available at the start of the collaboration, and shifted funding sources and institutional contexts.

In the face of these shifting resources and responsibilities, our nonprofit partners had continued to engage students and community members in data collection, but the collected data had not been processed in over two years. When the first author joined the project team in 2024, there was no functional method for cleaning, processing, analyzing, or visualizing incoming data even as the project team continued to focus on training new community scientists and collecting more new data. This paper explores the breakdowns we experienced as we worked to repair and maintain

[2] https://urbanheatatl.org/

[3] https://www.thepocketlab.com/

the technical infrastructure that enabled UrbanHeatATL to translate measurements recorded by volunteers into temperature maps of the city. We characterize these breakdowns as misalignments that made visible the terrain of a seamful space made of multiple, varied and dynamic infrastructures. Attending to the seams of civic data projects draws attention to specific kinds of maintenance and repair work necessary for long-term collaborative data projects and highlights the conditions of civic data projects, such as collaborations across organizations and the use of multiple low-cost tools to achieve information goals. Understanding the work and conditions of civic data production helps us better understand how to support community-based organizations seeking to use data for social or political goals and deepens our understanding of civic participation in a datafied world.

4 Methods

Our insights in civic data came out of a cross-disciplinary team with a common interest in civic participation collaborating on an action citizen science project. The first author originally pursued a collaboration with UrbanHeatATL in order to understand how participatory data production could support climate justice. They have worked with and around collaborators in this project across multiple institutions for three years and have been directly involved with the project team coordinating UrbanHeatATL for two years. During that time, the first author attended weekly meetings and was responsible for processing, visualizing, and mapping data. Part of this role included maintaining a data cleaning and standardizing pipeline and periodically reporting on the results to the community partners. In addition, the first author led sensor trainings, collected data with the temperature sensor, created promotional and training materials, planned and led workshops with community members, and prototyped technological tools for the urban heat context alongside UrbanHeatATL team members from our nonprofit partner. While all these activities informed our analysis of this sociotechnical system, this paper primarily focuses on empirical snapshots documented while participating in team meetings and working with data produced by volunteers. The second, third, and fourth authors are members of our nonprofit community partners and key contributors to UrbanHeatATL during the time period covered by this study. As such, they were deeply involved with the day to day and big picture planning of UrbanHeatATL, attended weekly meetings, coordinated community scientists, communicated with volunteers, led sensor trainings, created promotional and training materials, submitted temperature data, and planned events for community scientists. The fifth and sixth authors served in advising roles on the first author's research with UrbanHeatATL.

Our analysis draws on ethnographic notes taken by the first author as a participant observer, describing both ongoing data work and the organizations collaborating in UrbanHeatATL. We interpreted seams as a key theme of our work in this context as regular breakdowns in technical infrastructure demanded the time and attention of the project team. Aligning heterogeneous data types, information sources, and social infrastructures constituted a large portion of the first author's day-to-day work on the project. Using seams to frame data work at UrbanHeatATL, the first author listed key misalignments that had disrupted data production during their time on the project. Using this list, the first author experimented with different ways of grouping these breakdowns: whether misalignment was intentional or not intentional, whether the alignment was repaired or not, the degree to which alignments challenged data work, and what kinds of infrastructural changes lead to misalignment. Through this process, the first author settled on four key moments of disruption that helped us understand the multiple ways that seams were navigated in UrbanHeatATL. For each key moment, we identified additional misalignments that occurred during our field work with UrbanHeatATL and echoed similar patterns of misalignment. Returning to field notes for each of these moments, we analyzed the underlying infrastructures involved at each seam, the ways in which the seam had originally been aligned, factors contributing to misalignment, how the UrbanHeatATL team chose to navigate the misalignment, and the work that was required to achieve alignment again. The first author also continued to add to the list of misalignments throughout the process of writing. Some of these additional misalignments were added to explain or complicate the four key misalignments. The second through sixth authors offered repeated input to the misalignments and major themes in meetings where the work was presented, as well as providing feedback on written drafts. These discussions further shaped our reporting on seamful misalignments in UrbanHeatATL.

Through diagramming the space, reviewing field notes, writing about our observations, and reviewing related literature, we found membership to be a key theme that helped us better understand how seams were navigated in this project and why seams were navigated in particular ways. We attend to this aspect of seamful spaces as we analyze four examples of breakdowns in (mis)alignments in the specific context of UrbanHeatATL.

5 Civic Data Production in Seamful Spaces

Building on research that aims to understand data in community-based organizations (CBOs), we document ongoing maintenance and repair in civic data production. Our long term engagement with the UrbanHeatATL initiative provides insight not only into the everyday work of data production, but conditions that led to erosion, breakdown, and decay of the sociotechnical systems. Aligning with Jackson, we "take erosion, breakdown, and decay, rather than novelty, growth, and progress as our starting points in thinking through the nature, use, and effects of information technology and new media" in local civics. [50]. By engaging in the work of maintenance and repair, we find that seams are sites of agency where people act to sustain civic projects.

UrbanHeatATL provides a case study of data work occurring in a seamful space, a "heterogeneous, multi-infrastructural environment" [107]. Data production at UrbanHeatATL requires work across multiple sets of disparate infrastructures, including *technical infrastructures* (PocketLab sensor, the PocketLab mobile app, volunteer smartphones, cloud-based services like Google Drive, communication platforms like Email and Slack, and software such as QGIS and Tableau), *social infrastructures* (an interdisciplinary project team, training events, and communication practices), and *institutional infrastructures* (multiple universities, a non-profit, and a for-profit company). These infrastructures are overlapping and

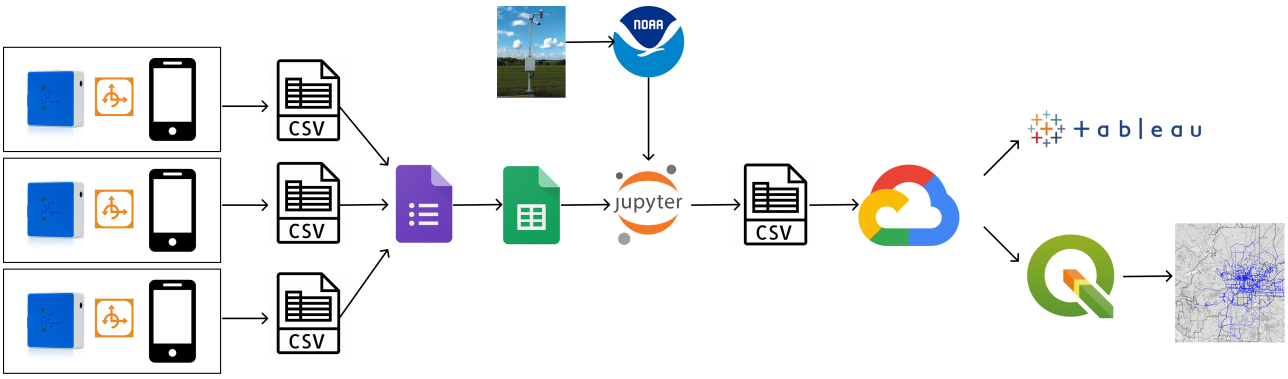

Figure 1: UrbanHeatATL used low-cost temperature sensors that connected to community scientist's mobile smartphones via an app. The community scientists downloaded temperature records as a CSV file onto their phone and submitted it to a Google Form. A Jupyter Notbook script accessed the CSV files via a Google Sheet. The data was cleaned, standardized, and augmented with historical temperature data from a NOAA sensor located at a nearby airport. Running the script generated a single CSV file combining all the temperature records. This master CSV file was stored first on Google Cloud, later on Google Drive, and used to create data visualizations in Tableau or maps in QGIS.

intertwined, creating a *seamful space*, which UrbanHeatATL endeavored to work across to produce civic data. We argue that all civic data work occurs in seamful spaces, and that the production of data artifacts in the context of CBOs and issue advocacy puts into contrast not only the technical seams of exporting and importing data, but what multiple layers of technical, social, and institutional seams mean for an organizations ability to accomplish social and political goals.

In seamful spaces, heterogeneous infrastructures overlap, collide, and breakdown [107] We refer to the gaps and overlaps between these systems as "seams," places where the edges of one infrastructure meet the edges of another. A "seamless" experience would be one where the gaps arising because of differences between multiple infrastructures remain invisible to someone working across the infrastructures. In contrast, "seamfulness" is an approach to design that highlights the seams between heterogeneous infrastructures, making them visible and exploitable by users as they work across multiple systems. In this paper, we do not argue for a seamless or seamful system design for data production. Instead, we seek to understand the way that systems are deployed by organizations to accomplish work across seams. In this context, seams are sites of agency where actors negotiate power, politics, and membership in civic projects.

