Constructing Survival:

Collaborative Imaginations in the Face of Social-Ecological-Technical Uncertainty

by

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ABSTRACT

This research interconnects three case studies to examine survivability as a framework through which to explore historic, current, and future collaborations in the face of existential threats, social-ecological-technical uncertainty, and indeterminate futures. Leveraging archival research, document analysis, and ethnographic field work, this study focuses on artist Georgia O'Keeffe's mid-20th-century construction of a nuclear fallout shelter, the COVID Tracking Project's response work in the first year of the Coronavirus Disease 2019 (COVID-19) pandemic, and three decades of future-facing scientific research performed at Biosphere 2. These cases demonstrate multidisciplinary collaborations across individual, organizational, and institutional configurations at local, national, and international scales in threat contexts spanning nuclear weapons, pandemics, and increasing climate catastrophe.

Within each of the three cases, I examine protagonists' collaborations within knowledge systems, their navigation of scientific disciplinary boundaries, their acknowledgement and negotiation of credibility and expertise, and how their engagements with these systems impact individual and collective survivability. By combining complex adaptive systems (CAS) framings with Science and Technology Studies concepts, I explore ways in which transformations of hierarchy and epistemological boundaries impact, and particularly increase, social-ecological-technical systems (SETS) survivability. Including notions of who and what systems deem worthy of protection, credibility, expertise and agency, imaginations, and how concepts of systems survivability operate, this work builds a conceptual scaffolding to better understand the dynamic workings of quests for survival in the 21st century.

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PREFACE: WRITING A DISSERTATION ABOUT SURVIVABILITY WHILE IN THE MIDDLE OF INCESSANT CRISES

I will not even attempt to describe the experience of working on a dissertation in the years 2020-2022, particularly a research project that focuses on survivability. I did not intentionally time my research to align so closely to current events—rising threats of nuclear war, a global pandemic, and a notable increase in climate-related catastrophes. I suspected when I chose to return to school that the world – which was already on literal and metaphorical fire – was more likely to get worse than better. I deliberately set out to learn about topics and perspectives that would help me think about survival in new ways and in the context of longer timeframes, and that this research pursuit would hopefully assist me to become more useful to my communities and the world in increasingly horrible times. However, I – perhaps naively – did not predict that each day I would find myself attempting to make sense of academic readings within the heightened context of current events—and vice versa.

On the specific day upon which I'm writing this prologue, I opened my document reader to find myself faced with the epitome of the dynamic within which I work. War is raging in Ukraine. Today, I discover that my app is created and maintained by Ukrainian developers. "Help us in Ukraine," a pop-up box exclaims. "PDF Expert was founded in Ukraine. Our team members are under Russian fire. Show your support and stand with us." Two action button options read "Donate now" and "Help in other ways," and the text upon a blue and yellow striped graphic above the "Help us" title proclaims "#StandWithUkraine." This black box, an artifact never otherwise seen within this app, sits upon an open article. Above it, I can read the words "ASSESSING VULNERABILITY," and below it the sentence "Identifying such thresholds for social systems is complicated by the relative and subjective nature of

risk and its variance in meaning among human populations" (Eakin & Luers, 2006, p. 373). I post to Instagram for the first time in weeks. I caption a screenshot, "tfw you're writing a dissertation on survivability in 2022 <heartbroken emoji>." I then praise the app design and cite the article.

In 2022, as with many other moments in history, we're living in complicated times.

A friend recently produced a letterpress broadside that I return to like a mantra while writing this dissertation. "Do not be daunted by the enormity of the world's grief," it quotes Pirkei Avot. "You are not obligated to complete the work, but neither are you free to abandon it." This dissertation is my way of attempting to sort out the focus and scope of a consequential aspect of the work and how one might intervene. As a result of performing this research, I have a nascent idea.

We need a different way of thinking about survivability – more relational, historical, and embodied in place. We need notions of survivability that do not just service war machines or reflect them. We need approaches to increasing our individual and collective survivability that direct us towards new ways in which we may come together with care for one another and the systems within which we live, towards meaningful transformation in ways in which we don't just survive, but support more to imagine and enact flourishing futures—and thrive.

CHAPTER 1

INTRODUCTION: HOW DO WE PARTICIPATE IN OUR OWN SURVIVABILITY?

"The future can't be predicted, but it can be envisioned and brought lovingly into being. Systems can't be controlled, but they can be designed and redesigned. We can't surge forward with certainty into a world of no surprises, but we can expect surprises and learn from them and even profit from them. We can't impose our will on a system. We can listen to what the system tells us, and discover how its properties and our values can work together to bring forth something much better than could ever be produced by our will alone" (Meadows, 2008, p. 169).

"Human beings have one survival skill that we've yet to find in creatures around us. We can pass on stories of how to cope with disaster and make it easier for the next group who confronts it" (Newitz, 2013, p. 10).

Within this project, I examine ways in which scientific and technological collaborations shape individual and collective notions of survivability. I investigate the influence of artistic, civic, and scientific imaginations on conceptions of agency and survival in the face of social-ecological-technical uncertainty and indeterminate futures. I build upon Science, Technology, and Society (STS) understandings about how expertise and credibility are gained, challenged, and transformed through collaboration with members of scientific institutions and civic sociotechnical systems to expand our comprehension of these dynamics within contemporary, urgent conditions. I am particularly interested in the ways in which negotiations of credibility and expertise may cause constructive reconsiderations of social-ecological-technical systems (SETS) and increase individual and collective survivability.

Survivability is concerned with but is a different concept than survival. As I will explain in greater detail later in this chapter, survivability interrogates and explains how systems are designed, assessed, and operated in ways in which functions persist as intended even when experiencing disturbance. Survivability as a concept is derived from military and information technologies (IT) systems literature, but within this project I expand upon and apply it to broader concerns regarding

various configurations of social-ecological-technical systems (SETS) to surface insights about how we may more broadly increase collective survivability. By developing and analyzing new data within an interdisciplinary approach, I seek to define, interrogate, and create new frameworks to comprehend the terrain of survivability

Increasing collective survivability means two things. First, it denotes expanding the designation of what is deemed essential for system persistence and (re)designing systems to meet this designation. Second, it describes making a system more responsive and resilient in ways which decrease the possibility of damage as a result of operation even during challenging or dangerous conditions. This two-part explanation can be applied to traditional domains within which the concept of survivability is used, but it can also be used as a lens through which to think about SETS within the context of broader critical conditions such as the threats of nuclear warfare, pandemics, and the increasing impacts of climate change.

To support my interrogation of systems within urgent conditions, this research study includes three cases. The first, Georgia O'Keeffe's building of a nuclear fallout shelter at her home in New Mexico, is a previously undocumented historical study grounded in archival research. I approach O'Keeffe's construction of a nuclear fallout shelter as a doorway into the artist's autodidactic studies of science, her relationships and collaborations with science and scientists, and how those studies and relationships may have informed her work, her worldview, and her decision to build defensive architecture. I employ O'Keeffe's story as a means of understanding how survival became a national project in mid-20th century America, forging new conceptions of survival that arise as risk becomes inextricably tied to emerging technologies, and how these may have played into O'Keeffe's notions of time, survivability, and persistence. O'Keeffe's story is not an all-encompassing

representation of the intersections between popular cultures, art, desert imaginaries, and the New Mexican – and national – nuclear imaginary. However, a focus upon the ways in which she employs her relationships to science and scientists in her life and work provides insights into aspects of an individual's place within mid-20th century survival systems.

The second case concentrates on the COVID Tracking Project (CTP) – a geographically-distributed, networked effort to gather and analyze pandemic data in the face of insufficient governmental sociotechnical response. Four co-founders – two journalists, a data scientist, and a content strategist – began CTP in March 2020 to acquire pandemic-related information that was not offered or easily accessed through U.S. state and federal agencies. Initially meant as a stop gap measure until federal and state data became more accessible, reliable, and comprehensible, the project evolved and expanded into a massive, mostly volunteer-powered civic technoscience initiative that persisted for the entire first year of the pandemic. Variably skilled team members taught themselves, each other, media outlets, governmental agencies, and wider publics how to comprehend evolving COVID-19 knowledge, parse multiple types of data, and utilize technological tools that they built and iterated upon to support their daily data collection efforts in the service of collective survival.

The third case focuses on the historic, current, and future research of Biosphere 2 (B2), a 40-acre campus located outside of Oracle, Arizona. B2 contains a distillation of our global ecologies. The primary building houses a four-story rainforest, a savanna grassland, mangrove wetlands, a desert, and the largest controlled ocean environment in the world. Completed in the early 1990s, the biomes were intricately crafted, connected to sustaining technologies, and equipped with monitoring systems. Biospherians and collaborating scientists have employed the

environments for controlled experimentation ever since. A private group originally designed B2 for closed system "missions" to explore the feasibility of establishing sustainable habitats on other planets. After the mission era, Columbia University utilized the biomes to undertake research for over a decade. Currently, the University of Arizona maintains B2 as they perform complex adaptive Earth systems science research with local and global scientists at field scale using lab controls. From the moment they began the facilities' construction, Biospherians explored survivability and practiced potential futures. The ways in which the different generations of multidisciplinary scientists have done so – as well as the scientific, institutional, and global climate contexts within which they've understood their work – have both persisted and evolved in their uniqueness, concerns, methods, and comprehension.

This first chapter sets up the dissertation questions, major themes, and definitions. Within the chapter I provide brief summaries and acknowledge my personal and scholarly involvement in the case studies, including my own situated knowledges and employment of feminist social science perspectives. I explain larger framings of sociotechnical and social-ecological-technical systems (SETS) perspectives, and I argue for the merit and potential impacts of the research.

We cannot talk about survivability without leaning into the future, but this move ought to be buttressed with learning from the past and present. However, the past, present, and future are not so neatly delineated. These case studies, all inevitably living in the past, are pregnant with futures and signal ways forward. Imagining the future is not a practice of projecting past and present onward, but instead tackling questions of risk, uncertainty, and ambiguity which are ideas in motion. The past and present can provide us with potential imaginative touch points, but I do not focus on them within this dissertation to be prescriptive for what the

future must be. Instead, I look for insights which might support and guide us towards increased, collective survivability.

I approach this project as an assessment to discover ways in which to improve the survivability and expand the survivability purview, who and what is deemed essential for system persistence, of various configurations of social-ecological-technical complex systems. Within each case study, I identify components which appear to be strong, nimble deterrents to harm within both specific and generalizable threat conditions. As a result of this research, I compile a summary of considerations, concerns, concepts, and constructive suggestions through which to imagine ways to increase collective survivability at individual, organizational, and multi-institutional scales. As Amitav Ghosh (2016) writes about how to engage and intervene in increasing climate catastrophes, "[T]he climate crisis is also a crisis of culture, and thus of the imagination" (p.9). Within this dissertation, I provide both evocative cases and conceptual frameworks through which to consider constructive solutions.

Within this research, I investigate conceptually interconnected stories with which to think about survivability as a field of study which explores historic, current, and future survival in the face of existential threats, social-ecological-technical uncertainty, and indeterminate futures. To interrogate survivability, this work draws from fields and concepts that probe how collaboration and change occur in complex systems. In opening up this STS-driven research to consider SETS, this work reveals how human culture and social institutions interface with technology and also how ecological matters and specificities of place figure into our interactions with both technologies and society (Smith & Sterling, 2010; Ahlborg et al., 2019). My presentation of each case highlights their unique configurations of expertise and agency while inviting us to imagine new paths forward, both individually and

collectively, when faced with both immediate and long-term danger. Through marshaling themes of SETS, expertise and agency, and imaginations to extend concepts of systems survivability, this work builds a scaffolding to better understand the dynamic workings of quests for survival in the 21st century.

QUESTIONS AND METHODS

The three case studies exemplify a range of protagonists who are deeply entangled in SETS, knowledge systems, multiple types of imaginations, and questions of uncertainty, risk, credibility, and expertise. The cases span local, national, and international configurations, while also responding to global concerns about nuclear annihilation, pandemics, and climate change. The protagonists of these case studies gain information and agency within their situations through different engagements with science and within different, but overlapping, U.S. social imaginations about the roles lay individuals and scientists play within larger national projects. Though each case study evokes its own, often related, questions, my primary question is:

> R1: How do artistic, civic, and scientific imaginations inform conceptions of agency and survivability in the face of social-ecological-technical uncertainty and multiple potential futures?

My secondary questions include:

> R2: How are expertise and credibility gained, challenged, transformed, and demonstrated by both laypeople and scientists through collaboration with scientists and scientific institutions within urgent conditions?
>
> R3: How do the protagonists acquire information, skills, and agency within their situations through their inter-personal collaborations, use of technologies, and intersections with civic and/or institutional processes? How do they teach, learn from, evolve with and care for one another? How do these acquisitions and exchanges inform their notions of survivability?

Within each case study chapter, I frame the ways in which I address each of these three primary questions alongside any other pertinent case-specific questions. For all three cases, I performed this research through a combination of ethnographic methods and both primary and secondary research. In the next paragraphs, I provide a brief introduction, but within each chapter I include additional notes on case study source materials and research methods.

I significantly grounded the historic O'Keeffe case study in archival research conducted primarily at the Georgia O'Keeffe archives in Santa Fe, New Mexico, where I read oral histories, personal correspondence, invoices and work orders, and publications held within her personal library. I supplemented the archival research with observational field visits to Santa Fe and Abiquiú sites, informal conversations with O'Keeffe experts, and secondary research on O'Keeffe, New Mexico history, scientific and military nuclear history, gardening as social-ecological systems, artistic imaginations, and the history of art conservation.

My understandings of CTP stem from six-months of ethnographic observations of the CTP team, informal conversations and official interviews with a small selection of CTP participants, viewing of internal CTP team training videos, document analysis of texts written by and about CTP, and contextual research on the history of pandemics, the AIDS Coalition to Unleash Power (ACT UP), the AIDS crisis, the global COVID-19 pandemic, and a broad selection of STS and anthropological research on community engagement with governmental sociotechnical systems.

The B2 case study is the result of my primary and secondary research alongside informal observation, official field visits, and supplementary informal conversations and formal interviews with B2 researchers and staff. Primary and secondary research included texts on B2 history and current scientific research, including memoirs, news articles on B2, B2-affiliated texts released to the public,

articles published within scientific journals, and scholarship published within other domains. Research additionally included topics such as social-ecological and ecological-technical systems, roles of simulations and models within futures thinking, history and current understandings of climate change, and local and global responses to the climate crisis. All cases were considered through the lens of STS writings that address the central project themes, while also supported by archival, academic, and popular texts – including those both about and generated by the foci of the case studies – specific to each context.

SURVIVABILITY: CONSIDERING SURVIVAL SYSTEMS

The concept of survivability arises from military literature; the term refers to human and technological systems' abilities to complete their missions within hostile conditions (Sterbenz et al., 2010; Castet & Saleh, 2012). The majority of survivability-focused writing may be found in military, engineering, information systems, telecommunications, security, and operations publications. A review of this literature leads me to categorize the use of the word "survivability" in three primary ways. First, survivability is a concept with which a system's ability to withstand harm may be described through qualitative and/or quantitative terms. In this and all the following cases, reflecting the literature, I use the term "system" to represent a complex machine/vehicle, technical system, and/or sociotechnical system. A qualitative example is Riqiang's (2020) analysis of China's nuclear weapons program's perceived survivability, whereas a quantitative example is Knight, Strunk, and Sullivan's (2003) mathematical definition for describing IT system survivability. Second, survivability is a design and/or engineering process through which a system may be effectively built and/or strengthened against potential known or uncertain attacks. Ben Yaghlane and Azaiez (2017), for example, propose specifications and

mathematical formulas which they argue will result in software information systems that may effectively withstand "intelligent threats." Some descriptions of survivability – such as Said's (1995) articulation of US Naval Ship design, engineering, implementation, and assessment processes post-1988 – may include both of the first two categories. Third, exemplified by Sterbenz, Hutchison, Çetinkaya, Jabbar, Rohrer, Schöller, and Smith's (2010) argument for increased internet resilience, survivability is positioned as a key component of a larger set of complex systems concepts – a system of systems – which need to be conceived and implemented to ensure system persistence. Though this literature describes survivability as an assessment process alone, my research confirms that the concept is better characterized as deeply embedded in notions of assessment, implementation, and integration across design, engineering, and computer science. Moreover, as we will see, these framings of survivability indebted to macho-militario-cybernetics-land ignore key dynamics that are needed to comprehend the fuller picture, and I hypothesize that this ignorance deters an ability to apply otherwise constructive notions born from a survivability lens towards increasing SETS survivability. Ascertaining these synthesized categories required that I take an interdisciplinary approach to the literature, and this exercise confirmed my belief that the concept of survivability may be employed beyond its current multi-disciplinary boundaries.

Social, biological, and natural science disciplines are under-represented within survivability literature, but their terminology and concepts are not. Existing texts often articulate survivability in terms also found in STS, SETS, complex adaptive systems (CAS), and sustainability literature. Two categories of overlapping concerns describe complex systems and address interactions within and between systems. Existing survivability literature acknowledges CAS conceptions of complexity, reliability, diversity, evolution/emergence, and interactions found within systems'

component parts (Riqiang, 2020; Knight et al., 2003; Ellison et al., 1999; Sterbenz et al., 2010; Castet & Saleh, 2012; Richards et al., 2007). Discussion of resilience, robustness, and vulnerability within and between systems reflects sociotechnical and SETS considerations found in STS and sustainability literature, though survivability literature addresses these topics to a more superficial degree (Riqiang, 2020; Sterbenz et al., 2020; Castet & Saleh, 2012; Said, 1995; Ball & Atkinson, 1988; Ben Yaghlane & Azaiez, 2017; Richards et al., 2007). Survivability literature also references risk and uncertainty as things to be essentialized and quantified (Riqiang, 2020; Ellison et al., 1999; Castet & Saleh, 2012; Said, 1995; Ben Yaghlane & Azaiez, 2017; Richards et al., 2007). I hypothesize that engineering, IT, and military theorists and practitioners could bolster survivability by integrating insights from other overlapping and adjacent disciplines, and in return, insights provided by survivability literature could benefit and inform those engaged with STS, SETS, and sustainability.

Conceptual understanding of survivability is mediated by conceptions of risk. Risk is an extremely multifaceted topic, and a range of disciplines each approach it differently. Geographers study risk as potential hazard probabilities and impacts (Craddock, 2000; Andrews, 1985). Anthropologists analyze how culture and ideology shape collective definitions of danger (Alaszewski, 2015; Andersson, 2016). Psychologists and social psychologists focus on perception, estimation, and choice-making (Lopes, 1987; Seligman et al, 2016). STS scholars extend these concerns into how risk informs governance, particularly – though not exclusively – in terms of emerging technologies (Guston, 2014; Scheufele et al., 2007; Maynard, 2006; Guston & Sarewitz, 2002). For my purposes, I look towards sociologists of risk, particularly those who take a social constructionist approach where they consider how risk and risk analyses are formed by intersections and variable boundaries

between social, cultural, and institutional factors (Tierney, 1999; Fischhoff et al., 1993). As sociologists Fischhoff, Bostrom, and Quadrel (1993) write about risk and public health, "Some of the apparent disagreement between experts and laypeople regarding the magnitude of risks in society may be due to different definitions of risk" (p. 190). Risk's definition, as it pertains to survivability as employed in its most used context, is both particular to those disciplines' specific priorities and partially generalizable in the relationships and concerns from which that definition emerges.

Survivability, as an IT, military, design, and engineering concept, often uses the language of CAS, which aims to measure and instrumentalize risk and uncertainty, and attempts to essentialize and quantify concerns so that all central concepts towards increased survivability can be assessed, executed, and improved upon. Within the primary existing disciplinary frameworks, humans and environments are footnotes while technologies are the primary focus. My use of survivability gives equal weight to concerns of and interactions between humans, environments, and technologies. It is relational and generative. I focus on the pieces of SETS – people, environments, technologies – as components with mutable relationships within variably transformable contexts. Whereas traditional notions of survivability are structural, I also differ in valuing both the systems and people parts of survivability, acknowledging both structural and anecdotal knowledge. I approach this last point through frameworks of feminist social science.

FEMINIST SOCIAL SCIENCE: TOWARDS EXPANDED NOTIONS OF SURVIVABILITY

Feminist social science offers a way to expand upon dominant notions of survivability by acknowledging both structural and personal components required for perseverance in social-ecological-technical contexts. Within this section I outline

theoretical underpinnings that influence my work and describe a conceptual landscape of anecdotal insights.

Positionality and Situated Knowledges

Ethics and epistemologies of feminist social science theories on positionality are fundamental to ways in which I comprehend the place of, and relationships between, individual human experiences and systems. In their stance against a positivist notion of "objective" science, feminist social scientists use standpoint theory to argue that sociocultural, geographic, and gender locations matter. Positionality, over the decades since standpoint theory was first introduced, has become increasingly influenced by black feminist thought to also include race and class, amongst other categorical and structural factors (Harding, 2009). Harding and Norberg (2005) argue that ethical research engagements must acknowledge the specificities of the researcher, the positionality of those engaged with the research, and the power dynamics between people as components of these systems. Standpoint theory acknowledges that both solo individuals and people in relation are in persistent relationships to larger SETS, and that both information that emerges from the interrogation of systems and anecdotal stories by and about individuals and communities are valid data (Harding & Norberg, 2005). Haraway (1988) describes these individual positionalities as useful partial perspectives, calling them "situated knowledges."

Some scholars, such as Hinton (2014), feel that Haraway's seminal "Situated Knowledges" text has been misinterpreted to consider situated knowledges as static positions. Instead, they state, Haraway's own text hints at situated knowledges' mutability—a result of our individual and collective ongoing repositioning as parts of larger systems. Stoetzler and Yuval-Davis (2002) take Hinton and Haraway's

conceptions a step further to propose a notion of "situated imaginations." This, they explain, acknowledges the dynamics of social imaginations, discussed in detail later in this chapter, as things always in shifting relationships to one another (Stoetzler & Yuval-Davis, 2002). Hughes and Lury (2013) argue even one step further; whereas other feminist theorists foreground sociocultural, socioeconomic, and sociotechnical relationships, they suggest that ecologically entangled epistemologies may have increased roles to play towards comprehending our social-ecological-technical entanglements. In their engagement of texts by Haraway and Barad, Hughes and Lury (2013) emphasize the importance of comprehending relationships as shifting and changeable, if not entirely unknowable, between people, each other, non-human entities, and systems. Whereas the majority of existing survivability literature prioritizes systems, and particularly the technologies of those systems, I approach my work and the conceptualization of survivability in a way in which SETS are seen with equal value. I additionally argue that acknowledging stories of people, systems, and even case studies in relationship to one another may provide insights into how we many increase collective survivability.

This project also borrows significantly from the work of anthropologist/STS scholar Anna Lowenhaupt Tsing and social activist adrienne maree brown, who combine cogent analyses of larger combinations of social, ecological, and technical systems with the recognition that writing from within uncertainty, means sitting within "the muck" in order to wrestle with complexity. Both argue for the usefulness of this approach, while they each navigate it differently. Tsing (2015) follows through-threads, focusing on a type of mushroom placed within multiple contexts, so that she does not lose her readers or herself in the enormity of what she attempts to address. Throughout this dissertation, my mushroom is the concept of survivability. Brown (2017) encourages iterations of comprehension, positioning analyses as

mutable forms, while articulating insights gained along the path. Similarly, I acquire insights from each of my case studies, and the insights I gain compliment and build upon one another. Together I accumulate these findings, through the iterative processes inherent in this research, into new perspectives that transcend the case studies alone.

For this project's work, I complement Tsing and brown's approaches with articulations of typical types of complex system configurations provided by CAS literature (Simon, 1962; Mitchell, 2009; Holland, 2014). I argue that muck and clarity may co-exist. Taking inspiration also from Perrow (1984), a sociologist of risk, I hypothesize that we increase our understanding of survivability when we approach the complex systems within which we live as not entirely predictable, even incomprehensible, while also knowable enough to navigate.

Anecdotal Models

Feminist social science theories argue for the usefulness of anecdotal data in research, and I additionally look to a broad landscape of literature to both identify considerations of using individual stories and to learn ways in which to include that data through means that prove compelling to broad audiences. The work of journalists and popular writers provides us with anecdotal models for increased survivability in the face of sociocultural and environmental disasters. Authors such as Philip Gourevitch (1998) and Rebecca Solnit (2009) narrate individual and community hero leadership stories where ordinary people respond to extraordinary things in humane ways that allow for collective perseverance. Annalee Newitz (2013, 2021) and Alan Weisman (2007) extend these types of narratives into longer timeframes, by providing insights from societal challenges of the deep past and speculating about our current detrimental impacts on our future environments.

Writing from within the fog of dangerous conditions, Ed Yong (2020) and Masha Gessen (2017) look for explanations of systemic collapse, as shown within Yong's documentation of U.S. governmental failures within the COVID-19 pandemic and Gessen's ongoing analyses of Russian politics and the global rise of authoritarianism.

Within survival narratives, as with all narratives, the positionality of perspectives matters (Haraway, 1988). Whereas anthropologist Joseph Masco (2006) documents the culture of Los Alamos National Labs as a long study of national notions of survivability from the perspective of a knowledgeable outsider, Solnit (2014) addresses the multifaceted impacts of the nuclear-industrial complex from her stance as a long-time anti-nuclear activist. Journalist Randy Shilts (1987) was considered a premier ethnographer of the AIDS crisis within the moment, but David France (2017) and Sarah Shulman (2021) have since written documentary accounts from their perspectives as epidemic front-line ACT UP activists.

More multifaceted visions provided by the collective accumulation of interior and exterior accounts often do not include both large-scale structural analyses and the ways in which details play into systems. In contrast, Epstein's (1995, 1996) STS work on ACT UP's navigation of credibility and expertise provides concrete insights into both ACT UP's actions and larger health regulation system dynamics, while the work of performance studies scholar Debra Levine (2012, 2021) describes the underlying ethical networks and sincere performances of palliative care that emerged between individual ACT UP members. I hypothesize that collaborations may increase, or at minimum impact, our collective survivability in the face of social-ecological-technical uncertainty and that studying people – both individually and collectively – and the systems – within which they are enmeshed and with which they are engaged – are essential to comprehending how increased survivability is understood and achieved—or not. This project builds upon strengths of journalistic popular narratives

alongside teachings provided by structural, focused analyses of scholars from multiple disciplines to entangle systems perspectives with human stories to create complex comprehensions of how we collectively shape our notions of survivability.

KEY CONCEPTS AND DEFINITIONS

This section introduces additional key concepts that will be used throughout this dissertation. I provide overviews that will be expanded upon within each of the case studies. This section provides background on the relevance of CAS, imaginations and imaginaries, SETS, knowledge systems, and futures thinking to expanded notions of survivability within the context of social-ecological-technical uncertainty.

Complex Adaptive Systems (CAS)

Survivability is most often concerned with the design, implementation, assessment, and improvement of not just complicated, but complex systems. Survivability literature includes war machines and software, but variations of sociotechnical, socio-ecological, and SET systems are also acknowledged as complex systems within complexity literature; they're often described as individual and coupled configurations of social, political, socioeconomic, biological and ecological systems (Goldenfeld & Kadanoff, 1999; Miller & Page, 2007; Krakauer & West, 2021). A system, at its simplest, requires elements interconnected with a function/purpose. As per Meadows (2008), systems' "[p]urposes are deduced from behavior, not from rhetoric or stated goals" (p. 14). Complex systems, as described in Herbert Simon's influential 1962 paper "The Architecture of Complexity," include at least four key characteristics. First, system components and subsystems display hierarchy within their interactions. Second, complex systems exhibit

evolutionary/emergent properties, which means that the whole of a system is greater than the sum of its parts, the results of a system may be unexpected, and outputs may change in unpredictable ways over time. Third, a complex system can decompose, the overall system may maintain its purpose when some aspects break down or work differently. Fourth, a complex system may be described, in that a summary of key system actions may produce a vision of the overall system workings at a single moment in time—even if not all pieces are completely understood. My analysis of the SETS found within my case studies is informed by my study of complex adaptive systems (CAS), complex systems that may also self-evolve towards greater chance of survival over time. Particularly useful in the context of SETS and survivability, Turner and their colleagues (2003) describe adaptive capacity as "the flexibility of ecosystems and the ability of social systems to learn in response to disturbances" (p. 8075).

Inspired by network analysis and CAS notions of description, I identify hierarchical structures, node boundaries and interactions, subsystems and communities, evolutionary steps that increase system survivability, and the use of "lookahead" subroutines—a complex adaptive system's way of practicing the future (Holland, 2014) that is also studied in game theory (Kroer & Sandholm, 2020). Though I may not always describe my case studies in as mechanistic of a way as much of CAS literature, these underlying concepts inform how I view interactions between people and systems towards increased survivability.

In addition, I reference concepts that arise from a second-level engagement with CAS. Whereas much CAS literature concentrates on defining the components and frameworks through which we may understand what defines a CAS, sustainability and STS literatures build upon these definitions to describe how CAS may behave within SETS contexts. Within all three case studies, I address resilience

and robustness as strategies through which we may achieve greater individual and collective survivability. Resilience broadly refers to systems' abilities to preserve their functions despite disturbance, shock, and change through maintenance or transformation (Anderies et al., 2004; Anderies et al., 2013; Eakin & Luers, 2006; Turner et al., 2003; Meadows, 2008). According to Anderies, Folke, Walker, and Ostrom (2013), resilience "does not include specific choices about performance measures" (p. 8). In contrast, Anderies and his colleagues (2004, 2013) describe robustness as an operationalization of resilience.

Robustness, too, refers to the maintenance of system functioning in the context of partial system or environmental fluctuations, even for systems only partially known. Comprehension through a robustness lens also includes parameters of concerns—including what parts of the system or interacting systems need to continue to run, whether persistence is short- or long-term (Anderies et al., 2004). Resilient and robust systems are definitionally described as operating at high levels of survivability, and any assessment of system survivability needs to account for vulnerability. Within complex systems thinking, vulnerability means the likelihood or susceptibility of a system, subsystem, system component, or other human/environmental element to experience damage or harm due to exposure to a hazard, perturbation, or stress/stressor (Turner et al., 2003; Eakin & Luers, 2006). Eakin and Luers (2006) explain that vulnerability is sometimes considered an outcome and sometimes a state of being. It is also notable, given my positioning as an STS researcher, that Eakin and Luers (2006) explain, per social systems scholar Timmerman, that "the vulnerability of a society to hazards is a product of rigidity resulting from the evolution of science, technology, and social organization" (p. 372).

As both the mechanistic and behavioral framings explain, CAS are most often layered or coupled. By definition, they display hierarchy but allow for transformation

of that hierarchy. Importantly, resetting boundaries between CAS components creates new outcomes. CAS perspectives provide insights into relationships—both acknowledged and not yet known.

My guiding focus within this dissertation is on collaborations between artists, scientists, and technologists within which artistic, scientific, and civic imaginations influence their – and subsequently, our – notions of survivability. Essential to my understanding of these collaborations are questions about people as parts of systems—summoning what imaginations mean, the roles of sciences and technologies, how credibility and expertise are navigated, and how conceptions of survivability are entangled with visions of the future.

Imaginations and Imaginaries

Artistic, scientific, and civic imaginaries influence our perceptions of survival and survivability. I ground my definitions of social imaginations and imaginaries with the work of Taylor (2002), Marcus (1995), and Jasanoff and Kim (2009, 2013). According to Taylor (2002), social imaginaries are constructed through the "great connected chain of mutations" of the public sphere, a market economy, and the citizen state (p. 116). All three intersect and evolve to create social conditions through which citizens imagine and invest in collective civic goals, projects, and commitments. Marcus (1995) explains imaginaries as the confluence of parts; for Marcus, "technoscientific imaginaries" arise from interactions between individuals, scientific systems, public perceptions of the utility and risks of scientific and technological developments, governmental structures and narratives about science, scientists, and the state. Within this dissertation's case studies, technoscientific imaginaries additionally intersect with cultural ideas about the importance of artistic imagination and creativity in national technoscientific projects. I ground my context

for this type of imaginary in histories of post-WW2 technical and cultural collaborations (Beck & Bishop, 2020).

Within STS literature, social constructions of imaginations are less about intersections with artistic worldviews and more about sociotechnical national projects. Jasanoff and Kim (2009) refer to technoscientific imaginaries as conceptions of scientific technological breakthroughs within society that "are almost always imbued with implicit understandings of what is good or desirable in the social world writ large" (p. 122-123). The authors also explicitly define the concept of sociotechnical imaginaries as "collectively imagined forms of social life and social order reflected in the design and fulfillment of nation-specific scientific and/or technological projects" (Jasanoff & Kim, 2013, p. 120). Within their 2009 and 2013 articles on the topic, they write extensively about the application of sociotechnical and technoscientific imaginaries to national nuclear imaginaries, and they elucidate the roles individuals and systems play within these social, technical, and political frameworks. Sociotechnical imaginaries also "articulate feasible futures. Conversely, imaginaries also warn against risks and hazards that might accompany innovation if it is pushed too hard or too fast" (Jasanoff & Kim, 2009, p. 123). However, they write, "A well-known feature of the U.S. sociotechnical imagination is that technology's benefits are seen as unbounded while risks are framed as limited and manageable" (Jasanoff & Kim, 2013, p. 190). In my work, I build upon these theories to examine how imaginaries are mobilized in different contexts, particularly how the research subjects' relationships to different types of imaginations and imaginaries impact their conceptions of their individual and collective abilities to stay and/or modify course towards their goals in the face of danger.

Social-Ecological-Technical Systems (SETS)

Sociotechnical imaginaries are inextricably linked to constructions and conceptions of sociotechnical systems—official and unofficial structures within which our sociocultural and scientific/technological systems are intertwined. Social processes develop and determine the uses of technologies, while technologies open up new social relationships (Smith & Sterling, 2010). Within this dissertation, I extend beyond STS scholarship about sociotechnical systems to borrow insights from CAS, sustainability studies, and disaster studies to address SETS. My choice to do so acknowledges the complexities and risks found within each of the three case studies, as it also extends STS scholarship to address essential parts that ecologies play within our sociotechnical navigations. By focusing on SETS considerations, I am able to identify and explore multiple types of imaginaries that inform subconfigurations of SETS systems, including sociotechnical as well as social-ecological, ecological-technical and social-ecological-technical systems and their associated imaginaries.

Research that includes SETS analyses requires increased considerations of place-based factors than research that focuses on sociotechnical system analyses, including acknowledgements of ecological factors as resources (Smith & Sterling, 2010). However, SETS considerations of all three systems expand beyond parallel sociotechnical and social-ecological systems analyses to unearth insights from the nexus of the three. Research, primarily found in STS and sustainability literature, that directly addresses SETS is limited due to the fact that SETS is a still emerging framework. Ahlborg, Ruiz-Mercade, Molander, and Masera (2019) acknowledge this dearth of literature and argue for the validity of an integrated SETS approach, the usefulness of examining the above-mentioned nexus, over the current dominant model of parallel assessments of social-ecological and sociotechnical systems.

The triumvirate of considerations unearths multifaceted dynamics that are particularly relevant to my case studies of one woman's efforts towards increased survival through science and technology within a specific location, a grassroots sociotechnical response to a global airborne pandemic, and scientists' climate-concerned research at an eco-technical cyborgian facility. Following Ahlborg et al. (2019), a social-ecological-technical systems approach "[e]xplores how technology contingently shapes the human-nature relationship and with what consequences; how emergent pressures in complex socio-technical-ecological systems are interlinked and; how intentional and unintentional technical mediation may result in ambiguous outcomes and feedbacks that displace / relocate but do not remove negative consequences'' (p.15). Though this research does not aim to prescribe interventions, Ahlborg et al. (2019) align with my motivational values, and reflect aspects of my case studies, when they argue that a SETS approach "[s]eeks to identify strategic interventions and ways of changing the kinds of relationships such that these embody values of reciprocity, care, and well-being for humans and non-humans alike" (p.15). In this project, I leverage insights from sociotechnical, social-ecological, and the limited SETS literature to examine how the entangled systems articulated through SETS perspectives and knowledge acquisition, negotiation, and dissemination through system dynamics articulated by STS are key to better understanding and supporting survivability.

Knowledge Systems, Credibility, and Expertise

Design, assessment, and improvement of survivability are inextricably linked to knowledge shared between people and institutions inhabiting complex systems. The potential for transformation of knowledge system hierarchies and boundaries provides opportunities for larger system evolution towards increased collective

survivability. Key to this exchange is power and how individuals and institutions gain entry, access, and influence over systems.

Affirmations of expertise and perceptions of credibility enforce who may be a part of any specific knowledge system, in what ways, and about what topics. This gatekeeping happens within individual scientific disciplines, multidisciplinary scientific contexts, and when intersections between science, other disciplines, and the lay public occur. According to Gieryn (1983), scientists set boundaries because they are anxious about their retention of authority, material resources, and liability regarding the implications of their research. Scientists' boundary-setting actions – particularly when they pertain to information assessment, acknowledgement (or disallowance) of multiple types of knowledges, and practices of information sharing within knowledge systems – may also increase or decrease system and situational survivability.

Through their participants' actions, the credibility economies internal to disciplinary scientific practices extend and reinforce boundaries between scientific disciplines, between science and other disciplines, and between scientists and lay publics (Shapin, 1995). When scientists, other disciplinary practitioners, and lay publics reinforce these boundaries, they often do so in ways tied to social and institutional identities (Epstein, 1995; Epstein, 1996; Wynne, 1992; Wynne, 1996). As Gieryn (1983) confirms, science is "no single thing," in part due to the boundary work performed by scientists to fulfill their own motivations (p. 792). He describes three key factors for why scientists construct and maintain walls both with the lay public and each other. First, inconsistencies between scientific disciplines exist "because of scientists' need to erect separate boundaries in response to challenges from different obstacles to their pursuit of authority and resources" (Gieryn, 1983, p. 792). Gieryn's (ibid) second and third factors appear to be a nuanced pair; boundaries arise from "different professional ambitions" and "separate professional

goals" (p. 792). Scientists' boundary work, both with the public and each other, reflects anxieties over retention of authority and material resources, as well as liability: "The goal is immunity from blame for undesirable consequences of *non-scientists'* consumption of scientific knowledge" (Gieryn, 1983, p. 789). Knorr-Cetina (1999), a sociologist of epistemology, argues that boundary-setting and collaborations within scientific disciplines vary. Experimental protocols happen differently in biological and physics cultures. Whereas biological experiments may be performed more in delineated competition, physicists may collaborate and compete more directly to push the entire discipline forward.

Even if particular scientific cultures may allow for boundary crossing towards larger goals, those with relevant, local knowledges about social, ecological, and technical risks and conditions may be dismissed as improperly or uneducated by scientists leading research (Epstein, 1995; Epstein, 1996; Wynne, 1996; Wynne, 1992; Suryanarayanan & Kleinman, 2013). For example, Suryanarayanan and Kleinman (2013) describe instances in which Environmental Protection Agency (EPA) scientists discounted the contributory expertise of professional beekeepers while addressing bee colony collapse disorder. The authors frame issues attached to the EPA's epistemic dominance as "shaped by the historically established social organization of knowledge production" (p. 219), and they describe ways in which academic toxicologists and EPA scientists aligned over time. "Thus," they write, "with the EPA's concurrence, the epistemic dominance of experimental forms that have come to be accepted among academic toxicologists is reinforced, and beekeeper data are dismissed" (Suryanarayanan and Kleinman, 2013, p. 232). Wynne (1992, 1996) describes similar patterns within his work on United Kingdom farmers impacted by both Chernobyl fallout and their local nuclear power plant; he describes ways in which the farmers understood their landscape to an extent that governmental

scientists nearly universally ignored. The government scientists performed experiments without proper context of land use, seasonal timing, and other local environmental details. By doing so, the government scientists' experiments failed to produce meaningful results, as the scientists succeeded in alienating the local farmers—accomplishing a far greater increase of distrust than useful scientific information. In both Suryanarayanan and Kleinman's (2013) and Wynne's (1992, 1996) studies, dismissal of the grounded, local knowledges of practitioners resulted in scientists' omission of pertinent information about and constructive opportunities to gain insights into the situations they researched.