Whereas "seamful" and "seamless" are useful terms for describing approaches to design, our focus on the work of data production leads us to center other terms, building on work from Vertesi's application of the vocabulary of seams [107]. We use the terms *alignment* and *misalignment* to describe an ability to work across multiple infrastructures. Below, we describe how UrbanHeatATL contributors strategically operationalized both alignment and misalignment to support their social and political goals. Doing so required creative work and ongoing maintenance at the seams of multiple infrastructures. Because asserting (mis)alignment requires specific creative work that responds to the context of the seam (the edges, gaps, and overlaps of specific infrasturcutres), we find that UrbanHeatATL tools and practices needed to change continuously to adapt to changes in the underlying infrastructures leveraged by the project. Breakdowns, then, refer to failures of the sociotechnical system that occurred when there is unwanted (mis)alignment. Below, we describe multiple different forms of work and approaches to navigating (mis)alignment: Section 6 details ongoing work was performed to maintain alignment, section 7.1, section 7.2, and section 7.3 describe cases where previously aligned systems fell into misalignment, and subsequently needed to be realigned, and section 7.4 documents a case where misalignment benefited our community partners such that the project team opted to maintain misalignment.

6 Alignments: Data Production at UrbanHeatATL

Data production at UrbanHeatATL required the alignment of multiple, heterogeneous technical, social, and institutional infrastructures. UrbanHeatATL used a set of free, low-cost, and custom tools to recruit and train volunteers, record temperature measurements, and process and map submitted data. A visualization of the technical aspects of this system can be seen in Figure 1. By describing how multiple infrastructures were aligned to produce heat data, we draw attention to the ongoing work that enabled us to work across multiple infrastructures and successfully produce data about urban heat islands. Instead of arguing for seamful or seamless design of civic data infrastructures, we use seams as an analytical lens to describe data work in seamful spaces [107].

The work of producing heat maps started by gathering volunteers to generate temperature records. Participatory data production relies on the ability to recruit, train, and motivate volunteers [84, 85]. This aspect of the sociotechnical system falls primarily under the responsibility of our nonprofit community partners, who are experts in community organizing and environmental education. After selecting dates to host sensor trainings, a team member produced recruitment materials in Canva, a free design tool, which were then shared on social media as well as the nonprofit's monthly

newsletter. The nonprofit provided space for the training, lead training sessions, and created and distributed training materials.

Training volunteers was a critical step for generating complete and consistent data across volunteers. The UrbanHeatATL project used an off-the-shelf temperature sensor made by PocketLab to generate temperature records as volunteers walk around the city. The Pocketlab sensor connects to the volunteer's phone via Bluetooth. For each walk, volunteers must ensure that they have selected the requested data, that the sensor is logging data at the rate of 1pt/second and that location permissions have been turned on. There is an accessory sensor thermistor that needs to be plugged in to accurately collect granular temperature measurements. Volunteers are trained to hold the sensor away from their bodies, to avoid direct sun, to wait until the thermistor acclimates to outdoor temperatures, and to avoid collecting temperature data indoors. When the route is completed, volunteers download the temperature records as a CSV file and then upload the file to a Google Form. In addition to providing an upload for the CSV file, the Google Form asks the volunteers name, contact information, their device type, and provides a space for volunteers to leave a comment or upload any images from their walk. Through this training, volunteers learn how to participate in the assemblage, generating data that is aligned with the data submitted by other volunteers and with the data processing infrastructure. Doing so required significant stitching work to align the sensor, mobile device, applications, and submission forms to contribute data.

CSV submissions come in many different formats, which then need to be processed and standardized through a custom python script. The submission Google Form is linked to a Google Sheet, which contains all the submission data, including a column of Google Drive links to csv sheets stored in Google Drive. A custom python script, originally written by a student intern in 2022, iterates through each CSV file, extracting and concatenating temperature records into a standardized format. This processing script creates a CSV file with over 1.5 million rows, over the limit of what can be processed by most data software like Excel or Google Sheets. As a result, that data can only be effectively analyzed through code, or in more specialized software such as Tableau or GIS software capable of handling larger datasets. Specialized skills and software licenses were needed to effectively use these tools, limiting the number of people on the team who could work directly with data as a whole.

From 2020-May 2021, data was processed monthly by a student intern and made publicly available on the project website through an ArcGIS plugin on the project website. From May 2021- June 2024, no data was processed. From June 2024 onwards, data was processed manually by the first author, who used the processed CSV file to create maps and data used in presentations to community members volunteering with the project.

Producing heat maps required many different alignments: our nonprofit partners aligned internal processes to plan and advertise training events, volunteers learned how to use the temperature sensor to produce records that were aligned with other volunteers and with the information needs of the project, and multiple low-cost platforms were used to gather and standardize incoming temperature records. The set of social and technical alignments that enabled data production was created by ongoing work of volunteers and the UrbanHeatATL project team. Social alignments included the work of communicating, coordinating, training, data collecting, and analyzing data artifacts. Meanwhile, technical tools like the processing script, PocketLab app, and submission forms represented a technical alignment where data files were created, uploaded, cleaned, used. The social and technical were inextricably intertwined: technical alignment could only be achieved where social practices created data that matched standardized formatting requirements and social alignment was predicated on the assumption that the technical tools would successfully aggregate data into a usable form. Seam work performed by volunteers and the project team allows for these disparate tools to be used in concert to produce maps of urban heat islands. UrbanHeatATL volunteers and project team expressed agency thorugh the creative work that leveraged multiple free or inexpensive tools to build capacity for civic participation through a specific strategy of collecting mapping data. In other words, we aruge that seams are sites of *agency*. While the many layers of infrastructure here are not naturally aligned, UrbanHeatATL contributors act through infrastructural seams to achieve alignment that enables civic data work. Together, the resulting patchwork database coordinated across volunteers and multiple organizations to produce city heat maps.

7 Misalignments: Maintaining UrbanHeatATL Data Infrastructure

Above, we described how multiple actors worked to create alignment between multiple heterogeneous tools to produce heat maps. Throughout our involvement in this project, we observed how the data pipeline changed, not due to plans for reducing overhead, better meet information needs, or accommodate new forms of information [111], but simply because infrastructures temporarily aligned at the seams became misaligned over time. Thus, the work of producing data in this context required ongoing maintenance work to re-align tools through multiple breakdowns. These breakdowns draw our attention to three forces of change that challenged data production: *product evolution*, *personnel turnover*, and *institutional change*. Additionally, we identified a case where misalignment was used strategically by our nonprofit partners to assert community ownership over data. In each of these breakdowns, we describe the conditions causing the breakdown, how breakdowns were negotiated, the kinds of work needed to achieve realignment, how seams influenced membership, and how these breakdowns impacted the autonomy of our community partners.

7.1 Misalignment 1: Product Evolution

> Towards the end of September, I'm processing incoming data to share updates with the team as the summer heat begins to fade. I run the processing script and pull the csv file into QGIS. With the last fully processed data file still on, I flash the new layer on and off, a feature I use to highlight new data added each month. There doesn't seem to be anything new, but I know we have had multiple submissions, including my own. I wonder if the processing script is broken, but nothing has changed. I open the most recent submission. It's missing latitude and longitude data, an

> error which happens fairly frequently if volunteers don't turn their location permissions on. I open another file; it's missing the same information. I look for my own files. I'm confident that I have been following the correct procedure, but my recent submission files are missing latitude and longitude as well. Through more tests I find that none of the files submitted after September 21st, 2024 include location data. Customer support tells me that the company has decided to stop collecting location data without a teacher login to protect the sensitive data of K-12 students. (October 2024)

In the earliest phase of the project in 2021, UrbanHeatATL tested multiple low-cost mobile sensors capable of measuring ambient air temperatures for use in the participatory science project. They selected a sensor originally designed for K-12 classrooms, appropriating it for use in a community science project by creating a submission procedure that would collect and aggregate individual temperature measurements. The PocketLab app, designed and maintained by a private company, was a critical tool for connecting the PocketLab sensors to the varied mobile devices of the community scientists. The PocketLab app connects the sensor to the volunteers mobile phone via Bluetooth, creating alignment that allows volunteers to access records of temperatures and locations. Using the app hid the seams of bluetooth device connection, emphasizing connectivity and ease over agency of visible seams [48]. This alignment allowed volunteers to record temperature measurements as they moved about the city, enabling the participatory activities of this community science project.

However, the PocketLab sensor and app were not static. Breakdowns surfaced as the product changed in unexpected ways to fit the needs of the K-12 classroom. Tools for processing incoming UrbanHeatATL data frequently needed to be adapted in response to changes made by PocketLab. The data processing script, originally written by a student intern, stopped processing incoming data when PocketLab changed a column name from "thermistor" to "temperature probe." PocketLab updated the wording to make the downloaded CSV data more accessible to students who may not be familiar with the term "thermistor". This change, directed towards improving the product based on an informed perspective on the primary user demographic, made it impossible for the existing script, which searched for the keyword "thermistor," to process incoming data. Though the update to the processing script was not particularly complex, identifying the change that was made, understanding how this change would affect the data processing script, and solving the error required specific kinds of technical expertise. Further, it is not realistic for civic data projects attempting alignment work to predict these changes. Therefore, the shifting nature of the infrastructures aligned by the processing script necessitated ongoing technical maintenance work.

In addition to adapting technical tools to reflect changes in underlying infrastructures, UrbanHeatATL also altered data practices to adapt to product changes. The choice to limit location data collection, described in the vignette above, was another product change that challenged the production of mappable data. This decision prioritized student privacy but did not align with UrbanHeatATL's goals because it made it impossible to collect mappable temperature records with the established data practices. As described in the vignette, this change added an additional step required to create alignment between the phone and sensor. In addition to connecting the sensor, specifying the record rate, and plugging in the temperature probe, volunteers now had to create and login to account to collect data consistent with the other volunteers that could be utilized by mapping software. To adapt to these changes, the project team tested multiple alternative workflows, different app versions, ways of managing accounts, and ultimately updated all training protocols and materials to reflect new instructions that would allow volunteers to collect location data as they traveled. Without the ability to influence the design or technical choices behind the sensor, app, and mobile devices, all controlled by private companies, the UrbanHeatATL team navigated different ways they could formulate data practices within the technical constraints. Thus realignment required the UrbanHeatATL team to reformulate data practices rather than data tools.

Again, we see agency enacted at the infrastructural seams: data practices were creatively adapted to get the PocketLab app to output a CSV file that was usable by the other tools in the data pipeline. We are not arguing that these are or should be seamless experiences. Instead, we argue that agency was enacted in the gaps and overlaps of infrastructures to create alignments that supported data work. The focus on seams as sites of agency, then, raises the question of who has the power, and sometimes the burden, or producing and reproducing alignment.

All of these breakdowns required additional, unexpected maintenance work. As the PocketLab app product changed over time to better suit the needs of its core audience, the alignments that had been crafted using previous versions of the app deteriorated. Some of these breakdowns were manageable using expertise that existed within our community partner's organizations, but others, especially maintenance work that required programming expertise, necessitated technical support from PocketLab or from university partners. While this collaboration enabled the participatory science project, it also posed challenges to the independence and autonomy of project partners, specifically the nonprofit managing UrbanHeatATL. The ongoing maintenance needs that arose among shifting infrastructures necessitated technical maintenance work from external partners, influencing partnerships between nonprofit, university, and private company stakeholders.

7.2 Misalignment 2: Personnel Turnover

> I reminded the team that we are looking for the backend to that form where people sign up to express interest in adopting a sensor. I said that I had read through the meeting notes from 2021 and 2022 and that my best guess is that S created it and would have access to it, since she is the one that designed the website that includes a link to the form. One of the team members on the meeting had already reached out to her personal email to ask about social media and website passwords with no response. She wondered if she was still working at my university. If S

> works at the university, then she should have an institutional email, but we need a last name to search for their email in the university database. Another team member wonders aloud if S is part of the Slack channel from 2021. The meeting goes on. When we reach a lull, she announces that she found S and her last name on Slack, along with a gmail address. With the last name, one of the team members from my university searches S in Outlook and reports back that she still has an active work email and it looks like she is still working for our university. C sent me links to her linkedin and university email, so I will reach out shortly and ask for some of the missing info. (August 2024)

Whereas the misalignments described in section 7.1 were caused by product changes in the underlying technological infrastructures, we also encountered breakdowns that occurred simply due to patterns of shifting team membership. The project team was a critical social infrastructure developed to manage civic data production. In section 3, we discussed how shifting funding landscapes, institutional restructuring, and staff turnover resulted in significant personnel change between 2022 and 2024. The turnover meant that the project team in 2024 had inherited tools, resources, and materials that had been created and used by previous team members. Breakdowns occurred when the team retained only partial access to tools that were created by members of other institutions.

Though the distribution of project responsibilities shifted over time, the tools that had been developed by the previous team remained tied to the institutions they originated within. While originally these seams were easily aligned through inner-team communication, personnel turnover made it more challenging to mediate access, creating misalignments that resulted in partial access to project tools. For example, our team could view but not edit the UrbanHeatATL website, which was originally created and maintained by a university staff member. Eventually, our nonprofit partners created a page for the project hosted on their own website, which allowed them to include and update information as they saw fit. Similarly, the UrbanHeatATL team used a slack channel that was set up in 2021 and included many previous team members but could not access messages over 90 days old and used a private channel to communicate only with the current project team. Among this collection of partially aligned infrastructures, the UrbanHeatATL team was able to continue producing maps of extreme heat but had to work around the constraints of institutionally mediated access. The emerging misalignments created more work for the UrbanHeatATL team.

The vignette above borrows from meeting notes where a group of the authors worked to regain access to Google Form responses indicating interest in sensor adoption. UrbanHeatATL used a Google Form to gather contact information for people interested in participating in the project. In July 2024, it became clear that nobody on the current project team could access the backend of the form. The stitching work to regain access involved past meeting notes, slack channels, and a university email database, to achieve fleeting alignment – communication between a current project team member and a past project team member. This alignment was possible when one of the authors leveraged their access to university contacts granted by institutional affiliation. Our nonprofit partners had previously tried unsuccessfully to contact this team member at an outdated personal address. Membership at the university afforded some team members access to additional contact information that was obscured from our nonprofit partners, who did not have access to the university's communication infrastructure. Here, the breakdown in access to the recruitment form was repaired when team members from multiple institutions collaborated to repair alignment. The ability to realign this seam was not evenly spread across the project team – members with shared institutional affiliations were able to access information that was not available to our nonprofit partners. In these cases, managing a civic data project meant navigating seamful spaces mediated by the technical infrastructure of large institutions.

Across these breakdowns in alignment, we see how project turnover contributed to the decay of aligned seams in the UrbanHeatATL data assemblage. Bopp et al. argue that turnover contributes to data fragmentation, leading to a cycle of disempowerment at mission-driven organizations [14]. We find a similar pattern in our work with UrbanHeatATL: member turnover made seams, the gaps and overlaps of multiple infrastructures, harder to navigate. Ultimately, the ability to access and use project tools required a re-alignment of technical and institutional infrastructure with gaps made visible by member turnover. Stabilizing the sociotechnical systems required a skilled navigation of information across multiple infrastructures. One pattern that becomes clear through the close observation of this seam work is that institutional affiliation influenced who was able to facilitate realignment. Therefore, some of our team members had greater agency to work between infrastructures than others.

7.3 Misalignment 3: Institutional Change

> All week, I've been hearing and reading news about government datasets removed from public view. In our meeting today, J told us that a data source she frequently uses for social determinants of health had been removed by the CDC. I checked on EJScreen. It's down too. The message on the screen reads:
> "This site can't be reached. Check if there is a typo in ejscreen.epa.gov."
> (February 2025)

Many organizations rely on open data as a key source of information about their work [32]. While these portals often increase the availability of data, they do not guarantee that data will be accessible or actionable [81, 104]. Adding to the discussion of open data use in by nonprofits and advocacy groups, we describe how changes to these portals over time created seamful breakdowns in data projects.

In the vignette above, an environmental justice mapping tool with data about many environmental indicators in the U.S. became unavailable during the first weeks of the Trump administration. On February 5th, the U.S. Environmental Protection Agency (EPA) removed EJScreen, which had been available to the public since 2015. The removal coincided with the removal of content from the

EPA website after Donald Trump's executive order seeking to end DEI initiatives.

In Fall of 2022, UrbanHeatATL had used data from EJScreen in a mapping workshop that put volunteer-collected temperature data in conversation with sociodemographic, environmental, and health indicators, many of which were accessed through EJScreen. The first author used data from EJScreen to create a series of maps that were shared in community workshop activities to contextualize and tell stories related to extreme heat data.

Unlike the other breakdowns described here, the loss of EJScreen did not affect UrbanHeatATL's ability to make maps of extreme heat. There were several reasons that the misalignment of this seam was not as disruptive as the other breakdowns we described. First, a hard copy of relevant raw data from EJ screen was saved in the first author's local files, meaning that the UrbanHeatATL team was still able to access the data included in previous workshops with community members. Though these saved files would eventually be outdated, the team could continue using the files that had been saved before EJScreen tool was removed. Second, communities of researchers and activists came together to recreate EJScreen resources, facilitating access to data that was no longer being provided by the U.S. Environmental Protection Agency. Through the infrastructural repair work done by other members of the environmental justice and research communities, UrbanHeatATL was able to maintain access to this data. The larger community worked to maintain data access by creating new infrastructure to patch the seam. As a result, the UrbanHeatATL team did not take significant action to realign this seam.

Like the other technical breakdowns we have described, this misalignment was caused by underlying social conditions: the shifting of political priorities through a changing administration. In a departure from previous U.S. presidencies, the 2024 Trump administration aggressively worked to limit access to information that did not align with their agenda. While not all administration changes lead to such dramatic change, administration changes and shifting political contexts might affect data availability across all levels of government, as funding availability, political support, and popular interest influences city, county, state, federal, and international data practices. We observed a similar pattern in an open data portal provided by the National Oceanic and Atmospheric Administration (NOAA), which shifted the online access point for local historical climate data to an updated system with a different data request format in Spring of 2023. Considering the dynamic factors that shape data availability, we should not consider open government data to be a static resource. Instead, open data portals are a dynamic infrastructure, with shifts that cause breakdowns in the alignments that facilitate civic data projects over time. These cases highlight how the technical requirements of data work and access were interwoven with social conditions that were subject to change over time.