Negotiating such authority and trust is a co-evolutionary and co-dependent process. Lay publics may also dismiss scientific expert knowledge as too uncertain or presented in ways that conflict with established cultural perceptions of credible storytellers, scientific expertise, and scientific objectivity, especially when economic systems are also involved (Oreskes & Conway, 2010; Mukherjee, 2010; Daston & Galison, 2007; Houston, 2013). Oreskes and Conway (2010) repeatedly describe a tactic used to influence public doubt through the promotion of credible scientific figures by institutions and organizations who hold varying positions of benefit from scientifically based claims. In addition to reputable scientists who backed the science, credentialed scientists – publicly known from notable Cold War efforts, governmental and university agencies, and the like, stood up and made scientific claims – about acid rain, climate change, and other unnecessarily controversial topics – that could be proved wrong. For instance, the scientists Oreskes and Conway (2010) studied "claimed that the link between smoking and cancer remained unproven" (p. 6) long past a critical mass of peer-reviewed science argued the opposite. These, often both corporate-backed and policy-influential, scientific old guards rarely created new science to further their claims. Instead, they positioned

themselves as detractors from mainstream views in order to sow doubt as to scientific veracity and to support the social and economic status quo.

However, perceptions of credibility and expertise may be transformed. Individual and community acquisition of deep scientific knowledge and disciplinary language may provide opportunities for those parties to pass through institutional boundary gates (Epstein, 1995; Epstein, 1996). As Shapin (1995) writes, within the credibility-economy "between expert groups and laity… We look instead for formal warrants of credibility—institutional affiliation or standing, the observance of explicitly framed methodical procedures, the display of expert consensus, and the like" (p. 270). He affirms why Oreskes and Conway's (2010) claims about the leveraging of power by scientists who check credibility boxes towards a misleading notion of scientific truth makes sense. He also opens a door that extends beyond the scientists themselves.

> Accessibility can cut both ways in such an economy. On the one hand, where we have independent access to the 'facts of the matter,' we may be able to use that knowledge to gauge the claims of experts. On the other hand, the representation of expert knowledge as far beyond lay accessibility can serve as a recommendation for its truth (Shapin, 1995, p. 270).

Epstein's (1995, 1996) descriptions of ACT UP members' mastery of scientific jargon or grassroot organization Safecast's members' publishing of radiation data in peer-reviewed scientific journals (Weston, 2017) are evidence of how lay publics can adopt and utilize credibility signifiers, so they may be perceived as experts in their own rights.

Despite the prominence of hierarchy within knowledge systems, the credibility of experts and lay publics is not only derived from a binary or parallel formula. Scientists and impacted communities may co-produce knowledge, and scientists may perform research in public in ways which strategically garner wider support (Miller &

Muñoz-Erickson, 2018; Brown, 2007; Latour, 1983; Daston & Galison, 2007). These tactics include the use of visual communications that are appropriate to the widespread notions of "objectivity" of a time (Daston & Galison, 2007) and participatory or community-led data collection and assessment (Miller & Muñoz-Erickson, 2018; Brown, 2007). Research co-production may sometimes, but does not always, challenge industrial and academic-focused science. However, as Ottinger (2013) writes about frontline communities impacted by industrial pollution, "[B]y supplementing accounts of illness with documentation of exposure to chemicals that could make people sick, buckets [DIY sensors used by community members] helped residents to weave together pollution and health in residents' testimony—and to demand that industry account for both at once" (p. 14). Visibility can be key to both the inclusion of multifaceted data sources and public buy-in to scientific research credibility with non-scientific audiences. In his essay "Give Me a Laboratory and I Will Raise the World," Latour (1983) describes Louis Pasteur as a master strategist for gaining public support of scientific research. By establishing a lab on a farm site, Pasteur explicitly demonstrated how his scientific pursuits were relevant to non-scientific daily life. By then taking research begun at the field site back to the lab, to perform complimentary experiments at different scales, Pasteur also clearly communicated the essential role of the lab in larger social-ecological-technical pursuits.

Communities comprised of variably scientific knowledge – and even those with no formal, credible background – may also adopt tools and practices to produce particular types of evidence that may challenge or extend comprehensions of a situation (Ottinger, 2013; Epstein, 1995; Epstein, 1996; Weston, 2017). In doing so, they challenge hierarchies and boundaries of knowledge systems in ways that may transform SETS towards increased collective survivability.

This dissertation also builds upon existing anthropological and STS research on lay communities' use of two types of critical technical practice. Critical technical practices refer to variably expert technologists' design and critique of technological configurations in ways that may lead to additional interrogation and renovation of those technologies towards relevant community goals (Agre, 1997). I will describe both in greater detail, including terminology origins and project examples, within the COVID Tracking Project chapter. First, technostruggle – as referenced by Weston (2017) – refers to community use of particular types of technologies, such as the employment of do-it-yourself (DIY) Geiger counters and environmental sensors in the wake of the Fukushima nuclear power plant disaster, to counter official scientific and governmental reports through the use of data collection practices deemed credible by those who proclaim information counter to the communities' lived experiences. Second, civic technoscience broadly includes the use of scientific, technological, and data practices that may both challenge and engage with civic processes (Kimura & Kinchy, 2019; Jalbert, 2016; Wylie, 2018; Harrell, 2020; Dickel et al., 2018; Wylie et al., 2014; Braun & Whatmore, 2010).

Though these practices may occur within many types of situations, communities' use of these tactics within urgent conditions are one way within which they gain information and agency in the face of uncertainty and danger; communities participate in epistemological reconfiguration (Quarantelli, 1998). Within each of my cases, I examine protagonists' collaborations within knowledge systems, their navigation of scientific disciplinary boundaries, their acknowledgement and transformation of notions of credibility and expertise, and how their engagements with these systems and concepts impact individual and collective survivability within their particular threat contexts.

Futures Thinking, Anticipation, and Uncertainty

Survivability is intrinsically about moving from a present state into a future state. Crises, disasters, and emergencies can be slow or fast, and they never move in neat lines. Yet survivability is a temporalized concept that includes an implicit desired transformation. "Disturbance opens the terrain for transformative encounters, making new landscape assemblages possible," writes Tsing (2015). "Whether a disturbance is bearable or unbearable is a question worked out through what follows it: the formation of assemblages" (p. 160). Each of the case studies within this dissertation examines a different type of epistemological reconfiguration, each at a different stage of formation. However, these cases represent more than disruptions and the ways in which they're addressed through the convergence and collaborations of multiple types of imaginations. When informed by futures studies scholarship, I also view these cases as ways of practicing the future.

Practicing the future, outside of the specificity of any particular methodology, means deliberately navigating uncertainty in the present as well as imagining plausible, not just probable, futures (Ramirez & Selin, 2014). Acknowledging and navigating uncertainty are survival skills for individuals, organizations, and communities, and deliberately developing their use of uncertainty within the context of practicing the future allows them to revise and expand their mental maps of how they might tackle obstacles and what their futures could hold (Tsing, 2015; brown, 2017; Ramirez & Selin, 2014; Seligman et al., 2016).

Individual and collective expectations always include evaluative data and values (Konrad et al., 2016). However, if they consider the future to be something that can be transformed, they engage with and embed additional values (brown, 2017; Levitas, 2013). The future is not fixed, even overly predetermined, or something to simply be filled (Adam & Grove, 2007). The future may be seen as

open, and individuals, organizations, and communities have agency to impact what the future may become (Ahvenharju et al., 2018; brown, 2017). Within this dissertation's three case studies, I present ways in which individuals, organizations, and communities not only respond to the present, but also strive for SETS persistence while they practice the future and grapple with questions of agency in the face of uncertainty. Within each chapter, I address how these forms of practice increase the case study subjects' sense of and quest for increased survivability.

Within this project, I aim to break new ground by mapping the notion of survivability amid complexity and uncertainty as nested in SETS. I build upon STS, sustainability studies, complex systems science, future studies, and disaster studies research, while extending STS approaches to survivability beyond sociotechnical systems to SETS approaches. I additionally expand upon and challenge previous academic research by gaining insights from ways in which popular, mainstream literature provides anecdotal survival models. By developing and analyzing new data within a multidisciplinary approach, I seek to define, interrogate, and create new frameworks to comprehend the terrain of survivability.

REFLEXIVITY STATEMENT

While strongly grounded within STS theories, this dissertation's multi-disciplinarity reflects my own academic and professional backgrounds. Within my undergraduate and master's degrees, I studied social and cultural history, art history, studio art, emerging technologies – through both theory and technical skills, and design. My professional pursuits include more than two decades synthesizing and translating complex concepts on a wide range of topics, in collaboration with experts, institutions, and communities, through the use of multiple forms of design, for broad audiences. Inspired by my professional work, I have personally pursued

increased comprehensions of different types of institutions—governmental, privately-owned, or community-led, as well as combinations of these categories such as museums. In parallel to my professional pursuits, I'm an artist, photographer, designer, and documentarian. I think through research, engagement with experts, the commitment of considerable time observing and documenting within applicable spaces and making multi-modal means of telling stories about what I learn. All aspects of this background influence the connections I discovered, the discipline hopping I pursued, and the particular juxtapositions that I made throughout this project.

In addition to my academic training, professional interests, and personal pursuits, the environment within which I grew up also influenced my worldview. My mother, who began her career as a teacher, retired decades later as a computer programmer who specialized in large-scale data mining. She assessed, designed, and maintained technological systems for corporations and utility companies. My father, a biological engineer with expertise in labor safety, focused his career on the safety of individuals within a myriad of workplace types. He spent considerable time collecting data in mines, on factory floors, in military vessels, on railroads, and riding around on garbage trucks and school buses, amongst many other environments. He spent more than a decade working for the National Institute of Occupational Safety and Health (NIOSH) and with the Occupational Safety and Health Administration (OSHA), the Centers for Disease Control (CDC), and international standards-setting organizations. Our home was filled with scientists, engineers, and epidemiologists. Amongst his dozens of peer-reviewed publications, he authored a paper on the impacts of pneumatic tools on uranium miners in Grants, New Mexico (Wasserman et al., 1991). According to the paper's acknowledgements, I served as his typist.

I am not merely a product of my upbringing, but acknowledging my early exposure to science, systems thinking, and safety concerns deters crafting a mythology that the topics of this dissertation were ones to which I only recently became exposed. Similarly, my choices of and perspectives on these case studies are also informed by my age. I am old enough to have grown up during the Cold War, under ongoing threat of nuclear annihilation, and to have come of age during the worst of the AIDS epidemic. I do not recall a time where I was not cognizant of the potential catastrophic threats that climate change poses, and I have lived through multiple waves of public dialogue that have accompanied that discourse over the last four decades.

I did not intentionally time this dissertation project to unfold during a political/cultural upheaval during a global pandemic while on the precipice of potential global war, but I cannot imagine a more appropriate context within which to work on questions of survivability. In addition, I began writing this dissertation while living in an area with significant right-wing militia activity. Though I do not focus on this other type of survival pursuit within my research, tangible questions of threat, response, and survival are something I spent formative project time grappling with daily.

My identification of and commitment to this project's three case studies are also tied to personal and professional pre-existing relationships. These relationships allowed for trusted exchange and increased access, and I acknowledge that I am not an entirely objective observer. I view the Georgia O'Keeffe case study through the eyes of an art historian – who chose not to pursue art history as a career, a museum professional, a trained archivist, a documentarian of nuclear-industrial history, and someone who pursues in her personal work regarding what stories get institutionalized and which remain untold. I first learned about the existence of the

nuclear fallout shelter from an old friend who's spent decades working for the O'Keeffe Foundation and Museum. His support of my research was crucial for my ability to gain access to both the site and those who preserve her legacy. My access to, and my ability to build trusted relationships with, the CTP team is due to friendship with one of the project co-founders. In the months before pursuing research about the team, before officially approaching this as a case study, we held ongoing conversations about our shared interests in varying configurations of credibility and expertise, data justice, and civic technoscience—ongoing conversations about how to comprehend and contextualize her team's work. In addition, it is the B2 research, and my previous collaborations with the scientists themselves, who inspired me to commit to this PhD program. I moved to Arizona to engage further with the scientists and their research, and I am excited by their work. I acknowledge this context as I also articulate my position in relation to that research in both as transparent and impartial a means as possible.

CHAPTER SUMMARY

This introduction is the first of five chapters. Within it, I have outlined the purpose, questions, frameworks, definitions, and contributions of this project, as I have also acknowledged my positioning within the research.

Chapter 2, titled PAST, RECONSIDERED, focuses on Georgia O'Keeffe's fallout shelter. I argue that Georgia O'Keeffe's construction of a fallout shelter circa 1962 provides us with a charismatic way into multiple essential topics. This case allows us to discuss the uncertainty surrounding emerging technological developments, nuclear anxiety as essential to Cold War-era U.S. life, post-WW2 sociotechnical imaginaries and notions of imaginations, expectations for citizen involvement in national safety projects, and dissemination of scientific information – through public and rarefied

channels. Though framed within U.S. nuclear-industrial history, this chapter concentrates on O'Keeffe's under-researched relationships to science and scientists, and how those may have impacted her work as well as worldview—including her autodidacticism and notions of personal and global survival within uncertainty. This chapter acknowledges that O'Keeffe's construction of the fallout shelter was likely both the result of rarefied access and an egocentric worldview, as it was also an unremarkable, timely reflection of expectations of individuals' participation within national security projects. While defining larger, entangled SETS between O'Keeffe and her surroundings, this chapter also serves as a backdrop and a partial foil to the justice concerns held within the collective-led efforts of the other case studies.

In Chapter 3: PRESENT, PERSEVERED, I address ways in which the COVID Tracking Project responded to governmental sociotechnical design that failed to operate in sufficient service to the U.S. populace during a time of crisis. In the early days of the COVID-19 pandemic, both state and national data tracking of U.S. cases lay somewhere between disarray and unavailable. Over the next year, the situation did not significantly improve. From March 2020 to March 2021, a collaborative team of novices and subject matter experts – in everything from data science to public health to computer science and journalism, gathered, parsed, made sense of, reported on, and distributed one of the most relied-upon data sets for U.S. comprehension and response.

Within this chapter, I concentrate on the story of a national, networked, grassroots collaboration that emerged out of need, the ways that participants taught themselves scientific and technological skills in order to aggregate and appropriately disseminate information to both scientific institutions and public audiences, the use of the project's data by major governmental institutions, and the ways in which

those involved in the project gained information and agency in the face of danger—for both themselves and in wider public service.

This chapter is strongly grounded within STS understandings of the roles of credibility and expertise within knowledge systems, as it places the COVID Tracking Project within the legacy of the ACT UP activists' activities within the AIDS epidemic, amongst other communities who perform critical technical practices, civic technoscience and technostruggle. While framing the research within questions of expertise and credibility, I also address concepts regarding knowledge systems, data justice, and performances of care.

In Chapter 4, FUTURES, IMAGINED, I outline how Biosphere 2's constructed, cyborgian environments allow scientists to perform field-scale experiments using lab-style, tight controls to address significant environmental threats. Biosphere 2's SETS also provide scientists with the ability to practice the future. Though all of the case studies address ways in which individuals and communities enhance survivability through practice, this chapter most explicitly references futures theories and methods. This chapter acknowledges Biosphere 2's historic, present, and planned future research as forms of haptic future-model testing, responses to contextual futures imaginaries, and charismatic means of futures imagination.

Chapter 5, CONCLUSION: CONSTRUCTING SURVIVAL, revisits the "so what" question of the dissertation and clearly articulates why it is important that we talk about survivability and the future. Within this chapter, I hypothesize, based on the previous chapters, *how* we might talk about survivability and the future. This chapter proposes where we go from here and how thinking about the future – by examining past, present, and practicing the future – will help to get us there.

CONCLUSION

Within this dissertation, I investigate conceptually interconnected stories with which to think about survivability as a field of study which explores historic, current, and future survival in the face of existential threats, social-ecological-technical uncertainty, and indeterminate futures. To interrogate survivability, this work draws from fields and concepts that probe how collaboration and change occur in complex systems. In opening up this STS-driven research to consider SETS, this work reveals how human culture and social institutions interface with technology and also how ecological matters and specificities of place figure into our interactions with both technologies and society. My presentation of each case highlights their unique configurations of expertise and agency while inviting us to imagine new paths forward, both individually and collectively, when faced with both immediate and long-term danger. By combining CAS framing with interrogation of knowledge systems, I look for ways in which transformations of hierarchy and epistemological boundaries may increase SETS survivability. Through marshaling themes of SETS, expertise and agency, and imaginations to extend concepts of systems survivability, this work builds a scaffolding to better understand the dynamic workings of quests for survival in the 21st century.

CHAPTER 2

PAST, RECONSIDERED

"Anachronistic in normal periods, in peacetime [defensive architecture] appears as a survival machine, as a shipwrecked submarine on a beach. It speaks to us of other elements, of terrific atmospheric pressure, of an unusual world in which science and technology have developed the possibility of final disintegration" (Virilio, 2008, p. 39).

"Did you read Eisenhower's speech about the vulnerability of cities, of how transport could break down and anyone without a garden could and very likely would succumb? It is an ugly situation: born of our fine Los Alamos fruit and Russia's logical fear. I will have a good garden somewhere. Not because of war, but because today it is sunny and warm—the feeling is there." - Maria Chabot to Georgia O'Keeffe, February 16, 1948 (Buhler Lynes & Paden, 2003, p. 443)

The legendary artist Georgia O'Keeffe built a nuclear fallout shelter at her home in Abiquiú, New Mexico. My research about potentially why and within what contexts she built the shelter provides new perspectives on O'Keeffe, including her relationships to science and how her autodidacticism may have related to her sense of agency, and allows us to discuss her place and participation as an individual within larger social-ecological-technical systems (SETS). As I will discuss throughout this chapter, O'Keeffe is an iconoclastic figure both of and outside of her time. This makes her a very useful figure through which to reflect upon the complexities of the nuclear age and its demand for both conformity and individual actions, even as the threat of mass destruction loomed.

Within this case study I present evidence about how both individuals and systems are essential to survivability in the context of collective safety. While later chapters focus on organizations' and institutions' relationships to SETS, here we peer into one woman's life as a window to decipher individual opportunities for participation in and transformation of survival. Before scoping out to include more complex interpersonal relationships within systems contexts, it is important to look at the dynamics of individuals with and within systems. O'Keeffe's story is not an all-

encompassing representation of the intersections between popular cultures, art, desert imaginaries, and the New Mexican – and national – nuclear imaginary. However, a focus upon a combination of her construction of a fallout shelter, her configurations of her home and studio in ways that support notions of survivability and persistence, and her relationships with science and scientists – regarding both her nuclear context and her artwork – all provide insights into aspects of an individual's place within mid-20th century survival contexts.

This case study plays multiple roles within this dissertation's pursuit of an expanded definition of survivability. In this chapter, I add arguments to the notion – introduced in the first chapter – that people are parts of systems, and that their credibility and expertise inform their positions in relationship to those systems. Using this case study, I introduce some ways in which an individual participates in national survival projects, including instances where risk is addressed through national and individual conceptions of survivability within urgent and uncertain conditions. I contextualize these relationships within a discussion of artistic, civic, and scientific imaginations. I also use the O'Keeffe stories to argue that multidisciplinary collaborations are means through which to gain information, agency, and to potentially increase individual and collective survivability. As a result of the research I performed for this chapter, I hypothesize that O'Keeffe's actions tell us less about her notions of the future as a larger concept to either be enacted or fulfilled than they hint at a worldview concerned with ideas of persistence in the face of the threats of the day, uncertainty, and just the inevitable passing of time.

This chapter will primarily, but not exclusively, focus on the fallout shelter because it serves as a literally concrete, metaphorically evocative symbol of both exceptional and ordinary individual participation towards increasing survivability. I make the argument that the fallout shelter is an evocation of, rather than an

anomaly in, O'Keeffe's views by also probing other aspects of the site – her garden and library, in particular – and her pursuit of effective preservation for her paintings. O'Keeffe was a veracious autodidact whose deep relationships with scientists and placement within contextual SETS impacted her work and worldviews.

QUESTIONS AND METHODS

Evidence of archival, citable materials that explicitly explain O'Keeffe's own justification for fallout shelter construction have yet to be found. However, pursuing leads for why O'Keeffe may have built the shelter reveals productively dark corners filled with information about and potential future scholarship regarding O'Keeffe's life and work. The majority of O'Keeffe research is undertaken by art historians and artists; STS research about O'Keeffe has been unrepresented within academic study.