7.4 Misalignment 4: Strategic Seamfulness

> The UrbanHeatATL website features a picture of a downtown mural, depicting an American civil rights activist. Under the heading of "mission" the website proclaims "The initiative aims to use this data, collected by community members, to further environmental and climate justice." In the top right, there's a tab labeled "data" right next to a link to "get involved". I navigate to the "data" page and follow a second link to "explore with ArcGIS." The page takes a while to load, and when it does, I see an alert with a red bar along the top of it across the bottom of the screen. "Unable to add layer Cumulative Data July 2, 2021 - Jan 27, 2022" I close the alert and zoom in on the city, but all I can see is the satellite map with the names of roads crisscrossing across the city landscape. Following a suggestion on the "data" page, I send an email to "request all data," introducing myself as a PhD student at the local university. (October 2021)

The previous cases reported in sections 6 through 7.3 are somewhat familiar, showcasing practices that might otherwise be described as articulation work [96] or repair [50]. In the other cases, we see an emphasis on alignment, interoperability, and cohesion that enable data production. In our final case, we provide a counter point where misalignment was valuable and productive, leading UrbanHeatATL contributors to engage in work that maintained misalignment, rather than alignment. In this case, repair means keeping things broken in meaningful ways. This final case helps us recast the examples shown thus far by highlighting the key point that civic data projects are not about creating seamless alignment. Instead, attending to the seams of civic data reveals sites of agency where power and politics play out through both alignments and misalignments.

Early iterations of the UrbanHeatATL project included an open data portal hosted on a website owned by the university partner. The vignette above describes a breakdown in the data pipeline as originally conceived. However, our nonprofit partners were not interested in realigning infrastructures to permit data access. Instead, our partners benefited from the misalignment because it offered more control over the data produced by UrbanHeatATL. For a nonprofit representing a community historically plagued by research extraction that casts community members as objects of study, part of the work of environmental justice meant maintaining control of and acknowledging community contributions for UrbanHeatATL data. In the absence of a seamless way for the public to access data, external stakeholders needed to contact the project team, build a relationship, and establish trust in order to access data. The nonprofit's role as a gatekeeper of data was enabled by strategic misalignment that prevented public data sharing. With this seam left misaligned, our partners could choose who could access the data, what data to share, and under what conditions.

The misalignment that ended public data sharing ultimately afforded more power to our nonprofit partners. Seams became a key resource for managing data governance [1, 54], through which our nonprofit partners negotiated who was a part of the team and who was not. Furthermore, rather than a single decision on whether to make data publicly available or not, the breakdown of this seam allowed our community partners to decide not only whether information was shared but what information was shared, when, and

with who. The breakdown shifted the user experience from seamless to seamful, emphasizing the agency of the UrbanHeatATL team through configurability rather than the agency of external stakeholders with a continuous, intuitive path to accessing information [48].

Our nonprofit partners also intentionally used seamfulness to protect information by adding additional steps to access information. For example, our nonprofit partners hosted a series of trainings on local college campuses. To ensure that only college students attended, they published recruitment materials that did not include a date, time, or location. Students interested in adopting a sensor would sign up on the interest link, then the project team would email them to tell them about the meeting details. Our nonprofit partners chose this method to ensure that they could provide a training session specifically tailored to college students. The choice disrupted access to information by inserting additional technical infrastructures (Google Forms and email communication) to mediate access to information. The insertion created additional seams, gaps and overlaps between technical infrastructures that required additional alignment work from potential volunteers and project team members. Student volunteers had to register interest and a member of the team needed to continually check for incoming responses to forward training session information on. However, creating seamfulness by inserting additional technical infrastructures protected training session details allowed our community partners to control when alignment occurred and for whom – ultimately allowing our community partners to control membership at the collegiate trainings.

Whereas the other seams we have discussed in the section are situations in which breakdowns challenged the autonomy and independence of our community partners, we argue that these strategic misalignments actually afforded more power to our partner organization. One critical difference was that these were seams our nonprofit partners could align using skills and capacities within their organization. While like many nonprofits, they had limited technical support available to create and maintain alignments using custom technical tools like the data processing script, they were experts in coordinating volunteers and building relationships with city stakeholders. The seams described here could be aligned through communication work without requiring technical support from external partners.

Working across seams is often a question of interoperability, an ability to construct "a shared, ephemeral space across multiple seamful infrastructures, establishing at the same time both interactional ground and membership" [107]. We aim to complicate this pattern by highlighting examples where a civic-data project strategically acted to disrupt interoperability, bounding the shared space in a way that included some and excluded others in concordance with specific values regarding how environmental data should be governed. The goal here is not seamlessness or even alignment, but an arrangement of multiple infrastructures that allows our community partners to effectively pursue political goals through civic data production.

8 Discussion

The vignettes shared from field work emphasize the political and temporal aspects of seams in a citizen science project. Our long-term engagement reveal that maintenance is necessitated when intended (mis)alignments are disrupted as underlying infrastructures change over time. While our perspective on long-term civic data work is tightly linked to conversations on infrastructure [62, 77, 96] and repair [50, 106], we chose instead to focus on seams, agency, and power to understand not only how UrbanHeatATL contributors interact with the technology but how the organization pursues political action through these systems. We argue that seams are a site of agency where actors can leverage existing tools to build new capacities that support their social and political goals. Just as importantly, seams are places where power is exercised by controlling access to information, and the ability to create alignment privileges those with specific skills and training. These patterns of seamful spaces must be considered in civic technology more broadly, especially in academic-based collaborations with community partners. Aiming for a more robust understanding of how data operates in civic spaces, we contribute detailed accounts of civic data work in a community-based organization, three forces of infrastructural change that necessitate ongoing maintenance work of (mis)alignments, and recommendations for establishing equitable collaborations across seamful spaces.

8.1 Seams Over Time

Sustainability of technology or design interventions has been a topic of concern within HCI scholarship [8, 40, 46, 72, 73, 79]. Vertesi characterizes alignment in seamful spaces as ephemeral, describing a temporal quality to seamfulness with implications for the ongoing work that enacts alignment [107]. Longterm engagement with UrbanHeatATL allowed us to observe how alignment work was negotiated across multiple collaborators and critically, how this data assemblage came apart at the seams. Through our ongoing work with UrbanHeatATL, we build on Vertesi's work by highlighting a key temporal quality of seams – that **intended (mis)alignments in seamful spaces decay as underlying infrastructures change over time**. We chose the term decay to capture the way previously aligned elements become misaligned over time as underlying tools, teams, and institutions change.

Our work points to the small, everyday changes that slowly accumulate to destabilize technical interventions. Others have discussed seam work in times of crisis [23, 30], including seamful misalignment during times of crisis such as breakdowns in human infrastructure in a youth empowerment program during the COVID-19 pandemic [17]. Adding to their research on infrastructural breakdowns, we acknowledge that these kinds of infrastructural change are not restricted to moments of crisis; rather, infrastructural change is the norm. Thus to understand how actors work across seamful spaces, we must acknowledge not only the heterogeneity but also the fluidity of infrastructures. Through our work with UrbanHeatATL we observed three forces of change that shifted underlying project infrastructures: *product evolution*, *personnel turnover*, and *institutional change*. Each of these forces changed the infrastructures underlying UrbanHeatATL, leading to seamful misalignments that caused breakdowns in data production.

These instabilities may be easier to manage when there are points of consistency in seamful spaces. In other words, continuity in infrastructures can help manage change in other infrastructures. In section 7.3 we saw how a community with long-term involvement in environmental justice came together to recreate EJScreen when the data portal was threatened by institutional change. Similarly, personnel turnover can be balanced out by product consistency to maintain more stable alignments. For example, "intergenerational databases" passed from museum curator to museum curator as described by Thomer and Rayburn benefit from a level of stability in the underlying products and institutions that allow these databases to maintain alignments through personnel turnover [98]. In contrast, UrbanHeatATL faced product evolution, personnel turnover, and institutional change within the same 1-2 year period. When all three forces of change are experienced at the same time, the work of maintaining alignment becomes more difficult.

The precarity of these alignments calls for ongoing care practices and attention to seams that contributes to longevity in seamful data assemblages [98, 101]. In UrbanHeatATL, the turbulence caused by the coalescence of multiple forces of change meant the work of maintaining alignments was primarily reactive rather than proactive. Voida et al. describe how volunteer managers in CBOs continuously make changes to homebrew databases in attempts to reduce overhead or accommodate new forms of information – in other words, to better meet the information needs of the organization [109]. In UrbanHeatATL, we see this work of adapting the data assemblage as reactive, responding as needed to misalignments caused by shifting infrastructures. The volume of reactive maintenance needed to realign the data pipeline through ongoing and unpredictable changes precluded proactive re-assemblage that might better meet information needs or reduce data work in the long-term. Awareness of the patterns of seamful decay described here is necessary to plan for the kinds of data work that will maintain initiatives in seamful spaces long-term. Proactively attending to seamful decay, rather than navigating misalignments as they surface, can contribute to long-term sustainability in civic data projects.

8.2 Seams, Membership, and Power

In civic data, understanding the landscape of power is critical. Seams offers useful language for understanding power in civic data infrastructures: "staying focused on what actors do with and across infrastructural seams reveals analytical opportunities for examining power structures in heterogeneous infrastructural environments" [107]. We saw two key ways that power influenced how and when seamful spaces were navigated by stakeholders.

First, we saw how individual **ability to navigate seamful spaces influenced project participation.** As others have pointed out, some may be better equipped to navigate seamful spaces than others [33, 38, 92]. As an example, Vertesi describes a scientist whose images are not visible in an important presentation because of a conversion between Mac and PC. The meeting moves on without the scientist's input and their ability to influence the project is diminished. In these moments, individuals may get "caught at the seams" in moments Vertesi describes as "multi-infrastructural torque" when the ability to navigate seams impacts an individual's status and influence within the group [107]. We see similar moments of "mundane miscoordination" in UrbanHeatATL: such as when volunteers were unsuccessful in aligning their sensor, mobile app, and google form to coordinate data submission. Often this resulted in data submitted without location or temperature data, making it impossible to compile these temperature records with those submitted by other volunteers. Though these community scientists participated in data collection, their choices about when and where to collect data would not be reflected in maps. In these instances, difficulty in navigating seamful spaces might diminish the ability of individuals to participate in constructing local heat maps.

Among the collaborators behind UrbanHeatATL, we also observed how the ability to align seams was not evenly distributed. Coordinating data production in UrbanHeatATL required a high degree of infrastructural competence, the ability to "recognize where infrastructural seams may have generative, rather than exclusionary, properties and then to draw upon this sociotechnical insight to fashion and implement an infrastructural strategy to achieve a desired goal" [33]. Perhaps different from the context of mobile work in which Erickson discusses the term, our study shows that infrastructural competence in this context required a high degree of technical capacity. The data processing script stands out as a clear example of a seam that could not be aligned by all group members. Further, we found examples of seams that could only be aligned by people in a shared organizational context. This shifts the question of infrastructural competence from one of individual ability to a question of organizationally navigability. Across both examples, the result of this pattern was ongoing dependence on external partners, particularly in navigating technical project seams, that sometimes challenged the autonomy of our community partners.

Second, we saw places where **seams were intentionally and strategically leveraged to exert power**. This has been underexamined in seams literature, which focuses more on experiences of users working across seams or experiencing torque when they fail to do so [92, 98]. Reading across the multiple moments of breakdown discussed here, we can see that seamful spaces become places where power is exercised through the strategic alignment or misalignment of seams. Our community partners exerted their status as community gatekeepers by refusing to align seams that would allow public access to community science data. This misalignment pushed other project stakeholders and even collaborators to the margins. Seams became a way of controlling group membership, which our partners used to pursue their vision of just community science by asserting community ownership over data. We also saw misalignments exercised as tools of power by the U.S. federal government. Removing EJScreen obfuscated the point of access to environmental justice data, which disempowered environmental justice orgs around the country and furthered the Trump administration's attacks on science and DEI initiatives.

In both of these examples, the strategic alignment and misalignment across seamful spaces highlight the ongoing, negotiated and partial nature of access and inclusion enacted across stakeholders [92]. In seamful spaces, ongoing inclusion requires ongoing maintenance of continuously decaying alignments. Together, these examples of the way power was negotiated across seamful spaces through data provide insight into how data works in civic contexts.

First, seamful spaces afford power to the individuals or groups with the capacity to create alignment. When our community partners had the resources and expertise needed to align seams, working across multiple heterogeneous infrastructures empowered our community partners to engage in community science data work. Thus, effective alignments can create power by building new capacities: the capacity to produce data attracted attention to our community partners and created a seat at the table in discussions about extreme heat. Misalignments also express power dynamics, shaping access and inclusion by multiple stakeholders across our research site. Thus, whether they are experienced as seamful or seamless, seams are always a site of ongoing negotiation of power. When the ability to align or misalign seams is not evenly distributed, seamful spaces afford power to those with the ability to do so, whether that be from individual capacity, resources, or organizational membership. This is a significant challenge to views that open civic data will act as a democratizing force [52] – civic data may instead simply replicate existing power structures. Designing "beautiful seams" in this context might not be a question of seam visibility [48], but designing for different kinds of alignment. For example, the move from EJScreen hosted on the EPA to EJScreen hosted by the broader environmental justice community transforms a centralized seam into a distributed one, with implications for the kinds of agencies that exist between and around infrastructures. Understanding and experimenting with the politics of seamful alignment is an open challenge for designing at the seams.

8.3 From Beautiful Seams to Beautiful Alignments: Collaboration in Seamful Spaces

HCI researchers frequently pursue collaborative partnerships with outside organizations, a pathway to knowledge production grounded in real-world contexts, engage communities in research and design work, and to create meaningful research impact [19, 26, 27, 42, 69, 76, 86, 116]. Embracing the messiness of community work, Le Dantec and Fox argue that the work of relationship building "fundamentally guided the research questions and approach" [59]. We build further on this claim by suggesting that these relationalities not only shape knowledge production but shape the design of technical interventions. In UrbanHeatATL, the technical infrastructure and data work follow the contours of the collaborative relationships established in early phases of the project. Even as the data pipeline was rebuilt and reorganized, the system remained mapped closely to organizational expertise, resources, and responsibilities settled early on. Our work suggests that the **relationships we form with collaborators are directly reflected in the technologies we develop and deploy**.

Casting ongoing maintenance as seam work highlights a need to attend to the seams of collaborative technological interventions in order to address power dynamics and sustainability over time. HCI researchers have worked to address these challenges with a wide range of methodological commitments to community work, including through participatory design [43, 119], action research [27, 49], or asset-based design [25]. Interest in addressing power dynamics and sustainability in community data work has also generated streams of research on data governance [54, 90], participatory data [18, 34, 120], infrastructural bricolage [78], and data interoperability [82]. Our work with UrbanHeatATL suggests that questions of power dynamics and sustainability in design systems are intertwined with relations between heterogeneous infrastructures.

Attending to the seams across collaborations before designing technical infrastructures greatly expands the levers designers and technologists can work with at the seams. In Inman and Ribes' literature review of seams and seamfulness, "techniques for designerly seams" revolve primarily around what is seen and what is not seen. Whether designing for interoperability, adaptation, or temporal difference, the designer's main tool is visualization, making seams a "question of not only what to reveal, but *how and when* to reveal" [emphasis theirs] [48]. The breakdowns we encountered with UrbanHeatATL occurred where seams were visible, but not actionable. Agency in seamful spaces, then, is not only about the visibility of seams but about the capacity to align them.

Moving from beautiful seams to beautiful alignments begins with designing social infrastructure of collaborative initiatives. For projects that aim to treat community organizations as an equal partner, arrangements need to be made such that alignment and misalignment work can be performed independently by community partners. When these negotiations are left to sort themselves out naturally, our work suggests that traditional power dynamics will greatly influence outcomes: those with more resources and more technical expertise have a greater ability to assert control. Or put differently, without careful attention, control defaults to locations of expertise and resource. The temporalities of seamful spaces further play a role: personnel turnover, product changes, and institutional change can fracture collaborative projects. Even as community engaged work often aims to undo or challenge practices of research extraction, our design interventions may be falling short of this goal in the long-term. In the context of seamful spaces, community ownership requires that organizations can align seams that enable data production and data access. In the case of many technical interventions, designing beautiful alignments may require capacity building around technical aspects of the project as well as design work that makes alignment accessible to project stakeholders.

9 Conclusion

Civic data always happens in the contexts of heterogeneous infrastructures, platforms, products, and institutions. This study is an exploration of how these disparate pieces come together and how they come apart. We, HCI researchers and our community partners, worked together to stitch tools and institutions together to enable participation in a civic science data project. Breakdowns regularly disrupted our work, requiring attention and ongoing maintenance. Through this process, we observed temporal and political qualities of seamful spaces. Using vignettes based in field notes during ethnographic observation, we illustrate alignments and misalignment happens at the seams, places where multiple infrastructures meet, as underlying infrastructures changed over time and how power dynamics manifested at the seams. Reflecting on community collaborations, we argue that the relations we form with collaborators come to be reflected in the technologies we develop and deploy. Design of civic tech must account for these dynamics in order to generate long-lasting impact.

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References

[1] Rene Abraham, Johannes Schneider, and Jan Vom Brocke. 2019. Data governance: A conceptual framework, structured review, and research agenda. International journal of information management 49 (2019), 424–438.

[2] Adriana Alvarado Garcia and Christopher A Le Dantec. 2018. Quotidian report: Grassroots data practices to address public safety. Proceedings of the ACM on Human-Computer Interaction 2, CSCW (2018), 1–18.

[3] Adriana Alvarado García, Alyson L Young, and Lynn Dombrowski. 2017. On making data actionable: How activists use imperfect data to foster social change for human rights violations in Mexico. Proceedings of the ACM on Human-Computer Interaction 1, CSCW (2017), 1–19.

[4] McKane Andrus, Sucheta Ghoshal, and Sayamindu Dasgupta. 2025. From Data Activism to Activism in a Time of Data-Centrism: Affirming Epistemological Heterogeneity in Social Movements. Proceedings of the ACM on Human-Computer Interaction 9, 2 (2025), 1–32.

[5] Paul M Aoki, RJ Honicky, Alan Mainwaring, Chris Myers, Eric Paulos, Sushmita Subramanian, and Allison Woodruff. 2009. A vehicle for research: using street sweepers to explore the landscape of environmental community action. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. 375–384.