This chapter primarily relates Georgia O'Keeffe's building of a fallout shelter to the embodiment of artistic, scientific, and civic imaginations that informed her conceptions of agency and survivability in the face of sociotechnical uncertainty and multiple potential futures. Second, it asks what roles her credibility and expertise might play in her conceptions of personal agency and survivability, particularly as they pertain to her collaborations with scientists. Third, this chapter investigates methods with which O'Keeffe acquired information, skills, and agency through inter-personal collaborations. To address these overarching questions, I interrogate the following clarifying questions: What do artistic, scientific, and civic imaginations mean in her specific case? How could individual scientists have informed O'Keeffe's scientific imaginations? How might mid-20th century civil defense discourse have influenced her perception of her role within civic participation and survival? And, how may O'Keeffe's situated knowledges – her childhood on a farm, her art career, her

residence in northern New Mexico – have influenced her conceptions of time, survivability, and the future?

Towards answering those questions, I performed archival research and site visits, studied secondary documentation, and held informal conversations with O'Keeffe scholars and former associates. For the archival research, I took five trips to the Georgia O'Keeffe Research Center, affiliated with the Georgia O'Keeffe Museum, in Santa Fe, New Mexico. During these visits, I read approximately forty years of correspondence between O'Keeffe and her collaborator and conservator Caroline Keck, as well as looked through all correspondence, invoices, and publications related to the conservation of O'Keeffe's work. I examined letters, event notices, and other paraphernalia that related to any intersection between O'Keeffe and Los Alamos National Labs or any other aspect of nuclear culture. I viewed site plans and historic landmark applications for the Abiquiú home and studio, alongside any other architectural information I could find about the fallout shelter. In addition, I spent hours in informal conversations with Dale Kronkright – Head of Conservation and Preservation at the Georgia O'Keeffe Museum – during each of these Santa Fe visits, talking about his conservation of O'Keeffe's work as well as his knowledge about O'Keeffe's relationship to science and scientists. As a result of this investigation, and my ongoing informal conversations with Kronkright, Dr. Sarah Rovang provided me with access to her 2019 unpublished report about the fallout shelter, written for the institutional group performing conservation at the Abiquiú site.

In addition to the letters, invoices, and various ephemera I studied during these visits, I also acquired copies of and studied select interviews from the Georgia O'Keeffe Oral History project, an initiative to collect information from friends and associates after her death, and I read through O'Keeffe's own copies of books and periodicals for which I requested access from the Abiquiú library list. I visited the

Abiquiú site itself twice. The first time, I visited on a special but public Abiquiú home and studio tour that also included entry to the fallout shelter (not all the public tours include this). Photo documentation was not allowed within any of the buildings, and the tour was held by an O'Keeffe Welcome Center tour guide. The second time, I visited alongside and with permission of the O'Keeffe Museum staff to photograph the fallout shelter and informally converse with staff on site. For both these site visits, I also visited the O'Keeffe Welcome Center itself in Abiquiú to view the exhibits about O'Keeffe's life in the area. I additionally travelled to Ghost Ranch twice. The first time, I arrived as a general visitor. I wandered the public areas of the site and hiked along the Ghost Ranch trails. The second time, I was invited to attend a private tour given to a group who was commissioned to work on an interpretive piece for the O'Keeffe Welcome Center in Abiquiú. Within this tour, we were taken to non-public areas of the site, including outside of O'Keeffe's Ghost Ranch home and to significant-to-O'Keeffe viewpoints in non-public areas of the landscape. Also, instigated by an ongoing conversation with Kronkright about the possible interrelation between her paintings of the location and increasing knowledge about nuclear physics, I journeyed out to a location O'Keeffe painted repeatedly and named the Black Place, in the Bisti Badlands near the edge of Chaco Canyon in northern New Mexico. I did not resolve my research on the Black Place to an extent that I felt that I could include it within this chapter's work, but the field visit to this significant O'Keeffe site nonetheless informed my thinking about O'Keeffe and her relationships to place and time. Within all of these site visits, I collected photographic documentation when allowed and recorded binaural ambient audio documentation when appropriate and possible.

I performed document analysis on both primary and secondary sources. Some primary sources that were not included at the O'Keeffe Research Center collections

were nonetheless published in ways in which I could still access them; this was the case, for example, for the letters between Maria Chabot and O'Keeffe (Buhler Lynes & Paden, 2003). Secondary research included scholarship written about O'Keeffe – including biographies, half a dozen exhibition catalogues, and the catalogue raisonneé (1999) – as well as books on Abiquiú, Ghost Ranch, and the history of art conservation. I also studied northern New Mexico history and culture, alongside relevant intersecting topics such as the Manhattan Project, Los Alamos National Labs, U.S. atomic culture, defensive architecture, nuclear-related sociotechnical imaginations, desert imaginaries, histories of gardens as national U.S. projects, definitions of expertise in art and science, and other realms of inquiry.

My analysis was the result of archival study, site visits and ethnographic observation, and document analysis of primary and secondary materials, and it was also considerably informed by trust I built with Kronkright, in particular, and his colleagues, secondarily, in order to gain access and perform the research that I did. My access was minimally rarefied, in that the materials that I studied at the Research Center could be requested by other researchers. However, it was my informal conversations with Kronkright that encouraged me to continue to ask the kinds of questions I asked—ones I had not encountered in art historical-driven research of O'Keeffe in the past.

SETTING THE BACKGROUND: GEORGIA O'KEEFFE

Georgia O'Keeffe was both an extraordinary individual and ordinary citizen/woman enmeshed in the social-ecological-technical systems (SETS) of her time. O'Keeffe is widely considered to be one of the most important visual artists of the 20th century. She co-led the modernist art movement in America while amassing international acclaim, created a prolific body of work, and was lauded as an artistic

pioneer throughout her more than six-decades-long art career. She developed new models of visual communication, painting methodologies, and roles a woman could inhabit within the art world. O'Keeffe's continued influence can be seen in the forms of blockbuster exhibitions staged in major institutions, ongoing scholarship, and identifiable aesthetic influence on contemporary artists and popular culture. Born in 1887 and initially raised on a farm in Wisconsin, scholarship frequently concentrates on her paintings' representations of landscapes, bones, and close-up imagery of botanicals. Much has been made of her attention to and deep knowledge of environmental science and natural history, alongside her relationships to physical locations—particularly those of New Mexico, where she lived for nearly forty years (Lisle, 1986; Buhler Lynes, 2001; Ruiz del Árbol, 2021).

Beginning in 1934, O'Keeffe spent summers in northern New Mexico. In 1940, she acquired a house at Ghost Ranch. In 1949, she permanently moved to the state from her home in New York City. In addition to the Ghost Ranch abode, she renovated and extended the dwellings of a home and studio in Abiquiú, New Mexico, between 1945-1949 (Lisle, 1986; Buhler Lynes & Paden, 2003; Buhler Lynes & Lopez, 2012).

O'Keeffe's Abiquiú property sits on approximately four acres. Parts of the compound date back to the eighteenth-century, and – at the time of her acquisition – the property's original buildings were in shambles. Though purchased in 1945, O'Keeffe claims that it took 10 years to buy the Abiquiú site (Buhler Lynes & Lopez, 2012). Her persistence in acquiring the property exemplifies her willingness to see a desire through over the course of a decade. Her choice to reconstruct – and reinforce – rather than tear down the property's old frames reveals her deliberate intermingling of modern and historic structural components. The two together hint that O'Keeffe's worldviews may have possibly fundamentally included longer

conceptions of time. O'Keeffe resided exclusively in New Mexico for four decades, until her death in 1986; she lived between the Abiquiú and Ghost Ranch properties.

Beginning in 1936, O'Keeffe spent her summers at Ghost Ranch. An exclusive northern New Mexico retreat for celebrities, intellectuals, and the wealthy, it was a veritable melting pot of the mid-20th century zeitgeist. Biographies of O'Keeffe and histories of Ghost Ranch acknowledge the simultaneous, 1940s-era presence of O'Keeffe and Manhattan Project leaders Dr. J. Robert Oppenheimer and Dr. Enrico Fermi. The scientists visited Ghost Ranch when on "rest and relaxation" leave from the nearby, secret Los Alamos site (Poling-Kempes, 2005). Starting shortly after their arrival in New Mexico, O'Keeffe developed and maintained friendships with multiple Manhattan Project-related, Los Alamos-based scientists (Goodman, 2010). Later in this chapter I will argue that her relationships to science and scientists have been underappreciated by scholars.

Throughout her life, O'Keeffe was a singular individual situated at the nexus of artistic, intellectual, and cultural milieus. Her artistic credibility and celebrity also provided her with access to information and resources rare for a woman of her time, while amplifying her status as an aspirational representation of what women – smart, accomplished women – could achieve.

Her physical location in the southwestern deserts generally, and New Mexico specifically, was also an influence on O'Keeffe's worldviews. O'Keeffe painted hundreds of paintings of her surrounding landscapes; many images were the result of her intrepid navigation out into often-remote lands. Her life, her work, and her viewpoints were inextricably tied to the physical and cultural geographies of her place, particularly that of northern New Mexico within the last two-thirds of the 20th century.

Though the complex intermingling of landscape-related imaginaries of New Mexico's history are beyond the scope of this dissertation, four are worth noting as context for this chapter—settler colonial (Blackhawk, 2006), desert (Davis, 2016; Koch, 2021), wasteland (Kuletz, 1998; Voyles, 2015), and forest (Kosek, 2006) imaginaries. As per Blackhawk (2006), the U.S. southwestern region cannot be understood in contemporary comprehension outside of socially and environmentally constructed layers of settler colonialism. Koch (2021) ties the settler colonial imaginary – a notion that the area was itself calling for settlement – to the desert imaginary, though Blackhawk (2006) does not limit settler colonial imaginaries to an ecological type. As per Koch (2021), "environmental imaginaries about deserts are geopolitical imaginaries, actively constituting and constituted by relations, identities, and potentialities across time and space" (p.87). In responding to the projected vacancy of desert visions, sites perceived as being empty of all but Native Americans (Blackhawk, 2006), Koch (2021) describes 20th century desert imaginaries as including the "frontier masculinity and modern violence of subverting nature to the will of man" (p.87). According to Davis (2016), the desert imaginary flourished in the mid-20th century, the period of O'Keeffe's settlement in New Mexico, for two reasons. First, a post-WWII United Nations concentration on an envisioned global reclamation (as per European views) of arid lands meant that widespread SETS collaborations inscribed deserts as sites of capitalist opportunity within global imaginations. Second, as a U.S. reaction to the early 20th century Dust Bowl, dry lands in the US were seen as something to be tamed and reclaimed. As per Blackhawk (2006), narratives of reclamation fit well within long histories of frontierism and manifest destiny. According to Kuletz (1998) and Voyles (2015), the U.S. southwest was enmeshed in not only desert imaginaries – in that the ecological attributes were not valued by Euro-centric worldviews, but they were also perceived through wasteland

imaginaries. In the social construction of wasteland sites, locations – and the people who inhabit them – are considered pollutable, expendable, and sacrificeable. However, southwestern environments deemed "landscape[s] of national sacrifice" (Kuletz, 1998, p. 12) as the result of internal colonialism in the U.S. are not places without value; these geographic locations are often resource-rich and frequently culturally sacred locations to Native American tribes. Wastelands' perceived values are also derived from their utility to the U.S. military's use of these sites for weapons development, testing, and training, and additional value is also the result of experimentation undertaken by military, scientists, and industry that simultaneously contaminates the environments and contributes to national security (Kuletz, 1998; Voyles, 2015). When O'Keeffe arrived in northern New Mexico, she may not have known about the burgeoning uranium mining industry emerging on the nearby Navajo Nation, for instance, but her decades-long entanglement with Los Alamos scientists could have likely informed her as to her location in the midst of wasteland-related SETS. Understanding the precariousness of the landscape and the long colonial, sacrificial histories of her location are essential for properly contextualizing O'Keeffe's outlooks on sustainability and survival.

"As westerners, we're haunted by the invisible poisons lurking in our dramatic landscapes," writes artist and northern New Mexico resident Lucy Lippard (2014, p. 115). As Lippard infers, northern New Mexico environments contain striated histories of deep geologic time, prehistoric extinction, multiple waves of colonization, and both the militarization and petrochemical industrial domination of the land. National imaginations enforced through colonization – first by the Spanish, then by Americans – utilized New Mexico's landscapes for different nefarious national purposes. Within the 20th century, New Mexico became the only U.S. state to house the entire cradle (Los Alamos, the birthplace of the atomic bomb) to grave (the Department of

Energy's Waste Isolation Pilot Plant nuclear waste site, located in Carlsbad, NM) lifecycle of nuclear science. New Mexico's land contains remnants that range from deep time (dinosaur skeletons were discovered on the Ghost Ranch property) to recent technological discoveries (the fallout from the first nuclear weapon test, held in Alamogordo, NM).

According to Kosek (2006), Los Alamos scientists themselves broadly participate in the co-construction of the literal nature of environments of both Los Alamos's and O'Keeffe's home region. "Los Alamos made the desert a refuge for scientists; the Trinity Site made the desert a place where utter destruction was realized," writes Goodman (2010) in her New Mexico history, *Lost Homelands* (p. 125). From before the bomb tests through present day, the scientific experimentation at Los Alamos has changed the land through the disposal of waste, dispersal of chemical particulates into the air, and radiation released as a part of both catastrophic experimentation and everyday nuclear scientific exploration. Kosek describes the evolving ecologies of northern New Mexico as environments of mutated (as per Masco, 2004) "future natures" (Kosek, 2006, Location No. 5200).

O'Keeffe's construction is one of many stories of individuals navigating New Mexico's land; her fallout shelter sits within a long legacy of regional individual and collective actions to ensure survival. As Goodman (2010) writes, in her history of 20th century New Mexico sociocultural and geographic landscapes, "stories inspired by encounters with the landscape thus serve the function of comforting the individual" while "confirming a group's shared values" (p. 9). Goodman's characterization describes a more frontier colonialist attitude, an idea of man against some notion of nature, whereas Kosek's (2006) work amplifies voices of communities both impacted by and entangled with the SETS and economies of the local nuclear-industrial complex. Kosek performed his interviews four decades after O'Keeffe's

shelter construction, but he describes relationships that begin at approximately the same time. Kosek (2006) writes of one family:

> Her father, Joseph, died just eight months before, after an extended struggle with thyroid cancer. Joe had worked in the lab for more than thirty-five years and when I interviewed him two years before he was one of the staunchest supporters of Los Alamos I had met. It was not that he didn't see the problems. He himself had dumped radioactive material into various canyons, including what has become known as "acid canyon," and had worked in TA (Technical Area) 21, the plutonium processing center at Los Alamos. He realized that some of these disposal methods were "a bad idea" but explained, "In those days we just didn't know better. It was 'out of sight, out of mind.'" For Joe it was worth the risk, even though he felt betrayed by the scientists he trusted, the scientists of Los Alamos who said he was never exposed to 'dangerous' situations. He still thought, "Los Alamos is the best job in the state." Joe's wife was not convinced. Flora told me, as she walked me back to my car after that early interview, that "he knows where the cancer came from—we all do—but it's hard to admit that you were wrong and it's hard to bite the hand that has fed us for over thirty years. Besides," she added, "it's hard to know for sure" (Location No. 4385-4390).

Kosek refers to the decades of New Mexican radiation exposure, from the pre-Trinity tests to the present day, as a haunting. "Haunting occurs when the boundaries between subjects and objects are broken, when the past and sometimes the future occupy the present" (Location No. 4888). The Los Alamos National Lab community's scientific and technological prowess has loomed large over northern New Mexico continuously since 1943. It has brought national prestige, uncertainty, and variably understood and recognized danger to the local landscapes. O'Keeffe's construction could be considered her personal shelter within New Mexico's 20th century, nuclear science storm.

BACKGROUND: THE FALLOUT SHELTER

Explicit evidence of O'Keeffe's construction intentions is yet to be discovered. However, this has not deterred anecdotal speculation about her motivations. On site visits, in informal conversations, and while attending public events, I encountered

multiple hypotheses. While participating in a public Abiquiú site tour, a guide told me that O'Keeffe was advised by "her friend" J. Robert Oppenheimer to build the shelter. An O'Keeffe Foundation employee informed me that this was one guide's individual interpretation rather than an institutional perspective. The most persistent story I heard aligns closely with a mythos of O'Keeffe as an individual who was deeply committed to landscape interpretation. She did not think she would survive long after a blast, multiple people hypothesized, but she wanted to paint the landscape after the destruction. The fallout shelter itself appears to be an anomaly when first viewed in relationship to the rest of the Abiquiú site, but it is the most emblematic artifact through which to investigate O'Keeffe's participation in and reflection of mid-20th century survival systems.

In approximately 1962, O'Keeffe constructed a fallout shelter at her home and studio in Abiquiú. Built into the cliff beneath her bedroom, the shelter's entrance looks out over the Chama River Valley. By the early 1970s, O'Keeffe and her assistants cleared out most of the materials housed within the structure. Discarded objects included food grown in her garden and preserved in jars. A small collection of items, including a disconnected phone, four bedframes without mattresses, and a drawer full of first aid supplies, remain.

Despite O'Keefe's attention to the creation and maintenance of the shelter, O'Keeffe scholars have ignored the fallout shelter, and O'Keeffe museum staff minimally maintain the structure. The authoritative book on her homes and studio, titled *Georgia O'Keeffe and Her Houses: Ghost Ranch and Abiquiú* (2012), almost entirely overlooks the presence of the fallout shelter at the Abiquiú home. In Fall 2019, the Georgia O'Keeffe Museum commissioned architectural historian Dr. Sarah Rovang to complete the first known research on the fallout shelter and its cultural context in service of the institution's larger conservation efforts at the Abiquiú site.

The report is both unpublished (as of the date of this dissertation) and the first to specifically date the structure's construction. Within her research, Rovang skillfully contextualizes the fallout shelter within general notions of Cold War insecurity and civil defense in mid-20th century America, more broadly, and northern New Mexico, in specific. Though she mentions some of the SETS I address in detail throughout this chapter, Rovang's remit focused on the shelter's architecture itself, including topics such as how it may have been constructed, who else erected similar structures at the time, and the roles these structures played in regional and national narratives about defensive architecture.

The term "fallout shelter" is one of multiple terms used for variations on similar forms of fortification structures. Fallout shelters belong to structural types of what Paul Virilio (2008) terms "defensive architecture," buildings that he describes as "instrumental, existing less in [themselves] than with a view to 'doing' something: waiting, watching, then acting, or, rather, reacting" (p, 43). The phrase "fallout shelter" will be used throughout this paper for multiple reasons; it is the primary term that Rovang's (2019) research report, historical documents, and communications by the Georgia O'Keeffe Museum – owners and caretakers of the Abiquiú property – use to describe the structure. In addition, Rovang (2019) writes, "Shelters like O'Keeffe's were meant not to provide any significant defense against the actual heat and explosive power of an atomic bomb, but to protect the occupants from the subsequent radiation exposure following a strike that happened at some survivable distance away" (p. 4). She states that it is therefore "more accurate to refer to this structure as a 'fallout shelter' rather than as a 'bomb shelter'" or bunker (ibid, p. 4).

The fallout shelter's aesthetic is anomalous within the context of O'Keeffe's larger property. Her home and studio building fuse traditional New Mexican

architecture with a clean, modernist arrangement. As Buhler Lynes and Lopez (2012) write, "the uncluttered spaces and simple furnishings O'Keeffe demanded demonstrate how her life in New Mexico was itself a component of the minimalist esthetic that is one of the distinguishing features of her art" (p. 14). O'Keeffe's dwellings are constructed of adobe and furnished with mid-century modern chairs, bookshelves, and tables. Some of the exquisite pieces of furniture, such as her Eames chairs, were gifted to O'Keeffe by her friends, the designers themselves. A combination of natural and well-designed lighting fills the rooms. Most walls are painted, in full or in part, a pristine white; the only exception is the grey mud plaster featured in O'Keeffe's bedroom, the result of the use of a particular dark clay found within northeastern New Mexico. Throughout the home, one sees no clutter or cracks. The entire compound is utilitarian, pristine, and elegant—except for the fallout shelter.