[6] Mariam Asad and Christopher A Le Dantec. 2019. " This is shared work": negotiating boundaries in a social service intermediary organization. Media and Communication 7, 3 (2019), 69–78.

[7] Elizabeth Bales, Nima Nikzad, Nichole Quick, Celal Ziftci, Kevin Patrick, and William Griswold. 2012. Citisense: Mobile air quality sensing for individuals and communities design and deployment of the citisense mobile air-quality system. In 2012 6th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) and Workshops. IEEE, 155–158.

[8] Mara Balestrini, Jon Bird, Paul Marshall, Alberto Zaro, and Yvonne Rogers. 2014. Understanding sustained community engagement: a case study in heritage preservation in rural Argentina. In Proceedings of the sigchi conference on human factors in computing systems. 2675–2684.

[9] Raissa Barcellos, Flavia Bernardini, and José Viterbo. 2022. Towards defining data interpretability in open data portals: Challenges and research opportunities. Information systems 106 (2022), 101961.

[10] Genevieve Bell and Paul Dourish. 2007. Yesterday's tomorrows: notes on ubiquitous computing's dominant vision. Personal and ubiquitous computing 11, 2 (2007), 133–143.

[11] Lehn M. Benjamin, Amy Voida, and Chris Bopp. 2018. Policy fields, data systems, and the performance of nonprofit human service organizations. Human Service Organizations: Management, Leadership & Governance 42, 2 (March 2018), 185–204. doi:10.1080/23303131.2017.1422072

[12] Ashley Boone, Carl Disalvo, and Christopher A Le Dantec. 2023. Data Practice for a Politics of Care: Food Assistance as a Site of Careful Data Work. In Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems. 1–13.

[13] Chris Bopp, Ellie Harmon, and Amy Voida. 2017. Disempowered by data: Nonprofits, social enterprises, and the consequences of data-driven work. In Proceedings of the 2017 CHI conference on human factors in computing systems. 3608–3619.

[14] Chris Bopp, Ellie Harmon, and Amy Voida. 2017. Disempowered by Data: Nonprofits, Social Enterprises, and the Consequences of Data-Driven Work. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17). Association for Computing Machinery, New York, NY, USA, 3608–3619. doi:10.1145/3025453.3025694

[15] Matthew Chalmers, Marek Bell, Barry Brown, Malcolm Hall, Scott Sherwood, and Paul Tennent. 2005. Gaming on the edge: using seams in ubicomp games. In Proceedings of the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology. 306–309.

[16] Cassandra Chanen and Robert Soden. 2025. Data Practices and Double-Binds of Toronto's Climate Governance. Proceedings of the ACM on Human-Computer Interaction 9, 2 (2025), 1–25.

[17] Adrian Choi, Grace Pfohl, Catherine D'Ignazio, Brooke Foucault Welles, and Andrea G Parker. 2024. Entangled Amid Misaligned Seams: Limitations to Technology-Mediated Care for Repairing Infrastructural Breakdowns in a Youth Empowerment Program. Proceedings of the ACM on Human-Computer Interaction 8, CSCW2 (2024), 1–33.

[18] Nazli Cila, Guido Jansen, Maarten Groen, Wouter Meys, Lea Den Broeder, and Ben Kröse. 2016. Look! A healthy neighborhood: means to motivate participants in using an app for monitoring community health. In Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems. 889–898.

[19] Caroline Claisse, Alison K Osborne, Elizabeth Sillence, Angela Glascott, Alisdair S Cameron, and Abigail C Durrant. 2025. Exploring Alternative Socio-Technical Systems for Careful Data Work in Recovery Contexts. In Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems. 1–17.

[20] Nicola Colaninno, Rounaq Basu, Maryam Hosseini, Abdulaziz Alhassan, Liu Liu, and Andres Sevtsuk. 2025. A sidewalk-level urban heat risk assessment framework using pedestrian mobility and urban microclimate modeling. Environment and Planning B: Urban Analytics and City Science 52, 5 (2025), 1071–1090.

[21] J Corburn. 2005. Street Science: community knowledge and environmental health justice. The MIT Press.

[22] Roderic Crooks and Morgan Currie. 2021. Numbers will not save us: Agonistic data practices. The Information Society 37, 4 (2021), 201–213.

[23] Dharma Dailey and Kate Starbird. 2017. Social Media Seamsters: Stitching Platforms & Audiences into Local Crisis Infrastructure. In Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing. ACM, Portland Oregon USA, 1277–1289. doi:10.1145/2998181.2998290

[24] Shiva Darian, Aarjav Chauhan, Ricky Marton, Janet Ruppert, Kathleen Anderson, Ryan Clune, Madeline Cupchak, Max Gannett, Joel Holton, Elizabeth Kamas, et al. 2023. Enacting data feminism in advocacy data work. Proceedings of the ACM on Human-Computer Interaction 7, CSCW1 (2023), 1–28.

[25] Jessa Dickinson, Mark Díaz, Christopher A Le Dantec, and Sheena Erete. 2019. " The cavalry ain't coming in to save us" Supporting Capacities and Relationships through Civic Tech. Proceedings of the ACM on Human-Computer Interaction 3, CSCW (2019), 1–21.

[26] Tawanna R Dillahunt, Alex Jiahong Lu, Aarti Israni, Ruchita Lodha, Savana Brewer, Tiera S Robinson, Angela Brown Wilson, and Earnest Wheeler. 2022. The Village: Infrastructuring Community-based Mentoring to Support Adults Experiencing Poverty. In CHI Conference on Human Factors in Computing Systems. 1–17.

[27] Jill P. Dimond, Michaelanne Dye, Daphne Larose, and Amy S. Bruckman. 2013. Hollaback!: the role of storytelling online in a social movement organization. In Proceedings of the 2013 conference on Computer supported cooperative work. ACM, San Antonio Texas USA, 477–490. doi:10.1145/2441776.2441831

[28] P Dourish, G Bell, and A Divining. 2011. Digital Future-Mess and Mythology in Ubiquitous Computing.

[29] Paul Dourish and Scott D Mainwaring. 2012. Ubicomp's colonial impulse. In Proceedings of the 2012 ACM conference on ubiquitous computing. 133–142.

[30] Michaelanne Dye. 2021. Un grano de arena: Infrastructural care, social media platforms, and the Venezuelan humanitarian crisis. Proceedings of the ACM on Human-Computer Interaction 4, CSCW3 (2021), 1–28.

[31] Sheena Erete, Emily Ryou, Geoff Smith, Khristina Marie Fassett, and Sarah Duda. 2016. Storytelling with data: Examining the use of data by non-profit organizations. In Proceedings of the 19th ACM conference on Computer-Supported cooperative work & social computing. 1273–1283.

[32] Sheena Erete, Emily Ryou, Geoff Smith, Khristina Marie Fassett, and Sarah Duda. 2016. Storytelling with Data: Examining the Use of Data by Non-Profit Organizations. In Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing. ACM, San Francisco California USA, 1273–1283. doi:10.1145/2818048.2820068

[33] Ingrid Erickson and Mohammad Hossein Jarrahi. 2016. Infrastructuring and the challenge of dynamic seams in mobile knowledge work. In Proceedings of the 19th ACM conference on Computer-Supported cooperative work & social computing. 1323–1336.

[34] Daniel Filonik, Markus Rittenbruch, and Marcus Foth. 2014. Participatory data analytics: collaborative interfaces for data composition and visualisation. In Proceedings of the 7th international symposium on visual information communication and interaction. 248–249.

[35] Lillian Flawn and Robert Soden. 2024. Autonomy, Affect, and Reframing: Unpacking the Data Practices of Grassroots Climate Justice Activists. In Proceedings of the 2024 ACM Designing Interactive Systems Conference. 3016–3028.

[36] Jennifer Gabrys, Helen Pritchard, and Benjamin Barratt. 2016. Just good enough data: Figuring data citizenships through air pollution sensing and data stories. Big data & society 3, 2 (2016), 2053951716679677.

[37] Eulalia Jadraque Gago, Julio Roldan, Rosalía Pacheco-Torres, and Javier Ordóñez. 2013. The city and urban heat islands: A review of strategies to mitigate adverse effects. Renewable and sustainable energy reviews 25 (2013), 749–758.

[38] Sucheta Ghoshal, Rishma Mendhekar, and Amy Bruckman. 2020. Toward a Grassroots Culture of Technology Practice. 4 (2020), 28.

[39] Apoorva Gondimalla, Varshinee Sreekanth, Govind Joshi, Whitney Nelson, Eunsol Choi, Stephen C Slota, Sherri R Greenberg, Kenneth R Fleischmann, and Min Kyung Lee. 2024. Aligning Data with the Goals of an Organization and Its Workers: Designing Data Labeling for Social Service Case Notes. In Proceedings of the CHI Conference on Human Factors in Computing Systems. 1–21.

[40] Jonathan Grudin. 1988. Why CSCW applications fail: problems in the design and evaluationof organizational interfaces. In Proceedings of the 1988 ACM conference on Computer-supported cooperative work. 85–93.

[41] Srishti Gupta, Julia Jablonski, Chun-Hua Tsai, and John M Carroll. 2022. Instagram of Rivers: Facilitating Distributed Collaboration in Hyperlocal Citizen Science. Proceedings of the ACM on Human-Computer Interaction 6, CSCW1 (2022), 1–22.

[42] Christina Harrington and Tawanna R Dillahunt. 2021. Eliciting tech futures among Black young adults: A case study of remote speculative co-design. In Proceedings of the 2021 CHI conference on human factors in computing systems. 1–15.

[43] Christina Harrington, Sheena Erete, and Anne Marie Piper. 2019. Deconstructing community-based collaborative design: Towards more equitable participatory design engagements. Proceedings of the ACM on human-computer interaction 3, CSCW (2019), 1–25.

[44] Clare Heaviside, Helen Macintyre, and Sotiris Vardoulakis. 2017. The urban heat island: implications for health in a changing environment. Current environmental health reports 4, 3 (2017), 296–305.

[45] Jeremy S Hoffman, Vivek Shandas, and Nicholas Pendleton. 2020. The effects of historical housing policies on resident exposure to intra-urban heat: a study of 108 US urban areas. Climate 8, 1 (2020), 12.

[46] Youyang Hou and Cliff Lampe. 2017. Sustainable hacking: characteristics of the design and adoption of civic hacking projects. In Proceedings of the 8th International Conference on Communities and Technologies. 125–134.

[47] Yen-Chia Hsu, Jennifer Cross, Paul Dille, Michael Tasota, Beatrice Dias, Randy Sargent, Ting-Hao Huang, and Illah Nourbakhsh. 2020. Smell Pittsburgh: engaging community citizen science for air quality. ACM Transactions on Interactive Intelligent Systems (TiiS) 10, 4 (2020), 1–49.

[48] Sarah Inman and David Ribes. 2019. " Beautiful Seams" Strategic Revelations and Concealments. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems. 1–14.

[49] Lilly C. Irani and M. Six Silberman. 2013. Turkopticon: interrupting worker invisibility in amazon mechanical turk. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13). Association for Computing Machinery, New York, NY, USA, 611–620. doi:10.1145/2470654.2470742

[50] Steven J Jackson. 2014. 11 rethinking repair. Media technologies: Essays on communication, materiality, and society (2014), 221–39.

[51] Marijn Janssen, Yannis Charalabidis, and Anneke Zuiderwijk. 2012. Benefits, adoption barriers and myths of open data and open government. Information systems management 29, 4 (2012), 258–268.

[52] Jeffrey Alan Johnson. 2014. From open data to information justice. Ethics and Information Technology 16 (2014), 263–274.

[53] Maxat Kassen. 2013. A promising phenomenon of open data: A case study of the Chicago open data project. Government information quarterly 30, 4 (2013), 508–513.

[54] Vijay Khatri and Carol V Brown. 2010. Designing data governance. Commun. ACM 53, 1 (2010), 148–152.

[55] Nam Wook Kim, Chang Won Lee, Jonghyuk Jung, Eun-Young Ko, Juho Kim, and Jihee Kim. 2015. Budgetmap: Issue-driven navigation for a government budget. In Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems. 1097–1102.

[56] Laura M. Koesten, Emilia Kacprzak, Jenifer F. A. Tennison, and Elena Simperl. 2017. The Trials and Tribulations of Working with Structured Data: -a Study on Information Seeking Behaviour. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (Denver, Colorado, USA) (CHI '17). Association for Computing Machinery, New York, NY, USA, 1277–1289. doi:10.1145/3025453.3025838

[57] Linda M. Lampkin and Elizabeth T. Boris. 2002. Nonprofit Organization Data: What we Have and What we Need. American Behavioral Scientist 45, 11 (July 2002), 1675–1715. doi:10.1177/0002764202045011005

[58] Christopher A Le Dantec, Adriana Alvarado Garcia, Ciabhan Connelly, and Amanda Meng. 2021. Resisting Resolution: Enterprise Civic Systems Meet Community Organizing. Multimodal Technologies and Interaction 5, 4 (2021), 20.

[59] Christopher A Le Dantec and Sarah Fox. 2015. Strangers at the gate: Gaining access, building rapport, and co-constructing community-based research. In Proceedings of the 18th ACM conference on computer supported cooperative work & social computing. 1348–1358.

[60] Chang Liu, Arif Usta, Jian Zhao, and Semih Salihoglu. 2023. Governor: Turning open government data portals into interactive databases. In Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems. 1–16.

[61] Martin Lnenicka and Anastasija Nikiforova. 2021. Transparency-by-design: What is the role of open data portals? Telematics and Informatics 61 (2021), 101605.

[62] Yao Lyu, Jie Cai, and John M Carroll. 2025. A Systematic Literature Review of Infrastructure Studies in SIGCHI. Proceedings of the ACM on Human-Computer Interaction 9, 7 (2025), 1–41.

[63] Jock D Mackinlay and Jeffrey Heer. 2004. Wideband displays: mitigating multiple monitor seams. In CHI'04 extended abstracts on Human factors in computing systems. 1521–1524.

[64] Manissa M. Maharawal and Erin McElroy. 2018. The Anti-Eviction Mapping Project: Counter Mapping and Oral History toward Bay Area Housing Justice. Annals of the American Association of Geographers 108, 2 (March 2018), 380–389. doi:10.1080/24694452.2017.1365583

[65] Gloria Mark and Norman Makoto Su. 2010. Making infrastructure visible for nomadic work. Pervasive and Mobile Computing 6, 3 (2010), 312–323.

[66] Alexandra Maxim and Emily Grubert. 2022. Anticipating climate-related changes to residential energy burden in the United States: advance planning for equity and resilience. Environmental justice 15, 3 (2022), 139–148.

[67] Duncan J Mayer and Robert L Fischer. 2023. Exploring data use in nonprofit organizations. Evaluation and Program Planning 97 (2023), 102197.

[68] Leena Bakshi McLean. 2025. Climate Justice in the Concrete Jungle: Exploring Urban Heat Islands and Equity. In Justice-Oriented Science Teaching and Learning: Anchoring Phenomena in Secondary Classrooms. Springer, 241–261.

[69] Janis Lena Meissner. 2025. Configuring Participatory Research as Give and Take Relationships: Methodological Reflections on Co-Designing Booklets with a Men Shed. In Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems. 1–17.

[70] Cecelia Merkel, Umer Farooq, Lu Xiao, Craig Ganoe, Mary Beth Rosson, and John Carroll. 2007. Managing technology use and learning in nonprofit community organizations: Methodological challenges and opportunities. 8. doi:10.1145/1234772.1234783

[71] Abraham Miller-Rushing, Richard Primack, and Rick Bonney. 2012. The history of public participation in ecological research. Frontiers in Ecology and the Environment 10, 6 (2012), 285–290.

[72] Claudia Müller, Dominik Hornung, Theodor Hamm, and Volker Wulf. 2015. Practice-based design of a neighborhood portal: Focusing on elderly tenants in a city quarter living lab. In Proceedings of the 33rd annual ACM conference on human factors in computing systems. 2295–2304.

[73] Acarima Nanthanasit, Sophia Ppali, Jaydon Farao, Luma Tabbaa, Chee Siang Ang, Siwaporn Sukittanon, and Alexandra Covaci. 2025. Building a Digital Ecosystem for Community-Based Rehabilitation: Insights from a Multi-Platform Social Media Strategy in Thailand. In Proceedings of the 2025 ACM Designing Interactive Systems Conference. 1691–1709.

[74] Jakob Nielsen. 1994. Enhancing the explanatory power of usability heuristics. In Proceedings of the SIGCHI conference on Human Factors in Computing Systems. 152–158.

[75] Anastasija Nikiforova and Keegan McBride. 2021. Open government data portal usability: A user-centred usability analysis of 41 open government data portals. Telematics and Informatics 58 (2021), 101539.

[76] Teresa K O'Leary, Dhaval Parmar, Stefan Olafsson, Michael Paasche-Orlow, Timothy Bickmore, and Andrea G Parker. 2022. Community dynamics in technospiritual interventions: Lessons learned from a church-based mHealth pilot. In Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems. 1–23.

[77] Firaz Peer. 2023. The human infrastructure of civic data: A taxonomy for participatory infrastructuring of civic data. Computer Supported Cooperative Work (CSCW) 32, 4 (2023), 825–859.

[78] Firaz Peer and Carl DiSalvo. 2022. The Work of Infrastructural Bricoleurs in Building Civic Data Dashboards. Proceedings of the ACM on Human-Computer Interaction 6, CSCW1 (March 2022), 1–25. doi:10.1145/3512971

[79] Lucy Pei and Bonnie Nardi. 2019. We did it right, but it was still wrong: Toward assets-based design. In Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems. 1–11.

[80] Kathleen H. Pine and Max Liboiron. 2015. The Politics of Measurement and Action. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). Association for Computing Machinery, New York, NY, USA, 3147–3156. doi:10.1145/2702123.2702298

[81] Aare Puussaar, Ian G Johnson, Kyle Montague, Philip James, and Peter Wright. 2018. Making open data work for civic advocacy. Proceedings of the ACM on Human-Computer Interaction 2, CSCW (2018), 1–20.