One could easily surmise that the fallout shelter has been an aesthetic anomaly since its construction. Slightly haphazardly placed stones surround the entrance door, made of wood and metal. The structure appears to be comprised of concrete block; the interior is painted crème. Ventilation pipes, barely visible from O'Keeffe's studio and bedroom windows, are painted a brown close in tone to the surrounding dirt—to blend in with the environment. Within the shelter, crème painted cork wall hangings supply hooks for securing supplies, the bed structures are made of metal, and speckled linoleum floors line the structure. One may connect the fallout shelter's mundane materials to its utility.

Within the context of this research, I find the shelter's anomalous design notable because of how effectively the fallout shelter may be understood as a material artifactual embodiment of O'Keeffe's both exceptional and quotidian relationships with sociotechnical systems of her time. Her own expertise gained her

unusual, direct channels to civil defense scientists and information. Her cultural standing and economic classes provided her with entry to spaces where she encountered relevant experts, and these bonafides similarly allowed her to independently acquire prime real estate proximate to scientific and technological developments. Her specific forms of participation in her own survival were a result of her privilege, her access gained by her credible notoriety, and her autodidacticism within the context of sociotechnical system expectations. However, part of what's incredible about O'Keeffe's fallout shelter is that, within larger contextual imaginations, her construction of defensive architecture is not extraordinary. She fulfills a common citizen's expected role. And, despite her defiance of norms in her own artistic realm, her boundary crossing into technoscientific realms may be unexpected but does not challenge or transform the credibility and expertise of those with whom she interacted in relevant scientific and defense domains. As understood through complex adaptive systems, modifications of nodes' boundaries and hierarchies may cause system transformation. O'Keeffe did not change the survivability of the larger, complex civil defense system within which she was enmeshed. However, she nonetheless took actions at her individual scale to increase the resilience and survivability of her personal SETS within the context of larger threats and cultures.

SCIENTIFIC IMAGINATIONS

Within this case study, I employ the concept of scientific imaginations for two reasons. First, I use the concept to evoke sociocultural perceptions of science and scientists within mid-20th century America, particularly – though not exclusively – as they intersected with art and artists. Second, I establish O'Keeffe's perceptions of

her specific local context of Los Alamos, a center of scientific innovation and emerging technologies.

During a public "behind-the-scenes" tour of the Abiquiú compound, held in September 2019, a guide claimed that O'Keeffe built the fallout shelter after doing so was suggested by J. Robert Oppenheimer. I found no archival evidence to support the idea that O'Keeffe and Oppenheimer were friends. Multiple sources confirm that they knew one another and that they had reason to cross paths over the years, but nothing reinforces that they were close enough to have a conversation that aligns with what the tour guide described. However, within her library, O'Keeffe owned multiple publications written by Oppenheimer. One of the books was *The Open Mind*, containing his essay "Prospects in the Arts and Sciences." Within the essay, Oppenheimer (1955) writes about what he perceived as the intertwined roles of artists and scientists within society.

> Both the man of science and the man of art live always at the edge of mystery, surrounded by it; both always as the measure of their creation, have had to do with the harmonization of what is new with what is familiar, with the balance between novelty and synthesis, with the struggle to make partial order in total chaos. They can, in their work and in their lives, help themselves, help one another, and help all men. (p. 145)

O'Keeffe built the fallout shelter in the early 1960s, a decade rich with collaborations between artists and scientific institutions. Examples include NASA's partnerships with artists James Turrell and Robert Irwin and Bell Labs's Experiments in Art and Technology program; art science collaborations, when aligned with national notions of constructive creative global dominance, were *de rigueur (*Beck & Bishop, 2020*)*. O'Keeffe operated outside of those structures and art historians have not perceived her as an artist who collaborated with scientific or technological institutions. However, examination of O'Keeffe's construction of a fallout shelter at her home in Abiquiú, when viewed alongside investigation of her personal archives,

reveals decades-long relationships and collaborations between O'Keeffe and individual scientists. In this chapter, I will discuss two of these relationships, with nuclear physicist Louis Rosen and chemist and conservator Caroline Keck, within the context of this research.

In tracing O'Keeffe's relationship to scientists, we need to first establish the historical moment and the potentials for collaboration. Collins and Evans (2002) note that in the 1950s and 1960s "a good scientific training was seen to put a person in a position to speak with authority and decisiveness in their own field, and often in other fields too" (p. 239). The authors reference scientists trained in "esoteric sciences" during what they term the First Wave of Science Studies; they're concerned with who is deemed expert enough to weigh in on scientific political decisions. However, their explanation combined with known respect for her technical acumen may provide cultural context for why scientists were amenable to discussing scientific topics with O'Keeffe. The intellectual circles within which O'Keeffe engaged in her east coast life with Stieglitz were notoriously multidisciplinary, but it is also notable that – despite the nuclear effort being named the Manhattan Project after the headquarters office in downtown New York City (NYC) – it was less likely that she would have dined with Los Alamos scientists if she had remained a NYC resident.

O'Keeffe's disciplinary boundary crossing provides us with clues to how she may have comprehended notions of survivability. According to Los Alamos scientist Louis Rosen (2003), O'Keeffe – from the time they met in the late 1940s – "was very anxious to talk about what was going on at Los Alamos—what would its impact be on the United States, on the world as a whole; is it really in the interest of humanity to build terrible weapons? She wanted to understand all of these things" (p. 4). Her interests, he states, encompassed questions related to the scientific underpinnings of nuclear technologies – both weaponry and energy, but her scientific interests were

broader. "She was interested in the impact of *science* on life in general" noted Rosen (2003, p. 4). In his 2003 contribution to the Georgia O'Keeffe Oral History project, Rosen claims that he and O'Keeffe talked more broadly about science, technological development, and knotty problems such as global hunger, as they also discussed nuclear physics and the developments that led to the atomic bomb.

CIVIC IMAGINATIONS

Rosen's testimony to O'Keeffe's sociotechnical curiosity supports a vision of O'Keeffe as an autodidact interested in both complex and everyday concerns born of nuclear weapons' emergence on the local, national, and global stage. Defensive architecture, as one type of response to nuclear risk, responds to acute threat alongside mundane and structural aspects of society. As Felicity D. Scott (2016) writes in *Outlaw Territories*, "Architecture is a political technology, one that remains endowed, quite literally, with the task of regulating the health, socialization, and productivity of a country's citizens" (p. 18). O'Keeffe's construction of a fallout shelter, in part, embodies her notions of civic imagination and elicits examination of how national sociotechnical and sociopolitical imaginations impact individual visions of collective survival.

Within their 2009 and 2013 articles on the topic, Jasanoff and Kim write extensively about the application of sociotechnical and technoscientific imaginations to national nuclear imaginations, and they elucidate the roles individuals and systems play within these social, technical, and political frameworks. Technoscientific imaginaries, conceptions of scientific technological breakthroughs within society "are almost always imbued with implicit understandings of what is good or desirable in the social world writ large" (Jasanoff & Kim, 2009, p. 122-123). Sociotechnical imaginations also "articulate feasible futures. Conversely, imaginaries also warn

against risks and hazards that might accompany innovation if it is pushed too hard or too fast" (ibid, p. 123). Jasanoff and Kim posit that examination of our relationships to the nuclear-industrial complex, and responses such as O'Keeffe's building of the fallout shelter, is useful for comprehending our places within collective survivability.

Novel structures of control emerged with the birth of the U.S. nuclear age, as did new articulations of individual citizens' roles within America's atomic futures. For individuals within the state, Jasanoff and Kim (2009) explain that the concepts of risk and threats need to be controlled. As it pertains to potential anxiety-invoked responses, "the public figures as needing containment just as much as the potentially runaway physical hazards of atomic energy" (p. 122-123). However, they write, "A well-known feature of the American sociotechnical imagination is that technology's benefits are seen as unbounded while risks are framed as limited and manageable" (Jasanoff & Kim, 2013, p. 190). America's sociotechnical systems create "a durable imaginary of containment" of both nuclear technologies and public fears (ibid, p. 190).

O'Keeffe was never one to be contained—by social mores, expectations, gender roles, or anything else within her life. She embodied the unexpected, and this often positioned her as a threat to institutional and authoritative powers. During the most secretive governmental operation of the 20th century, O'Keeffe lived within miles of its scientific headquarters. Though she was an international celebrity by the time she moved to New Mexico, she was still perceived as an outlier to restrain. The Federal Bureau of Investigation (FBI) opened a file on O'Keeffe in 1953, in response to what was seen as her dangerously left-leaning tendencies. The FBI reportedly closed the file in 1954 due to lack of evidence that she was a threat to U.S. political stability (Rovang, 2019). Despite her intellectual, cultural, and artistic trailblazing tendencies, and though O'Keeffe maintained a decades-long friendship with suffragist

Anita Pollitzer and developed relationships with the communist-supporting, blacklisted scientist, and J. Robert's brother, Frank Oppenheimer, O'Keeffe primarily engaged only on the periphery of political thought. She did not want to be seen as a politically inclined person, and she eschewed labels such as "feminist" for most of her life. Her civic engagement appeared to mostly involve her own, individual navigation of notable individuals and the larger world.

O'Keeffe's self-focus aligned perhaps surprisingly well with U.S. governmental attitudes regarding public safety in the face of potential destruction by nuclear weapons. Within her books *Thinking in an Emergency* and *Thermonuclear Monarchy*, Elaine Scarry (2011, 2014) describes an ongoing disjunction between U.S. nuclear responsibility and accountability towards collective survival, particularly as it pertains to post-WWII construction and use of defensive architecture. National policy deprioritizes the building of shelters for the populace, while the U.S. government spends billions to build protective structures for the President, Congress, and select additional individuals. Should nuclear war occur, elite citizens will gain access to safe enclosures. If a nation does not construct policies that enact "equality of survival", Scarry (2011) asks, how may citizens survive (p. 61)? O'Keeffe, as a wealthy, smart, autodidactic, well-connected individual, had access to information that allowed her to comprehend the risks she faced, as she also held the resources to potentially ensure her own survival.

Later in this chapter, I will describe O'Keeffe's library as a site through which to imagine how her autodidacticism provided her with information and likely agency within the face of uncertainty. Her library also includes examples of how her notoriety in one domain provided her with access to exclusive information within others. One of the books found within O'Keeffe's Abiquiú library is titled *The Effects of Atomic Weapons* (United States Department of Defense, Los Alamos Scientific

Laboratory, 1950). A publication notice, written by Civilian Mobilization Office Director Paul J. Larsen, appears within the first pages. The text indicates that this book was likely not meant for public consumption. The note reads:

> The Civil Defense Office, National Security Resources Board, commends this publication as a source of scientific information for *technical personnel* [emphasis added] engaged in civil defense planning activities. Its detailed description of the physical phenomena associated with atomic explosions provides certain basic data helpful in the preparation of practical plans for atomic warfare defenses (p. III).

Considering that other O'Keeffe resources, such as her copies of the *Bulletin of Atomic Scientists*, were widely available, we may theorize that she may have acquired this exclusive text through her exclusive connections. In Collier and Lakoff's (2008) book chapter on the history of U.S. risk calculations, safety, and critical infrastructure, they identify *The Effects of Atomic Weapons* as a direct product of the U.S. military's Strategic Bombing Survey (SBS). The SBS is a fundamental piece of context for comprehending defensive architecture within mid-20th century national sociotechnical civic defense imaginations.

Performed in the immediate days at the end of World War II, the Strategic Bombing Survey leadership convened engineers, architects, social scientists, and military personnel to document and assess the damage caused by multiple forms of aerial combat upon Germany and Japan. The SBS teams evaluated the impacts of firebombs and the first uses of nuclear weapons. These assessments were then leveraged for multiple purposes. In addition to select details made public to support efforts to both horrify and assure wider publics of U.S. military domination, detailed SBS reports justified tactical approaches to future military strategy, supported establishment of an independent air force, and provided guidance for the development of more resilient U.S. architecture through the use of materials and structural tests at U.S. nuclear proving grounds. SBS teams' quantification of the

destruction of enemy structures informed U.S. development of more effective U.S. architecture meant to withstand U.S. weapons of mass destruction (Gentile, 1997a, 1997b, 2000; Barnett & Mariana, 2011). Mid-20th century guidance on the material and structural makeup of domestic defensive architecture was deeply informed by this reflexive social-ecological-technical security system, even if the reach of these insights were limited. SBS teams studied the impacts of atomic bombs, while the threat of hydrogen bombs dominated the early 1960s. The deliberate minimization of national civil defense construction, and the wide range of shelter creators – with their own equally wide range of expertise – that arose to fill in widespread needs, also bounded whom might benefit from the iterative knowledge system ignited by the creation of the SBS reports.

O'Keeffe's construction of the fallout shelter occurred within the approximate timeframe of the Berlin Crisis, Kennedy's July 1961 public address regarding potential nuclear war, and the Kennedy Administration's 1961 inauguration of the National Fallout Shelter Survey. The National Fallout Shelter Survey was part of a larger effort reignited within the Kennedy Administration to increase civil defense education, even if not necessarily architectural and civic infrastructure (Weart, 2012; Vanderbilt, 2002). Within his history of Cold War civil defense, *Survival City*, Tom Vanderbilt (2002) explains that "[i]n addition to naturalizing the presence of the bomb and gamma radiation, the government, and architects themselves, had to work to resolve the overwhelming paradox of civil defense, that architecture created to resist the effect of an atomic bomb would be incompatible with everyday life" (p. 102). Given evidence that O'Keeffe knew considerable amounts about nuclear physics and kept herself informed regarding the known and potential impacts of nuclear weaponry, her construction of a fallout shelter very likely addressed both her long-term and her everyday concerns.

O'Keeffe resided within a particular national milieu. Spencer Weart (2012) refers to the approximate moment of O'Keeffe's shelter construction as an age of intense nuclear fear; literary and media narratives from 1958-1965, in particular, portrayed the potential of not only nuclear destruction but also nuclear weapons-related accidents to a previously unprecedented degree. O'Keeffe also specifically lived within close proximity to America's nuclear project headquarters, Los Alamos National Labs. Rovang (2019) suggests that the orientation of the fallout shelter door towards the north may in itself indicate that O'Keeffe may have been more concerned with an accident at nearby Los Alamos, located South of Abiquiú, than a weapons attack.

Potential threats must have been viscerally imagined by those within proximity to Los Alamos, though danger also extended beyond northern New Mexico in all directions. In addition to Cold War enemy perils, the U.S. above-ground nuclear testing program set off 210 atmospheric and five underwater detonations between September 1945 and August 1963, "turning much of the planet into an American nuclear test complex and producing nuclear victims on an equally large scale" (Masco, 2006, p. 60). For dramatic effect, current caretakers of O'Keeffe's Abiquiú complex set newspapers announcing the Cuban Missile Crisis on her empty fallout shelter beds. It is feasible that the Cuban Missile Crisis influenced O'Keeffe's choice to build the fallout shelter, given the hyper-intense widespread cultural reaction (Weart, 2012), but it is unlikely that a single instance determined her decision. Danger loomed over anyone who lived through that era, particularly within northern New Mexico, and who paid attention to their sociopolitical and sociotechnical surrounds. O'Keeffe leveraged her personal credibility, her autodidacticism, and her expertise to gain information and agency about potential threats and what she might be able to do to protect herself in the face of social-ecological-technical uncertainty.

EXPERTISE AND AGENCY

O'Keeffe's actions were undeniably in dialogue with her sociotechnical surroundings, but simply positioning her as a tiny component within larger systems underplays the ways in which she exerted individual agency over her own potential futures. Masco (2006) writes, "Approaching nuclear politics in northern New Mexico as a multidimensional, nonlinear, complex system underscores its complexity; however, it does not capture the intense, lived reality of these politics" (p. 37). O'Keeffe may have been influenced by her socio-cultural, environmental, and scientific surroundings, but all records of her life reinforce her strong-minded individuality. She questioned, observed, and learned from both the intellectual and biological landscapes within which she lived, but she made her own choices about how knowledge and systems influenced and manifested in her life and work. O'Keeffe was a notoriously smart, independent autodidact who gained both official and lay expertise across a variety of disciplines.

O'Keeffe is most known for her position as a respected, influential luminary of 20th century art. She's likely second most known for her intensive knowledge about natural history. O'Keeffe began her life on a farm, and her connections to lands she inhabited spanned beyond her artistic documentation to lived forms of exchange. Her Abiquiú property is fed by a persistent community irrigation water source, which both nourishes the land and connects O'Keeffe to the communal acequia culture of northern New Mexico. The acequias are a legacy of the Spanish Land Grant system, and their continued, useful persistence push back against the notions of sociotechnical infrastructural modernization of which the regional nuclear-industrial complex was a part. In addition, in the period of the 1930s to 1960, Abiquiú homeowners who were also Mexican land grant holders won legal battles against Anglo individual land consumers in order to assure their ownership and access to

communal resources such as the acequia system (Correia, 2013). Enabled by the water source, O'Keeffe's Abiquiú compound contains extensive gardens which Buhler Lynes and Lopez (2012) confirm were constructed for both beauty and nourishment. "The garden produced nearly all of the fruit, herbs, and vegetables for O'Keeffe and her many guests, and she canned, froze, or dried the remaining bounty for consumption during winter months" (p. 133). Even within her mundane, immediate, daily actions, O'Keeffe strategically ensured that her surroundings provided her with resilient systems infrastructure, actively took care of her own needs, and engaged with multiple simultaneous timelines.

As established earlier in this chapter, I believe that I found sufficient evidence to argue that the fallout shelter is a representative artifact of her thinking about survivability. Two other locations at her Abiquiú site, her garden and library, and her efforts towards her artwork preservation, provide hints to her relationships with larger SETS and navigation of uncertainty. The garden, in particular, may be meaningfully contextualized alongside and evokes similar sociotechnical patterns to the fallout shelter.

Gardening in the US in the early- and mid-20th century constituted participation in a particular kind of U.S. national project. During World War I, a collection of U.S. government agencies instituted a national "war garden" effort that simultaneously provided sustenance for overseas allies and citizens at home. National directives filtered through regional, state, and local organizations to encourage and instruct citizens in how to participate in shoring up both their own familial and community resources alongside their support of the larger national military pursuits. Towards the end of the war, these efforts were redesignated as "victory gardens," and program rhetoric included an increased shift towards local sustenance and small-scale opportunities for classic U.S. entrepreneurship using

gardens as supplemental household income. Within the onslaught of the Great Depression, "victory gardens" also became "sustenance gardens." Gardens were widely acknowledged as social-ecological systems through which to supplement national food production, decrease local produce costs, and ways to offer under- and unemployed Americans opportunities to apply their physical labor towards larger social good. Gardens were again implemented through multi-scaled governmental, community, and individual relationship structures, and they were located in a combination of municipal plots, community spaces, and attached to individual homes. At the end of the Great Depression, World War II provided the backdrop for a repeat of widespread support for gardening as a national means through which to assure one's commitment to citizenship. A robust gardening effort shored up the health of both the nation and individuals, as gardening was touted as great exercise through which to keep one's body strong—especially just in case one was called up to fight for the war (Lawson, 2005; Miller, 2003; Schupp & Sharp, 2012).

The garden was possibly both a cultural and deeply personal response. Built upon remnants of the existing landscape, Maria Chabot led the creation of O'Keeffe's garden during Chabot's oversight of the Abiquiú compound's construction. Chabot and O'Keeffe discussed the roles of gardening before its inception and kept in close touch about the garden's progress when planted. "I am convinced more and more that one must plan to grow food if one wants to be sure to have it," O'Keeffe wrote to Chabot in 1943 (Buhler Lynes & Paden, 2003, p.70). O'Keeffe may have been a wealthy woman by the time she arrived in Abiquiú, but her life experiences were not always affluent and stable (Lisle, 1986). A garden was both an aesthetic and functional decision for the site. And, acknowledged or not, she lived both within and beyond the notions of her time. Gardens were inextricable from the kinds of mid-20th century civic imaginations mentioned earlier in this chapter, as they were also a

sustenance technology necessary for remote rural places. I found no official governmental gardening pamphlets within the Abiquiú book inventory, but O'Keeffe's library contained more than a dozen gardening manuals (Georgia O'Keeffe Museum, 2013).

Within *Thinking in an Emergency* Scarry (2011) argues that we may live within national sociotechnical imaginations, but – particularly in the ways in which we choose to take care of others and ourselves – we are not powerless. O'Keeffe's personal library reveals her own search for information as agency, exemplified by deep investigations into known impacts of atomic weapons, the sociocultural and environmental ramifications of both nuclear energy and nuclear weapons, and structures through which one might survive nuclear war. O'Keeffe owned commercially distributed pamphlets about prefabricated shelter structures, governmental civil defense propaganda about how one may survive an attack, and government publications on nuclear science marked as not meant for public distribution. Her personal library included scientific magazines and technical manuals, alongside philosophical and historical narratives addressing how we – as individuals and societies – might think differently about persistence and time.