[82] David Ribes. 2017. Notes on the concept of data interoperability: Cases from an ecology of AIDS research infrastructures. In Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing. 1514–1526.

[83] Ahmed Memon Rizwan, Leung YC Dennis, et al. 2008. A review on the generation, determination and mitigation of Urban Heat Island. Journal of environmental sciences 20, 1 (2008), 120–128.

[84] Dana Rotman, Jen Hammock, Jenny Preece, Derek Hansen, Carol Boston, Anne Bowser, and Yurong He. 2014. Motivations affecting initial and long-term participation in citizen science projects in three countries. IConference 2014 Proceedings (2014).

[85] Dana Rotman, Jenny Preece, Jen Hammock, Kezee Procita, Derek Hansen, Cynthia Parr, Darcy Lewis, and David Jacobs. 2012. Dynamic changes in motivation in collaborative citizen-science projects. In Proceedings of the ACM 2012 conference on computer supported cooperative work. 217–226.

[86] Samar Sabie and Tapan Parikh. 2019. Cultivating care through ambiguity: Lessons from a service learning course. In Proceedings of the 2019 CHI conference on human factors in computing systems. 1–14.

[87] Belén Sanz-Barbero, Cristina Linares, Carmen Vives-Cases, José Luis González, Juan José López-Ossorio, and Julio Díaz. 2018. Heat wave and the risk of intimate partner violence. Science of the total environment 644 (2018), 413–419.

[88] Parisa Shahmohamadi, AI Che-Ani, I Etessam, KNA Maulud, and NM Tawil. 2011. Healthy environment: the need to mitigate urban heat island effects on human health. Procedia Engineering 20 (2011), 61–70.

[89] Renee E Sieber and Peter A Johnson. 2015. Civic open data at a crossroads: Dominant models and current challenges. Government information quarterly 32, 3 (2015), 308–315.

[90] Harriet Simms, Aditi Surana, Carlos Guerrero Millan, Natalia-Rozalia Avlona, SJ Bennett, Ewa Luger, and Bettina Nissen. 2024. Data of/by/for the People: Designing Participatory Approaches to Data Governance. In Companion Publication of the 2024 ACM Designing Interactive Systems Conference. 405–408.

[91] Nidhi Singh, Saumya Singh, and RK Mall. 2020. Urban ecology and human health: implications of urban heat island, air pollution and climate change nexus. In Urban ecology. Elsevier, 317–334.

[92] Ranjit Singh and Steven J Jackson. 2017. From margins to seams: Imbrication, inclusion, and torque in the Aadhaar Identification Project. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems. 4776–4824.

[93] Alana Conner Snibbe. 2006. Drowning in data. Stanford Social Innovation Review 4, 3 (2006), 39–45.

[94] Robert Soden, Taneea S Agrawaal, Austin Lord, Cassandra Chanen, Lillian Flawn, Zeina Seaifan, Michael Classens, and Steve Easterbrook. 2025. Climate Data Practices: A Research Approach for HCI and Climate Justice. ACM Transactions on Computer-Human Interaction (2025).

[95] Susan Leigh Star and Karen Ruhleder. 1994. Steps towards an ecology of infrastructure: complex problems in design and access for large-scale collaborative systems. In Proceedings of the 1994 ACM conference on Computer supported cooperative work. 253–264.

[96] Susan Leigh Star and Anselm Strauss. 1999. Layers of silence, arenas of voice: The ecology of visible and invisible work. Computer supported cooperative work (CSCW) 8, 1 (1999), 9–30.

[97] Randy Stoecker. 2007. Research practices and needs of non-profit organizations in an urban center. J. Soc. & Soc. Welfare 34 (2007), 97.

[98] Andrea K Thomer and Alexandria J Rayburn. 2024. "A patchwork of data systems": Quilting as an analytic lens and stabilizing practice for knowledge infrastructures. Science, Technology, & Human Values 49, 5 (2024), 1073–1102.

[99] Rundong Tian, Christine Dierk, Christopher Myers, and Eric Paulos. 2016. Mypart: Personal, portable, accurate, airborne particle counting. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems. 1338–1348.

[100] Camilo Toruno, Andrew Schallwig, Ritvik Jain, Claire McKenna, Parth Vaishnav, Seth Guikema, and Michael T Craig. 2025. Climate change will trade-off summer and winter energy burdens. Environmental Research: Energy 2, 2 (2025), 025012.

[101] Ahn-Ton Tran, Ashley Boone, Christopher A. Le Dantec, and Carl DiSalvo. 2022. Careful Data Tinkering. Proceedings of the ACM on Human-Computer Interaction (Nov. 2022).

[102] Anh-Ton Tran, Ashley Boone, Christopher A Le Dantec, and Carl DiSalvo. 2022. Careful Data Tinkering. Proceedings of the ACM on Human-Computer Interaction 6, CSCW2 (2022), 1–29.

[103] Anh-Ton Tran and Carl Disalvo. 2024. Counting Up: Designing Agonistic Data Collection in the Court Room. In Proceedings of the 2024 ACM Designing Interactive Systems Conference. 3257–3271.

[104] Anh-Ton Tran, Grace Guo, Jordan Taylor, Katsuki Andrew Chan, Elora Lee Raymond, and Carl DiSalvo. 2024. Situating Datasets: Making Public Eviction Data Actionable for Housing Justice. In Proceedings of the CHI Conference on Human Factors in Computing Systems. 1–16.

[105] Jürgen Umbrich, Sebastian Neumaier, and Axel Polleres. 2015. Quality assessment and evolution of open data portals. In 2015 3rd international conference on future internet of things and cloud. IEEE, 404–411.

[106] Nervo Verdezoto, Naveen Bagalkot, Syeda Zainab Akbar, Swati Sharma, Nicola Mackintosh, Deirdre Harrington, and Paula Griffiths. 2021. The invisible work of maintenance in community health: challenges and opportunities for digital health to support frontline health workers in Karnataka, South India. Proceedings of the ACM on Human-Computer Interaction 5, CSCW1 (2021), 1–31.

[107] Janet Vertesi. 2014. Seamful spaces: Heterogeneous infrastructures in interaction. Science, Technology, & Human Values 39, 2 (2014), 264–284.

[108] Michalis Vitos, Julia Altenbuchner, Matthias Stevens, Gillian Conquest, Jerome Lewis, and Muki Haklay. 2017. Supporting Collaboration with Non-Literate Forest Communities in the Congo-Basin. In Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing (Portland, Oregon, USA) (CSCW '17). Association for Computing Machinery, New York, NY, USA, 1576–1590. doi:10.1145/2998181.2998242

[109] Amy Voida, Ellie Harmon, and Ban Al-Ani. 2011. Homebrew databases: complexities of everyday information management in nonprofit organizations. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11). Association for Computing Machinery, New York, NY, USA, 915–924. doi:10.1145/1978942.1979078

[110] Amy Voida, Ellie Harmon, and Ban Al-Ani. 2011. Homebrew databases: Complexities of everyday information management in nonprofit organizations. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. 915–924.

[111] Amy Voida, Ellie Harmon, and Ban Al-Ani. 2012. Bridging between organizations and the public: volunteer coordinators' uneasy relationship with social computing. (2012), 10.

[112] Amy Voida, Ellie Harmon, Willa Weller, Aubrey Thornsbury, Ariana Casale, Samuel Vance, Forrest Adams, Zach Hoffman, Alex Schmidt, Kevin Grimley, et al. 2017. Competing currencies: Designing for politics in units of measurement. In Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing. 847–860.

[113] Mark Weiser. 1991. The Computer for the 21 st Century. Scientific american 265, 3 (1991), 94–105.

[114] Mark Weiser. 1994. Creating the invisible interface: (invited talk). In Proceedings of the 7th annual ACM symposium on User interface software and technology. 1.

[115] Mark D Weiser. 1994. Ubiquitous computing. In ACM Conference on Computer Science, Vol. 418. 197530–197680.

[116] Cedric Deslandes Whitney, Teresa Naval, Elizabeth Quepons, Simrandeep Singh, Steven R Rick, and Lilly Irani. 2021. HCI tactics for politics from below: Meeting the challenges of smart cities. In Proceedings of the 2021 CHI conference on human factors in computing systems. 1–15.

[117] Andrea Wiggins. 2013. Free as in puppies: compensating for ICT constraints in citizen science. In Proceedings of the 2013 conference on Computer supported cooperative work. 1469–1480.

[118] Andrea Wiggins and Kevin Crowston. 2011. From conservation to crowdsourcing: A typology of citizen science. In 2011 44th Hawaii international conference on system sciences. IEEE, 1–10.

[119] Heike Winschiers-Theophilus, Shilumbe Chivuno-Kuria, Gereon Koch Kapuire, Nicola J Bidwell, and Edwin Blake. 2010. Being participated: a community approach. In Proceedings of the 11th Biennial Participatory Design Conference. 1–10.

[120] Ying Xu and Carleen Maitland. 2019. Participatory data collection and management in low-resource contexts: a field trial with urban refugees. In Proceedings of the Tenth International Conference on Information and Communication Technologies and Development. 1–12.