O'Keeffe's explorations likely fueled her visions of and her actions towards survival. They also echo descriptions of exchanges provided by her scientist friends. She owned texts gifted by friend Lewis Mumford (inscribed warmly with messages from Mumford to O'Keeffe and her husband, Alfred Stieglitz), which hints that she may have been thinking about sociotechnical systems early on. She maintained friendships with scientists, conversing with them on both technical and sociocultural aspects of their work. Per Louis Rosen (LR) in his oral history told to Sarah Burt (SB):

> LR: She was very bright and a quick study. She wanted to know about scientific things that I was worried about being able to explain to her. But if I made the effort, she understood big parts of what I would tell her: how accelerators work; what nuclear physics was all about; what were protons, neutrons, gamma rays, etc.
>
> SB: And she was really interested in that?
>
> LR: And she was interested. But mainly she was interested because she wanted to know [things like]: How does that relate to how people live? How does it help people fight disease, hunger? How does it provide energy to keep them warm? She was always interested from the viewpoint, not of being inquisitive about scientific aspects, but about how these developments impact the daily lives of people.
>
> SB: So it would be practical application of the theory?
>
> LR: Applications of the research. Practical applications, that's what she was interested in.
>
> SB: So we're talking about a humanitarian side of her that I don't recall many people talking about.
>
> LR: It didn't come out, no, it didn't come out very often. But maybe it was just with her scientific friends that she delved into that (Rosen, 2003, p. 9).

O'Keeffe built a fallout shelter of minimal size. Whom would be protected – beyond herself and her dogs – is unclear. Was she just another wealthy person building their bunker for the end times? Rovang's (2019) argument for why O'Keeffe's structure should be categorized as a "fallout shelter" rather than a "bomb shelter" suggests that she prepared for disaster but did not ensure a long-term insular containment. The structure is neither indelible enough, nor sufficiently militarized enough, for O'Keeffe to have survived for prolonged periods. This nominal sturdiness could be a mistake in construction on her part, but – given the highly technical information found within her library – that appears unlikely.

Returning to Scarry, we know that O'Keeffe built her shelter in a time when national, community safety was de-prioritized and individual responsibility was espoused as the way in which to protect oneself and one's family in the name of U.S. civil defense. O'Keeffe, as an individual, took care of her own needs in ways which

aligned with the 1960s U.S. social contract but was also interested in wider social benefits of nuclear technologies that could temper the individual approach. It is unlikely that her pursuit of nuclear-related scientific knowledge, and the associated implications of the related emerging technologies, was a quest to gain agency in the face of civic, structural ineptitude. She would not have been seen as compensating or overcompensating for governmental neglect; instead, O'Keeffe appears to embody the timely, entrepreneurial American spirit.

A NOTE ON SELF-PROTECTIVE KNOWLEDGE SYSTEMS

As proposed in multiple ways throughout this chapter, and as will be explored in the next chapters, knowledge systems operate at scales that may be both global in their concern and local in their focus. It would not be a conceptual leap to place O'Keeffe's pursuit of lay expertise within the context of transformative, collective protection movements such as the AIDS Coalition to Unleash Power (ACT UP) and the COVID Tracking Project—the focus of the next chapter. Similar to these movements, O'Keeffe was one of many who sought information and agency in the face of collective, uncertain danger. She also leveraged her credibility and expertise to speak with and gain knowledge from scientific experts. Unlike the members of these movements, she appears to have sought literal and figurative shelter only for herself.

However, some aspects of her individual autodidacticism reflected activist knowledge systems. One of the ways in which O'Keeffe closely aligned with social, environmental, and biological justice activists was her use of her situated knowledges to participate within "kitchen table" knowledges. I introduced the concept of situated knowledges in detail in the first chapter, and kitchen table knowledges are one particularly gendered way in which a woman's positionality

operates within grassroots activist efforts. As Ottinger (2013) writes in *Refining Expertise*, "Kitchen table stories [draw] attention in particular to the shifting, incomplete, and necessarily situated nature of the knowledge on which residential choices are supposed to be based" (p. 31). Due to her economic privilege and celebrity status, O'Keeffe may have had both the access and means within which to self-educate and provide for her own safety. But, fundamentally, as with all self-protecting citizens, she pieced together partial knowledge. She acquired lay expertise through her literal kitchen table conversations with Louis Rosen and others.

"[E]veryday encounters with scientific rationality and technology in ordinary women's lives help to produce various theories and practices for actively improving the conditions of their local communities and environments," writes Di Chiro (1997, p. 212). O'Keeffe may have been anything but ordinary, but her interactions were inevitably gendered, and her acquisitions of scientific knowledge intertwined with and impacted her everyday activities. Whether potential implications of nuclear physics, or – as I will address later in this chapter – chemistry and perseverance, her pursuits of scientific understanding allowed O'Keeffe to ensure for herself comprehensions, options, and potential actions towards her own survival. She also applied these tactics to increase the material survivability of her paintings.

ARTISTIC IMAGINATIONS

In order to address how artistic imaginations intersect with scientific imaginations in considerations of survivability, I find it useful to reflect back and expand upon an earlier piece of this chapter. Scientific and civic imaginations, as I employ them within this context and addressed earlier in this text, are deeply enmeshed within the definitions I provided in the first chapter. As Taylor (2002), Marcus (1995), and Jasanoff and Kim (2009, 2013) define them, these types of

collective imaginations include entanglement of social, technological, scientific, and economic norms. They are the result of collective buy-in to beliefs of what is considered good for society, and they include particular types of power structures and civic engagements. This conceptual framing remains fundamental for interrogation of O'Keeffe's positionality within larger sociocultural and sociotechnical systems. However, given O'Keeffe's identity as an artist, I need to employ one more type of imagination for this case study to explore how these imaginaries are co-informed by one another. My earlier description of scientific imaginations includes some indications of what mid-century attitudes were about scientific intersections with art, but this alone is not enough to lay the groundwork for my discussion of O'Keeffe's collaboration with her conservator, chemist Caroline Keck.

I am faced with a conundrum when I attempt to appropriately address an idea of "artistic imaginations" within the STS shell. On one hand, the notion of intermingling influence between culture, technologies, economy, individuals, and collective affirmation persists within a larger, systems view of O'Keeffe and her artistic context. On the other, this chapter outlines the importance of one individual's deeply rooted worldview while placing her as a person in conversation with larger systems. Though this multi-scale dynamic falls within the bounds of STS imaginations, this individual is an artist. The word "imagination" as defined by STS scholars feels insufficient to address ways in which O'Keeffe's personal "artistic imagination" intersects with larger cultural imaginations.

In order to remedy this conceptual inadequacy, I searched for a concrete definition of creative, artistic, imagination. My quest may have been a fool's errand. When not discounted as a general notion of imitation or irrational "flight of fancy" feelings (Shields, 2020; Aristotle, 1986; Bundy, 1922), I found that notable specific philosophers deeply interrogate the concept of "imagination" without proposing clear

definitions (Stock, 2007; Savickey, 2017; Sartre, 1936/2012). Academic surveys of the history of cultural notions of imagination acknowledge that the word means something about visualizing and manifesting new comprehensions when presented with partial information (Kaag, 2014). All these approaches may have some relevance, but none of these foundations scaffold a proper conceptual frame.

A most useful definition of "artistic imaginations" for my purposes might arise from a combination of cognitive psychology, neuroscience, the concept of techne, and educational theory. Both cognitive psychologists and neuroscientists acknowledge our biological abilities to compile mental maps of our physical and intellectual worlds. These maps allow us to navigate our conceptual and material surroundings, and they can be continually revised to account for new information while we extend our abilities to project into our immediate and longer-term futures (Seligman et al., 2016; Kemp, 2022). As per STS scholar Scott (1998), the concept of techne involves how "knowledge is to be codified, expressed, and verified, once it has been discovered" (p.320). The rules of techne "facilitate the production of knowledge that can be readily assembled, comprehensively documented, and formally taught, but they cannot by themselves add to that knowledge or explain how it came into being" (p. 320). John Dewey, a philosopher and influential educational theorist, takes the constructive knowledge organization of techne one step further. He posited a loose concept of imagination as our ability to tangibly bring together our knowledge and circumstances to – additionally – solve problems by making meaning within specific situations and our places as parts of a larger world (Bleazby, 2012).

Dewey's approach to imagination values intellectual and material components. In order to situate O'Keeffe within larger scientific and civic

imaginations of her time, I think we need to begin by acknowledging relevant fundamental aspects of her artistic intellectual and material worldviews.

In his 1965 essay "Arts and Sciences: A Proposal for Collaboration," artist and Massachusetts Institute of Technology (MIT) instructor Gyorgy Kepes wrote:

> In a less fragmented life, before the common life of society was frozen into separate compartments each with its specialized interests and jargon, priests and laymen, scholars and artisans, poets and artists could communicate to a larger degree in the same language and could pool their feelings and knowledge in a common cultural stream (p. 123).

I suspect that the formation of O'Keeffe's artistic imagination occurred within what Kepes would consider to be a "less fragmented" time, even as the focus of this chapter falls in an era full of both fractured expertise and notable increase in some types of art-science collaborations.

O'Keeffe's art practice always included science, even if her training was framed as meticulous craftsmanship rather than an education in chemistry or optics. She created art. It was also art which she pursued with the discipline of a scientist conducting rigorous experiments (Ruiz del Árbol 2021, p.243). However, writes Dale Kronkright, Head of Conservation and Preservation at the Georgia O'Keeffe Museum and Research Center, "this precision is not for the sake of engineering prowess. O'Keeffe's great precision as a painter is meant to communicate the clarity of her intention: the artist wants us to consider the many questions posed by the characteristics of her paints, the forms she creates with them, and the visual frame and focus that contains them" (Ruiz del Árbol 2021, p. 257). Her technical mastery was embedded within and in service to the creative intentions of her art.

O'Keeffe is widely considered an exquisite painter on a technical level, in that her use of materials has been studied and emulated long past her time. She gained that competency through education and rigorous practice, to a degree which is rarely

taught today. Before gaining international respect as an exhibiting artist, O'Keeffe supported herself primarily through teaching. As both a painter and an instructor, she comprehended and communicated art as a combination of expression and chemistry.

O'Keeffe's reputation within the art world was inextricably coupled with her relationship with photographer and gallerist Alfred Stieglitz. In addition to her role as muse, subject, and artist whom he championed, she also collaborated with Stieglitz in the printing of his photographs. Her mastery of art-related chemistry extended beyond a single medium.

Within art historical texts, O'Keeffe is sometimes referred to as the "mother of American Modernism," and it is within this context that her artistic legacy and science again merge. This moniker arises from both her association with Stieglitz, an early and notable proponent of Modernist thinking in America, and conceptual approaches employed within her art. Modernism refers to a collection of early- and mid-20th century art and design styles that embody the shifting intellectual, sociocultural, and technological landscapes of western Europe and America. "Often these styles include the use of modern materials and technology to express the activity of the artist as creator and to depict the essence of the modern model of reality revealed by science" (de la Croix et al., 1991, p. 953).

PRESERVATION AS A FORM OF RESILIENCE

In addition to her inquiries into nuclear science and sociotechnical systems, O'Keeffe pursued scientific knowledge pertinent to the construction and conservation of her paintings. In an essay by pre-eminent O'Keeffe scholar and former Georgia O'Keeffe Museum Director Barbara Buhler Lynes (2001), the artist's interest in conservation is described as O'Keeffe being "keenly interested in the condition of her

works" and begins and ends with the fact that she "often had them cleaned or otherwise treated by conservators" (p. 67). However, after reading 40 years of letters between O'Keeffe and chemist/conservator Caroline Keck, I found that Buhler Lynes's superficial description betrays the existence of much deeper collaboration. The letters contain materials advice from Keck to O'Keeffe, requests for technique recommendations from O'Keeffe, and even Keck sending O'Keeffe chemical supplies and instructions as to how to treat her own paintings to ensure longevity. In parallel to other aspects of O'Keeffe's life, work, and the construction of the fallout shelter at Abiquiú, O'Keeffe was not just thinking about the mundane task of cleanliness. She engaged with larger questions about science and time, about preservation and durability. In this way, I hypothesize that an examination of O'Keeffe's engagement with Keck regarding the conservation of her paintings is an extension of the worldview from which her construction of the fallout shelter emerged.

Research on O'Keeffe's relationship to Keck supplements my investigation of the fallout shelter construction for three reasons. First, given their genders and the context within which they worked, this may be another case of the employment of kitchen table knowledge tactics. Both were experts in their complementary fields, but their modes of information exchange were professional and also partial, cumulative, and highly colloquial. Second, and most importantly, evidence of O'Keeffe's collaboration with Keck supports my argument that scientific pursuits – such as that related to her acquisition of information about nuclear threats and her construction of the fallout shelter – were not an aberration. Their relationship confirms that scientific collaborations were fundamental to O'Keeffe's work and worldview. It is possible that O'Keeffe's work is a manifestation of the intersection of artistic and scientific imaginations. Third, the O'Keeffe-Keck relationship again hints at how O'Keeffe may have thought about survivability and time. In addition, she pursued

resilience, a key component of SETS thinking about which I wrote in the introductory chapter.

Bernard Berenson notoriously described the conservation/restoration lab as "the kitchen of art" (Grassi, 2003, p. 23). This nickname was meant to be derogatory to the profession, to indicate its less valued behind-the-scenes intersection with and influence on the art world (Grassi, 2003). It is in a flip to this notion, a lack of subjugation, that this reference aligns with the idea that the Keck-O'Keeffe relationship in part was a form of kitchen table knowledge exchange. As per Kohl and McCutcheon (2015), a kitchen is a "complicated, racialized, and gendered space" (p. 750). Kitchens "reproduce patriarchal structures" (ibid) and "can be spaces of power and emancipation" (ibid) where women communicate, create, and reinforce structures of care. I want to be careful to not overemploy this concept here, particularly as kitchen table knowledges and the related concept of kitchen table reflexivities are concepts grounded in black feminist thought (Kohl & McCutcheon, 2015), and I'm referring to two middle- and upper-class white women. However, though Keck and O'Keeffe rarely occupied the same physical location, they nonetheless carved out a space for themselves outside of the gender norms of their time to provide support, knowledge, and everyday communications.

The O'Keeffe-Keck relationship was unusual for its time because both women were rare and extremely notable in their respective fields. Their collaboration may have also been extraordinary because of the contemporary state of artist-conservator relationships. In his history of art restoration/conservation, Marco Grassi (2003) describes the bifurcation of the roles of artist and conservator beginning in the late 1700s and coming to a distinct head in the mid-20th century. Before the late 1700s the roles were not necessarily separate, and the subsequent distinction became about more than who performed what tasks. Until the 1960s, Grassi (ibid)

claims, it was not clear that conservation's scientific purpose was to preserve artistic intent, and he notes that Keck's husband (also a conservator and Caroline's close collaborator) was notorious for being an "operator" who prized materials science over artistry and nuanced consideration. The professionalization of conservation as a scientific endeavor exclusive of and deliberately ignorant to artistic intent should have placed O'Keeffe and Keck in opposition. Instead, as proven through the knowledge exchange described within their correspondence, they positioned their artistic and scientific expertise in ways which placed science in service to art.

O'Keeffe and Keck's collaboration was reciprocal to the point of what Kronkright terms the "influence of the conservator in shaping [O'Keeffe's] aesthetic" (Barilleaux, 2006, p.29). "With your experiences—will you tell me do you find that cobolt [sic] blue almost always cracks? It is such a beautiful color but I have such bad luck with it," writes O'Keeffe to Caroline Keck in December 1959 (Caroline Keck Papers, 1959). "PLEASE do not use this color again," writes Keck to O'Keeffe (regarding a particular brown) earlier that same year (ibid). "Maybe another tube would be all right," she continues, "but substitute something else for it if you can" (ibid). Changes within O'Keeffe's materials and color palette may sometimes be tracked back to her correspondence, her collaborations, with chemist/conservator Caroline Keck.

Their collaboration spanned beyond aesthetic modifications to include tangible impact on O'Keeffe's paintings towards increasing material resilience. O'Keeffe painted with highly controlled purpose, and it was through her increasing scientific knowledge that she gained control over her art. According to Buhler Lynes (2001), "By the mid-1930s, [O'Keeffe] had destroyed approximately thirty-five pictures… Although she never explained why she destroyed them, one can presume either that their condition had deteriorated to the point that effective restoration was not

possible or that they did not in some way meet O'Keeffe's evolving standards" (p. 34). Kronkright, in his essay "Painter and Conservator: A Collaboration", confirms this perspective on the destruction (Barilleaux, 2006, p.29). O'Keeffe's artistic imagination integrated conceptions of time. It is through examination of her nearly four decades of correspondence with Keck that we discover ways in which O'Keeffe increased her scientific knowledge, and collaborated with Keck, in order to ensure the artistic intent of her paintings for the long-term.

Modifications of practice and preservation towards long-term resilience appear both within O'Keeffe's lifetime and in the ways in which the Keck-O'Keeffe collaboration's knowledge systems spanned beyond the individuals with whom they began. Kronkright describes contemporary encounters with O'Keeffe paintings as falling into one of three categories due to pragmatic material constraints, the public visibility and frequent transportation of her work, and the passing of time. First, one very rarely might encounter an O'Keeffe painting to which no modifications have been made; these pieces were likely meticulously maintained and rarely exhibited. Second, one might view an O'Keeffe-Keck collaboration—a painting impacted by their collaborative preservation of the artist's original intent. Third, some paintings have been conserved by students of Keck, and their students, trained in the Keck-O'Keeffe ways (Barilleaux, 2006). As Whitaker Peters writes, "O'Keeffe's charge to Keck was to see to it that her pictures did not change" (ibid, p. 19). Keck fulfilled her charge, and their collaboration instituted ways in which the mission continues to be followed through subsequent generations—ensuring O'Keeffe's work's resilience for the uncertain, indefinite future.

CONCLUSION

Georgia O'Keeffe was both extraordinarily and ordinarily enmeshed in the SETS of her time. Her construction of a nuclear fallout shelter exemplified both her personal entanglements with art and science while it also reflected roles of agency within expectations of individual participation in national, U.S. mid-20th century notions of survivability. Her own rarefied credibility and expertise allowed O'Keeffe access to exclusive information and scientific insights, while part of what's notable about her construction is that fallout shelter construction was not itself unusual.

O'Keeffe's agency and participation in SETS of survival were a result of her privilege, her exclusive access due to her credibility and expertise, her autodidacticism, and system expectations. Despite her boundary pushing within her own artistic realm, her disciplinary boundary crossing – when seen within this chapter's contexts – did not challenge scientific knowledge systems or increase collective survivability in a civil defense context.

Within this chapter I also argue that O'Keeffe's engagement with science – as seen through investigation of her construction of a nuclear fallout shelter at her home in Abiquiú – was not an anomaly. When placed within the context of her relationship to art conservator Caroline Keck, O'Keeffe's explorations of nuclear science reflect her fundamental commitments to and collaborations with science and scientists. Within both the civil defense and conservation contexts, O'Keeffe's scientific collaborations increased her agency and potential survivability. Through her transformation of her own place within multiple science-related information hierarchies and disciplinary boundaries between herself and other SETS nodes, O'Keeffe potentially modified the outcomes and survivability of those systems within which she had influence—and were most likely to impact her own ability to survive the looming crises of her time. In this way, I hypothesize that O'Keeffe's future

visions were ones less to be enacted or formed, but rather that her worldview prioritized persistence—to potentially paint the landscape after catastrophic destruction, as the anecdotal story goes, but also to ensure that her paintings themselves could be viewed long into the future.

CHAPTER 3

PRESENT, PERSEVERED

"If AIDS activism can teach us anything, it can demonstrate how more ethical political formations attuned to the individual needs and identities of each person and privileging the most vulnerable among us can create rich imaginative acts of mourning and memorialization that also expose the injustices and inequities of life outcomes. We are still in the early stages of unraveling and naming all the social fissures that catapulted this public health crisis into a pandemic. What I have learned from the AIDS epidemic is that our methods of mourning should not exclude the way in which politics affect the matter and the circumstances of our bodies" (Levine, 2021, It's Mourning in America section, para. 8).

"If there's one thing we've learned about the many datasets we've wrestled with this year, it's that all the data—every single point—is the result of human decision-making. Decisions about how to define metrics, what to collect, how to group and publish the data, and—on our side—how to label and interpret it. The same principle holds true for the way we worked together as a group of highly disparate mostly-strangers who self-organized to fill some of the gaps in the country's public health data systems" (Kissane, 2021, para. 2).

"We measure and count in response to disasters as a way to ensure that the losses are not forgotten, to put down a mark when it is too hard to tell a story, and to preserve the possibility of accountability. From those numbers, we rebuild memories fragmented by trauma and we create the tools we will need to survive or even avoid the next catastrophe" (Soden et al., 2022, para. 1).

In the early days of the COVID-19 pandemic, public U.S. governmental epidemiological data about COVID cases lay somewhere between unruly and unavailable. Over the next year, the situation did not significantly improve. From March 2020 to March 2021, a collaborating team of novices and subject matter experts – in everything from data science to public health to computer science and journalism, gathered, parsed, made sense of, reported on, and distributed one of the most relied-upon data sets for American comprehension and response. This team, the COVID Tracking Project (CTP), responded to governmental sociotechnical systems design that failed to operate in sufficient service to the U.S. populace during a time of crisis.

Within this chapter, I concentrate on the story of CTP's national, networked, grassroots collaboration that emerged out of need. I focus on the ways that participants taught themselves scientific and technological skills to aggregate and appropriately disseminate information to both scientific institutions and public audiences, the use of the project's data by major governmental institutions, and the ways in which those involved in the project gained information and agency in the face of danger—for both themselves and in wider public service.

Survivability is concerned with the assessment and design of systems' abilities to persevere in the face of threat contexts, including determinations of what system components are deemed essential for systems' functions, and CTP's work engages with this concept in multiple ways. CTP supplemented governmental systems that were designed with approaches insufficient for widespread usefulness, and CTP established their own organizational configurations to produce clarified data in the face of governmental data obfuscation. CTP's efforts pushed for greater accountability from governmental social-ecological-technical systems (SETS) that failed to provide for the informational and public health protection needs of the U.S. populace, supported a high level of survivability in their own data systems, and prioritized the well-being of their members. In addition, through both internal and external engagements, they bolstered the quality and comprehension of information understood and communicated by journalistic outlets while also providing reliable, credible data accessible to broad publics. In these initiatives, as with others I describe in this chapter, CTP's efforts provided insights into how to strengthen existing SETS by modeling new ways forward. This chapter is strongly grounded within Science and Technology Studies (STS) understandings of the roles of credibility and expertise within knowledge systems, as it places CTP within the legacies and contexts of other communities who perform scientific and technical

practices in their efforts to gain agency in the face of danger. I contextualize my research on what we might learn from CTP about increasing collective survivability within questions of epistemologies of expertise and credibility, data ontology and performances of care.

QUESTIONS AND METHODS

Though a considerable amount has been written about CTP by outside journalists (Cohen, 2021; Fausset, 2021; Allsop, 2021; "Why Slack," 2021; Harford, 2021; Salkever, 2021; Jo, 2021) and CTP members themselves (Meyer & Madrigal, 2021; Kissane, 2021; Glickhouse, 2021; French & Camberg, 2021; Hoffman, 2021; French & Li, 2021; Gilmour, 2021; Schechtman & Simon, 2021), this dissertation is the first study to consider both external narratives and internal observations of the CTP community's leadership team. This is also the first examination to contextualize CTP's work as that of a complex adaptive system entangled with notions of survivability. Reflecting my unusual inside-outsider dynamic with the organization, I examine CTP through multiple lenses. I put CTP's work in historical context and situate it in STS scholarship on epistemologies of critical technical practices. I examine CTP's external and internal engagements with institutions, expertise, and imaginaries to elucidate how they are both nested in broader social-ecological-technical systems (SETS) and how the organization constitutes a complex adaptive organizational system.

Within this case study, I address the primary dissertation questions in overlapping ways. First, I interrogate what roles credibility and expertise play in how civic and scientific imaginations inform CTP members' conceptions of agency and survivability in the face of social-ecological-technical uncertainty and multiple potential futures. Additionally, I ask what roles CTP enacts within public imaginations

on these topics—including how the organization's expertise and credibility are represented and perceived. Second, I ask how both organizational and members' expertise and credibility are gained, challenged, transformed, and demonstrated by both laypeople and scientists through collaboration with scientists and scientific institutions within urgent conditions. Third, I examine how CTP's members' expertise and credibility are entangled with how they individually and organizationally acquire information, skills, and agency within their situations through their inter-personal collaborations, use of technologies, and intersections with civic and/or institutional processes. In addition to these entangled variations of the central dissertation questions, I ask how a particularly striking and important aspect of internal CTP culture—the performance of care—intersects with notions of survivability both within the organization and in comprehending what we can learn from their work about survivability in the 21st century. By putting CTP's work into context both historically and in conversation with work accomplished by other organizations performing critical technical practices for civic engagement, I am led to inquire as to whether or not CTP was responding to governmental sociotechnical failure, or if it was instead responding to systems designed to fail many because the survivability of the system is focused on the persistence of some, not all.

My research methods for this case study included approximately six months of participant observation from January 2021 to June 2021 – spanning normal operations, their wrap-up and shutdown, and their post-shutdown archiving process. I observed leadership meetings, data collection, all-hands meetings, select team meetings, internal and public events, and their ongoing communications within their Slack—an online platform for organizational communication. In addition, I attended related pandemic-focused events held by governmental agencies and research organizations, including those who hosted CTP speakers such as the Annenberg

Innovation Lab (April 8, 2021), the CSV Conference (May 4, 2021) and the Barnard College Empirical Reasoning Center (May 17, 2021). Document analysis also informed my findings. I read and coded CTP-created documents, articles written about CTP, journalistic and academic articles about the pandemic more broadly, and U.S. government reports (Biden, 2021; Pandemic Response Accountability Committee, 2021). I also watched select media broadcasts that mentioned and/or included materials produced by CTP and read the CTP Twitter stream – one of their primary forms of communication – and responses to their posts. In addition, I had dozens of informal background conversations with team members, held a select number of formal, semi-structured interviews with members of the leadership team, and studied contextual information about topics such as pandemic history, the history and legacies of the AIDS Coalition to Unleash Power (ACT UP) during the AIDS epidemic, data politics and justice, and civic imaginaries. Before finalizing this chapter, the text was reviewed by both a CTP co-founder and an ACT UP alumnus to ensure that my descriptions and characterizations of their work did not misrepresent them.

Although of course this qualification applies to the whole dissertation, I especially want to explicitly state here that I take full responsibility for the perspectives that I convey about CTP. The leadership were incredibly kind to allow me to observe, and at times participate, in their efforts, even when they did not always allow entry to others. I witnessed at least one of these debates between team leaders about whether or not to allow a researcher access to meetings and data that were not widely available to all CTP members. It was clear that the trust I built with them, alongside my pre-existing relationship with a highly respected project leader who vouched for me, was essential to my access. I also admit that, though I intellectualize and contextualize their work, I am personally very supportive of both

the organization and the people with whom I intersected. Within the course of my observations, I created CTP "fan art" when I mocked up potential t-shirts and made exemplary icons to represent the work of the end-stage archiving team.

PLACING CTP IN CONTEXT: HISTORIES AND EPISTEMOLOGIES OF EXPERTISE

I ground this case study in two contexts before diving into the specifics of CTP's efforts. First, I provide a brief history of the AIDS Coalition to Unleash Power. In doing this, I acknowledge a significant organizational precedent within public health activism and STS research. Second, I place CTP's work within anthropological and STS conceptions of epistemologies transformed through communities' use of scientific and technological tools to gain information and agency within their particular threat contexts. By establishing these contexts as groundwork for my discussion of CTP, I situate CTP as a part of a larger discussion within previous related scholarship and movements.

History: Acting Up in the Face of Death

A grassroots precursor to CTP in the public health response space, the AIDS Coalition to Unleash Power (ACT UP) formed in New York City in 1987 as a queer community response to the AIDS epidemic. During the worst years of the AIDS crisis, ACT UP expanded to include approximately 148 chapters in 19 countries (France, 2020). Often when one encounters ACT UP referenced in culture, history, and/or media, the name is shorthand for the first, extremely charismatic and engaged NYC chapter. Or, in the case of Steven Epstein's (1995, 1996) seminal STS research about layperson engagement in governmental health agencies, ACT UP means primarily the NYC and Bay Area chapters.

I include ACT UP's history and teachings within this chapter for three reasons. First, I lived through the height of the AIDS epidemic, and doing so was formative to how I perceive and understand the COVID-19 pandemic. Second, Epstein's (1995, 1996) research on ACT UP is a significant precursor to my research on CTP and to comprehending CTP through an academic, STS lens. Also, notably, both ACT UP and CTP's work intersect with many of the same governmental agencies and public imaginaries about roles and responsibilities of the U.S. public health system, while both communities also include members with embodied knowledge (Brown et al., 2004; Brown et al., 2012) – personal, first-hand experience – of the illness. Third, living alumni of ACT UP (Levine, 2012, 2021; Gonsalves, 2021; France, 2017; Shulman, 2021) are my elders in pursuing survival concerns. I have sought the work and ongoing insights of these veterans throughout the COVID-19 pandemic in order to make sense of both the public health emergency and CTP. Though, throughout my research, my understanding of CTP's place in ACT UP's legacy evolved, perspectives and accounts by and about ACT UP members helped me find my way in yet another extraordinary time.

ACT UP was particularly known for their performative protests and their incredible efforts to humanize and make visible the crisis to larger publics while fighting for People With AIDS's (PWAs) rights and demands for proper healthcare. In the midst of their wide range of community-supporting activities, subsections of the organization taught themselves about treatments, the science behind the emerging immunological and pharmaceutical investigations, and the rhetoric necessary to negotiate within scientific institutional settings. ACT UP members cataloged and navigated sanctioned drug trials, as well as participated in their own drug experimentation, and ACT UP members transformed the U.S. pharmaceutical system

and patients' place within it (Epstein, 1995; Epstein, 1996; France, 2017; Shulman, 2021).

STS scholar Steven Epstein (1995, 1996) powerfully documented and analyzed ACT UP's work at the intersection of emergent community science and sanctioned governmental scientific negotiations that was accomplished at the height of the crisis, from the late 1980s through the mid-1990s. Epstein's research provides a structural lens onto ACT UP's negotiation with and within U.S. sociotechnical health systems. His work elucidated processes that inspired other health activist communities – such as those who have fought for transformed rights for breast cancer patients (Epstein, 1995).

Epstein names individual members within his structural-focused scholarship, providing glimpses into some human aspects of ACT UP's engagement of systems, but members' stories are not his strength. As confirmed by later member accounts (France, 2017; Shulman, 2021), Epstein's description of life within ACT UP was accurate while not comprehensive or refined. In contrast, considerable nuance about the internal personal interactions may be found within the work of ACT UP alumnus and performance scholar Debra Levine (2012, 2021). As Levine (2021) wrote, a year into the COVID pandemic:

> As a queer activist movement, ACT UP did not only use direct action to speed anti-retroviral development and opportunistic infection treatments through the government's testing and approval process. ACT UP's legacy is that ethos of collective care in support of self-determination. The group supported People With AIDS' (PWAs) right to choose not only the course of their medical care but the way in which they could continue to matter politically and socially. This ethos was conceived in opposition to the historical disempowerment of the ill when they transformed into 'patients,' vulnerable in relation to state power (Bodies in Motion section, para. 4).

According to Levine (2012, 2021), the value of ACT UP's efforts extended beyond their negotiation of complex sociotechnical systems to include performances of care

that reified agency in less monumental ways. Within both her dissertation and the same article within which the above quote appears (ibid), she describes ways in which members enforced PWAs agency to choose how they lived their remaining lives, the conditions – and community – within which they died, and whether or not to remain involved in ACT UP in their afterlife—extending to the use of their bodies in street protests to ensure that their deaths did not disappear into silence. I will return to Levine's ACT UP scholarship later in this chapter, within a discussion of the prioritization of care as a form of both resistance and resilience.

Key to understanding intersections of the interpersonal and institutional dynamics of ACT UP, both internally and externally, is an acknowledgement of the Treatment and Data Committee's adoption and deployment of scientific jargon to gain expertise internally and credibility externally in their dealings with governmental health agencies. Through the mentorship of those with scientific expertise, a dynamic ignited by member Dr. Iris Long (Eigo, 2004) and supported through internal educational collaborations by mostly lay experts, ACT UP members were able to acquire information, gain comprehension, and communicate with scientists, publics, and the media about contemporary knowledge regarding emerging treatments for a poorly understood disease. ACT UP members served as data repositories, connectors, and advocates. The Treatment and Data Committee acquired, parsed, and translated emerging scientific studies and pharmaceutical data. Members collected information regarding drug trials, and they connected PWAs to these trials and sometimes to the drugs themselves. ACT UP members protested and presented at scientific conferences. And they both protested at and negotiated with members of the National Institutes of Health (NIH) and Food and Drug Administration (FDA) to transform scientific processes in ways in which PWAs could consent to participate in pharmaceutical trials earlier than contemporary legislation allowed, thus gaining

critical access to potentially life-saving drugs. ACT UP members were fervent advocates, but they were also data collectors, scientific translators, and public educators at a time when an HIV/AIDS diagnosis was only understood as a death sentence (Epstein, 1995; Epstein, 1996; France, 2017; Shulman, 2021).

Despite a potential easy translation of ACT UP's legacy onto an understanding of CTP, I instead hypothesize that the two organizations can be envisioned more as a Venn Diagram of concerns than a direct genealogy. The organizations' critical overlaps fall into two primary categories, one internal and the other external. First, like the ACT UP members before them, CTP members – of varied scientific backgrounds – taught themselves how to comprehend and communicate the science of their pandemic to both organizational members and wider publics. Second, also similar to ACT UP, select CTP members interacted with employees of U.S. governmental health institutions, and both organizations broadly publicized their work in ways that were meant to benefit all Americans. These broad communications demonstrated how they personally fought for collective safety while they also simultaneously held governmental institutions accountable for protective actions – or the lack thereof – widely perceived to be under public health systems' responsibilities. However, the two organizations' notions of accountability were different. ACT UP negotiated for earlier, consensual layperson involvement in pharmaceutical trials, and they argued for increased access to both information and medications. CTP also wanted access to information, specifically COVID-related data collected at state and national levels, and they wanted the information made public. Though they discussed emerging pharmaceuticals internally, CTP did not consider advocacy or information about medications, or even vaccines, within their scope. Both organizations pushed for increased transparency between governmental institutions and the public, but while ACT UP emphasized the performance of science

and everything that entailed, CTP focused solely on epidemiological data itself—and what the data represented for public comprehension of risk, uncertainty, and catastrophe.

Epistemologies of Expertise: Use of Critical Technical Practices

Another helpful context for CTP's work is within scholarly conceptions of epistemologies transformed through communities' use of critical technical practices. As per Agre (1997), technologists perform critical technical practices through their dual application of design and critique to interrogate and potentially transform technologies and related systems. Agre (ibid) framed his original definition of the term within the context of his role as a computer scientist and Artificial Intelligence researcher. According to Wylie, Jalbert, Dosemagen, and Ratto (2014), Agre's definition has since been expanded through "[p]ractices of critical making, community-based environmental health and justice research, science and technology studies (STS), and participatory design," as these communities have "generate[d] new alternate spaces and tools for scientific research" (p. 117). I utilize the term as a conceptual umbrella that frames ways in which communities comprised of variably scientific knowledge – and even those with no formal, credible background – may adopt tools and practices to produce particular types of evidence that may challenge or extend comprehensions of a situation (Ottinger, 2013; Epstein, 1995; Epstein, 1996; Weston, 2017). Though these practices may occur within many types of situations, communities' use of scientific and technological design and critique within urgent conditions are one way within which they gain information and agency in the face of uncertainty and danger. For example, as mentioned above, ACT UP negotiated greater involvement in drug trials, while also collecting their own data on trials as well as performing some of their own pharmaceutical experimentation

(Epstein, 1995; Epstein, 1996). Communities situated on the front lines of environmental and public health concerns entangled with the petrochemical industry designed sensors and collected data through which to engage with regulatory processes (Ottinger, 2013). And residents impacted by fallout from the Fukushima nuclear power plant disaster created their own Geiger counters to collect radiation data (Weston, 2017). As per these and other examples found throughout this chapter, communities participate in epistemological reconfiguration (Quarantelli, 1998).

As I mentioned in the first chapter, this dissertation builds upon existing anthropological and STS research within my focus on lay communities' use of two types of critical technical practice—technostruggle and civic technoscience. These two concepts contain considerable overlaps in their use of scientific and technological practices for use of epistemological reconfiguration, particularly within their struggles with power and hierarchy. Both concepts also describe means through which to engage with civic processes. However, technostruggle's and civic technoscience's delineations together also provide a more multifaceted backdrop with which to think about CTP's work.

First, technostruggle – as referenced by anthropologist Weston (2017) – refers to community use of particular types of technologies, such as the employment of Geiger counters and environmental sensors in the wake of the Fukushima nuclear power plant disaster, to counter official scientific and governmental reports through the use of data collection practices deemed credible by those who proclaim information counter to the communities' lived experiences. This concept, in the ways in which Weston employs it, initially sounds like it focuses on data. However, while technostruggle is concerned with data, it also specifically describes the use of technological hardware and software. Weston's recount of the Fukushima radiation

response is both about the data collected and the community construction of Geiger counters themselves.

Though Weston employs the term technostruggle as a description for challenges over credible instruments and the quantification of environmental conditions, the conceptual framing originally appeared within media studies as a way to describe contestation that arose alongside widespread availability and adoption of consumer, handheld audio and video (AV) recording devices. Fiske (1994) is cited as first using the term in reference to the filming of Rodney King's beating by Los Angeles Police in 1991 (Jenkins, 2010), and he revisits the concept with Hancock to provide additional examples of ways in which communication and surveillance technologies create, maintain, and/or subvert power between government and communities (Fiske & Hancock, 2016). Jenkins, a media studies scholar particularly known for his study of grassroots fan communities, considers Fiske's notion of technostruggle skeptical and cautious. He argues that Fiske's definition of the concept does not extend far enough to embrace the possibilities of emergent forms of digital media and that Fiske underestimates the gap between what forms of contestation may be harnessed by techno-use and entrenched forms of power (Jenkins, 2010). Weston, however, employs the term to extend Fiske's original notion into technological and media contexts beyond early AV hardware in ways which both address Jenkins's argument and situate the concept in an expansive enough frame to serve my purposes for this project.

Second, civic technoscience broadly includes the use of scientific, technological, and data practices that may both challenge and engage with civic processes (Wylie et al., 2014; Jalbert, 2016; Wylie, 2018; Harrell, 2020; Kimura & Kinchy, 2019; Dickel et al., 2018). Braun and Whatmore (2010) loosely place technoscience as a means through which to negotiate between political and scientific

epistemologies and tangible practices. Kimura and Kinchy (2019) term this concept as one form of "environmental citizen science," outlining involvement with government as one of multiple roles that citizen technoscientific efforts play. Wylie et al. (2014) specifically define and situate "civic technoscience" as an intersection between the epistemologies of technoscience and critical making communities in ways which enable wider participation by, as well as challenge and transformation to, traditional scientific norms within civic contexts by layperson, or those with variable expertise, participants. Dickel et al. (2018), building upon definitions cited to Wylie et al. (2014), also describe civic technoscience as material participation in creating and modifying the use of technologies in the public sphere in ways which manifest new technological solutions for public challenges while increasing the credible positioning of public participants in these endeavors as both inventors and subjects. Harrell (2020), a technology industry practitioner, defines what she calls "civic tech" from the position of someone who works with and for governmental institutions. She may de-emphasize the explicit scientific efforts that are the focus of academic theorists of civic technoscience, but she aligns in what she sees as its goal— "making government more responsive, efficient, modern, and more just" (p. 17).

Examples of civic technoscientific and technostruggle projects may include the work of individuals and groups in both centralized and networked configurations that may interact with a variety of scientific, academic, and civic organizations. It is notable that CTP was a collaborative, interdisciplinary, networked organization engaged with funding bodies, variably academic researchers, and civic concerns; these characteristics have also been discussed within scholarship on civic technoscience and social movements. Networks, as with those described by Epstein (1995, 1996), Ottinger (2013), Weston (2017), and Jalbert (2016) – in his examination of knowledge networks geographically located in the Marcellus Shale,

are what Lejano, Ingram, and Ingram (2013) describe as "communities that narrate themselves into existence" (p. 5). "Networks do not promise new, more democratic patterns of engagement, but they can, sometimes, help us imagine them," they write (Lejano et al., 2013, p. 5). Though referencing environmental efforts rather than the public health context within which CTP worked, Lejano et al. (2013) also explain that "environmental narratives, and the networks which they are inextricably linked to, are important places to look for practical inspiration about new ways of living with the world" (p. 12). In my view, as I will describe later in this chapter, CTP's narratives and networks perform a similar function.

CTP reflects technostruggle in that they used contemporary technologies of data science, organizational collaboration, and internet communications to aggregate, make sense of, display, and challenge pandemic data comprehension and dissemination that was widely believed to be the obligation of the government. CTP's Kissane explained to me through personal communication (April 28, 2022), that this belief was one they heard communicated by major governmental players. As per Dr. Deborah Birx, a physician, diplomat, Army Colonel, and the White House Coronavirus Response Coordinator from 2020 to 2021, in her 2022 account of the pandemic response:

> From using data collection and analysis to structure the public health response (CDC), to developing therapeutics and vaccines (NIH and the private sector), to having these therapies and vaccines approved (FDA)—the Department of Health and Human Services and its agencies were central to the Covid-19 response and to protecting Americans (p.70).

In their technostruggle, CTP used contemporary technological tools, those quite possibly used by the governmental health agencies themselves, to reflect and challenge the official, partial, obfuscated governmental narratives. CTP also participated in a form of civic technoscience without practicing the types of

procedural engagement on which most STS scholars focus. They did not provide evidence to directly engage in or challenge governmental processes, but instead gathered and disseminated governmental data in ways accessible and comprehensible to both the media and the American public. In this way, CTP operated more like one of Harrell's (2020) civic tech practitioners. CTP designed better interfaces for government information. In doing so, as only one of multiple ways in which they gained credibility and expertise with government agencies, researchers, the media, and the public, they signaled the nature and context of their work. They also both participated in and transformed, to some degree, the complex knowledge systems within which they resided. As discussed in the first two chapters, the modification of node behavior and/or hierarchical boundaries may transform the behavior of an overall system (Holland, 2014). Though CTP's work did not substantially change the U.S. public health system's notion of survivability in terms of who is deemed essential for persistence, their work and interactions impacted research, policy, and agencies' technological solutions (Glickhouse, 2021). They influenced the work of other system nodes and perception of system behavior, and in doing so they impacted system outputs.

COVID TRACKING PROJECT

Now that I have provided a contextual landscape of precedents and lenses through which to see relevant practices with tendrils leaning forward, in the next two sections I provide a more thorough examination of CTP itself before then analyzing how they operated. The seeds of CTP were planted in early 2020, when Alexis Madrigal and Robinson Meyer collaborated on a spreadsheet to gather all the COVID-19 testing data they could find. Both were journalists for *The Atlantic* magazine, and the two have individually reported on a range of complex and interrelated topics

including science, technology, culture, environment, and futures, amongst many others. They attempted to make sense of the emerging pandemic, particularly as it was playing out in the early days of American exposures and emerging deaths. Simultaneously, data scientist Jeff Hammerbacher performed the same task. He and Madrigal were old friends, and they discovered their mutual pursuits. They decided to combine efforts and reach out publicly, via social media, the News Nerdery and Help With Covid websites (French & Camberg, 2021), and personal channels, for help. Interested volunteers, some known to the co-founders and many not, applied to work on the project through a basic website form. According to CTP members French and Camberg (2021), "almost 2,500 people offered to volunteer for the COVID Tracking Project in a span of just under 11 months" and "800 volunteers contributed" (How many people volunteered section, para. 2-3). Respected tech industry veteran and editor Erin Kissane joined the team as one of the first volunteers, was immediately promoted to co-founder status, and took up the position of Managing Director. CTP officially began in March 2020. Project leaders believed that the initiative would only need to exist for a few weeks, until better data collection, comprehension, and dissemination appeared from government sources. CTP proceeded to collect, comprehend, and disseminate data for a year.

Under the daily leadership of Madrigal and Kissane, CTP emerged as a networked, grassroots response to the U.S. sociotechnical public health systems' failure to publicly disseminate accessible and understandable epidemiological data in the first months of the COVID-19 pandemic's emergence in the United States. CTP team members found sources and learned how to read, scrape, assess the data strengths and weaknesses, and visualize COVID-19 test data, hospitalizations, and impacts by race, ethnicity, and geographic regions. CTP's capacity building stretched from within the team to a wider public audience, through public communications and

a possibly unprecedented level of data transparency. In addition to daily updates to their regularly expanded and improved upon website, CTP wrote 100 blog posts within their first year, provided social media communications about each day's statistics, and hosted talks about the project, data ethics, and data science skills.

Additionally, CTP informed and contributed to news articles as a part of their efforts to educate journalists about the data "arcana and [to] help them contextualize the numbers for their readers" (E. Kissane, personal communication, April 28, 2022) at local, national, and international scales. This effort was essential to CTP's efforts not only because of the organization's roots in, and ongoing affiliation (via the support of *The Atlantic*) with, journalism, but also because they believed that increasing journalists' data literacy was essential to making the pandemic more comprehensible for all. Per personal communication with CTP's Kissane (April 28, 2022), she and Madrigal communicated with "hundreds of journalists… both in groups and one on one" as an ongoing "service." Though they centralized journalists within their educational efforts, both the informants to and consumers of their explanatory expertise expanded considerably over time.

Nationally networked team members collaborated with scientific, technological, and public health experts, as they together gained new skills and actively transferred scientific and technical knowledge within their team through team trainings and skill share events. The self-reported composition of the organization included members from 27 states who committed to a wide range of organizational support. Some members did not contribute to data collection shifts, and some participated in more than 100. Of those who did participate in data gathering, the greatest number (112) participated in 2-9 shifts, with 55 people participating in 10-19, 33 participating in 20-49 shifts, 22 participating in 50-99 and 17 people working more than 100 data collection shifts during the organization's

active year (French and Camberg, 2021). Members spanned genders and self-reported that their pronouns included she/her (222/215), he/him (132/132), and they/them (13/7), in descending order (ibid). When given tags to indicate "area of expertise" in their Slack profiles, members self-identified their applicable skills. The areas ranged from engineering and epidemiology to art and audio. The top ten categories included: data, design, science, management, analysis, health, writing, research, project, and visualization (ibid).

The CTP team's critical technical practices nudged government agencies to improve upon their data releases (Glickhouse 2021), informed federal reports and policies (ibid), and provided an invaluable public informational service for making sense of the pandemic (Hayes, 2021; Maddow, 2021). Behind the scenes, the CTP team coalesced as a geographically distributed mutual aid organization, holding themselves to ethical, intellectual, and technological standards, while they also prioritized the performance of care for both the data and one another as a central tenant of their operations. The team stopped collecting new data in early March 2021. Within their organizational shutdown steps, the CTP team held a series of public workshops about their most trusted sources and reliable processes to teach others what they learned, while they also archived and publicly documented the project for use by both researchers and organizations who want to perform similar work.

VIEWING CTP THROUGH SYSTEMS, COMPLEXITY, AND SURVIVABILITY

This case study focuses on the manifestation and work of CTP, including CTP's roles as a complex organizational system within larger social-ecological-technical systems (SETS) as well as the participation and interactions of people who are inevitably parts of both the CTP organizational subsystems and broader SETS. In the

first chapter, I explained how Ahlborg et al. (2019) argued for examination of SETS as combinations of systems rather than parallel analyses of sociotechnical and social-ecological systems. In this case study, I think of SETS as four parts that undergird the stories and findings. In this chapter, SETS appear as social systems, social-ecological-technical systems, social-ecological systems, and as sociotechnical systems.

Throughout this case study, social systems are addressed both as the interactions of members of the CTP subsystem and relevant aspects of larger pandemic social systems with which CTP interacts. The project's social-ecological-technical system can be found within the ways in which the distributed geography of CTP team members played a role in the national, networked character of the organization. I understand their distributed, technologically mediated interactions in the spirit of Virilio (2000), who describes virtual communities as a "new type of localness, of social 'tele-localness' which totally revolutionizes the notion of neighbourhood, the temporal and spatial unity of physical cohabitation" (p. 59). CTP responded to a social-ecological system in that it addressed an *airborne* pandemic; physical and social spaces cannot be disentangled when considering COVID-19 safety and survivability. Within this case study, my examination of sociotechnical systems includes three types of inter-related components. The first sociotechnical systems components refer to scientific processes, and the related research bureaucracies, which CTP sought to understand and interacted with in order to make sense of emerging pandemic information. The second components are the data which they collected and the associated contexts from which the data arose. The third components are the technologically enabled processes through which CTP communicated about, compiled, made sense of, and disseminated their findings.

In the O'Keeffe case study, I examined one woman's context within local, regional, and national systems. In contrast, CTP and its individual members are parts of both CTP's systems and multiple larger configurations of SETS. Both the organization and the member individuals are nodes who both responded to and impacted the systems within which they resided. Changes in node boundaries and hierarchies can impact larger systems' behaviors, potentially transforming systems' outputs in unexpected, and potentially emergent, ways (Holland, 2014). CTP was itself an evolving, complex adaptive system interacting with other variably adaptive complex systems.

As I mentioned in the last chapters, adaptive capacity is the "flexibility of ecosystems and the ability of social systems to learn in response to disturbances (Turner et al., 2003, p.8075). CTP learned, iterated, and visibly evolved within their data practices, supportive techniques, and sociotechnical systems' infrastructures. Their adaptability was a central tactic to their resilience. CTP members operated in an environment of informational uncertainty, and they responded to changing conditions with an ethos of nimble transformation in ways I describe throughout this chapter.

Complex systems science defines resilience and robustness as concepts that are related but not duplicative. They both address notions of persistence through disturbance, but when one employs a robustness lens, they operationalize resilience by defining what components are essential to protect for overall systems persistence, and for how long, versus those that may take damage without entirely compromising the whole (Anderies et al., 2004). Because of this delineation between overall and targeted persistence, an examination of systems through robustness is one way to think about survivability.

In this case study, robustness – the operationalization of resilience through maintenance of essential system characteristics (Anderies et al., 2013) – and survivability – the assessment and design of systems' abilities to persist in their critical functions within threat conditions that include risk and uncertainty (Sterbenz et al., 2010; Castet & Saleh, 2012) – are defined differently for CTP as a complex subsystem versus the overall SETS of the U.S. public health system. Essential components for CTP's survival included the persistence of their data collection efforts, the knowledge system processes they set up to allow for members of varying expertise to contribute to the project, and the well-being of their members who performed CTP's work. Analysis of the overall SETS of the U.S. public health system is beyond the scope of this dissertation, but – as I will describe later in this chapter – one feature, how the U.S. public health system was designed and operated to protect some—and not all—is essential for understanding CTP.

It is within the context of CTP's organizational notions of essential survival that I find the biggest takeaways about what insights we gain about increasing survivability, expanding who and what is deemed critical for systems' persistence and increasing the robustness of those social-ecological-technical components, from studying CTP. I will return to these at the end of this case study, where I will additionally identify supporting ideas found throughout the chapter. As a preview, these insights may be summarized by four statements. First, allowance for adaptive capacity is essential for increased survivability. Second, system transformation arises from structures and cultures of support. Third, a culture of care is essential to protecting more—not some. Finally, conceptions of the future based on data can only be partially imagined.

Each of these insights reminds us that no systems that address survival are truly abstract, no matter how survivability may be treated within military,

epidemiological, or political contexts. Within this dissertation, I continue to emphasize that studying both people and systems is essential for increasing collective persistence.

EPISTEMOLOGIES OF EXPERTISE: CTP

Within each of my cases, I examine protagonists' collaborations within SETS – including embedded knowledge systems, their navigation of scientific disciplinary boundaries, their acknowledgement and transformation of notions of credibility and expertise, and how their engagements with these systems and concepts impact survivability within their particular threat contexts in order to increase individual and collective survivability. An inquiry into these topics as they pertain to CTP requires that I examine knowledge systems in two contexts. First, I describe CTP's interactions with external entities. Second, I outline practices internal to the organization.

External Interactions

CTP was an incredibly layered entanglement of people, information, and systems, supportive both within the ways in which the organization operated internally and how they intersected with governmental agencies and the general populace. In public, they presented their findings and became a go-to source for government, media, and broader publics. Behind the scenes, throughout the project, they spoke with members of governmental agencies, including those agencies from whom we might expect to see the work that CTP accomplished. These conversations included verification and clarification of data, strategic perspectives on related systems designs, suggestions for strengthening data collection and dissemination,

and discussion about what CTP learned about the pandemic from their data collection, collaboration with scientific and public health experts, and dissemination.

CTP members gained this credibility and access through signifiers of expertise found within the "credibility economies" (Shapin, 1995) of scientific systems. The organization's leadership spokespeople included an award-winning journalist, a highly respected member of the tech community, and a public health expert with impressive degrees and experience. All CTP representatives spoke eloquently and appropriately, clearly and in an accessible manner, but also with reference to relevant scientific jargon when their engagements with experts deemed necessary in order to verify CTP members' knowledge and comprehension of the experts' domain. CTP's work was also supported by funding provided by notable, respected foundations, and they were verified as trustworthy through the presentation of their data visualizations on a wide range of media outlets deemed credible by members of both ends of the U.S. political spectrum. CTP's external engagements in many ways echoed the achievements of their ACT UP predecessors in that CTP members were always considered outsiders, but they gained the trust and respect of governmental insiders in ways which had some level of positive impact upon governmental data processes. To those not in the government, their incredible work was widely perceived as an exemplary science-related, civic tech project to be studied and considered a benchmark for those doing similar work in the future. In March 2021, U.S. civic technology leader Cyd Harrell (2021) tweeted, "[T]his project will be one of the examples of good work I refer to for the rest of my life." Select individual CTP team members, including those without previous expertise in the public health, data, and science space, were recruited – post-project shutdown – to work on similar types of ongoing pandemic projects for respected foundations and non-governmental organizations. CTP operated both in public and behind the scenes, building expertise

and credibility for themselves, alongside increased survivability for larger publics than those for whom the governmental systems were designed to protect.

One of the ways in which CTP improved governmental data systems was through the transparency of their own comprehension of the public data with which they interacted. On their website, CTP created "state reporting assessments" (COVID Tracking Project, 2021a) that displayed their discernment of the quality of states' data. This aspect of their transparent efforts to narrate how they navigated what they found in the data also secondarily served as a lever to push states to improve their collection and reporting practices. Their efforts supported improvement in government data systems, and they were repeatedly called upon to present their perspectives and findings to members of government who appeared to earnestly attempt to assess where the US government had gone wrong in its response. In their last months of operation, they held public workshops about their processes, data sources, and findings, and their extensive project documentation may be unprecedented for an initiative of their sort. These workshops were geared towards journalists, but members of governmental, research, and non-profit organizations were welcome. The shutdown events were also open to public attendance, recorded, and archived as a part of CTP's extensive online documentation.

On their last day of data collection in March 2021, a massive outpouring of appreciation reached them directly, popped up across social media, and began to appear through more traditional media channels. Two of my personal traditional media channel favorites were by Chris Hayes and Rachel Maddow. Chris Hayes (2021) spoke for approximately two minutes about the importance of CTP's work to his MSNBC show's reporting. He acknowledged use of both their charts and analysis for his show's own ongoing comprehension of the pandemic. He also noted that the project was ending in part because it should not have been needed in the first place.

CTP arose to compensate for major governmental failure, he summarized, and – though we could now see multiple ways that addressing a crisis could play out – we should expect better. Immediately following Hayes's broadcast, Rachel Maddow interviewed Dr. Walensky, the then new head of the Centers for Disease Control (CDC). Before their discussion, Maddow (2021) described the March 2021 glimmer of American pandemic hope within which CTP ceased their data operations:

> Saturday, we hit 2.9 million shots in one day. Absolutely fantastic. And that was on the day the Senate passed the COVID relief bill as well. So, we get this $1.9 trillion relief bill and we get 2.9 million vaccine doses all administered that day. That`s a great day. That is – that is more where we need to be (p.4).

In the midst of Maddow and Walensky's conversation about the CDC's pandemic response, Maddow acknowledged how CTP "tried to pick up the slack" (p.17) and that CTP ceased data collection with the expectation that the CDC would step up to "become the authoritative, definitive source of data about the epidemic, not just for practitioners and experts, but also for the general public, because so many of us want to be tracking these things day-to-day" (p.17). Maddow (2021) described the data on the CDC's then current website as unnavigable and perceived as unreliable. She pointedly said that "other people who are good in this space are leaving so that you can take up that room" (p.18) of credibility, expertise, reliability, and guidance. Maddow asked why the CDC could not be more like CTP and/or when the CDC would begin similar efforts. Walensky described fallible data infrastructures and the CDC's reliance on others (states and tribal nations) for the data. Walensky said that she looked forward to the CDC working on this issue—more than a year into the pandemic and after CTP undeniably proved that Maddow's request could be accomplished, even by those who began without the CDC's perceived expertise.

Internal Interactions

Though one of CTP's co-founders, Jeff Hammerbacher, has a background in data and biotech (Related Sciences, n.d.), and the advisory board (COVID Tracking Project, n.d.) included public health, biostatistics, and medical experts, the majority of CTP members did not enter the project with self-reported pandemic-related scientific expertise. Thirty-nine self-reported as scientists, 31 described themselves as health experts, 14 with backgrounds in epidemiology, 9 with biology, 5 each for healthcare and medicine, and 2 as immunologists, amongst other variations (French & Camberg, 2021). CTP communications provide no correlation between self-reported expertise with member activity levels, so it is not possible to quantify even an approximate number of volunteers whose scientific expertise informed the project. However, I conclude from my observations that a portion of the team leads had medical, epidemiological, public health, and/or scientific statistical or technological expertise, and their science communications lead, Jessica Malaty Rivera, brought both an essential background in immunological research and public health communications to the team's leadership. What CTP lacked in science-heavy expertise, they gained from both personal, embodied experience (as per Brown et al., 2004; Brown, 2007; Brown et al., 2012) of the pandemic and a dynamic mix of necessary skills. Members had experience with, and personally understood the urgency for information about, the disease. They were living through the pandemic every day. They were also technologists, designers, data interpreters, statisticians, journalists, researchers, and project managers, amongst many other backgrounds. Volunteers ranged in age from teenager to elder, and though I could not discern exact ages and CTP published no data on this, prominent members ranged from a high school student to volunteers with decades of industry and academic experience. Volunteers, and some paid team leaders, often maintained full-time school

commitments (high school, undergrad, and graduate students of both masters and PhD levels) and full-time jobs, while also sacrificing time that could have been put towards other commitments and/or their families to perform CTP tasks and participate in community dialogue and data production.

CTP members taught themselves and each other through multiple configurations. The entire project began with three co-founders independently attempting to make sense of the testing data, as journalists Madrigal and Meyer – together – and data scientist Hammerbacher – independently – compiled spreadsheets from publicly available data sources. They soon combined their efforts, Kissane brought her extensive experience in technology and communications to bear, and the nascent organization proceeded to gain and disseminate data collection expertise in two ways. First, CTP members iteratively learned how and where to collect data, as they also formed relationships with individual members of state health organizations to whom they could ask questions about publicly posted information. Second, CTP members iteratively codified their data collection process in ways in which they could ensure data quality while also relying on a wide swath of CTP members to perform the tasks. In early 2020, CTP members manually collected data twice a day and by early 2021 collected it once a day, as the Race and Ethnicity (epidemiological categories that were not consistently gathered by all states) data team also collected data twice a week. As mentioned earlier in this chapter, the vast majority of members volunteered for 2-9 data collection shifts. CTP learned, standardized, iterated, and taught their data collection process in ways in which the widest possible participation could occur. CTP's emphasis on iteration as a central ethos for the continual improvement of their processes and data comprehension, despite the persistent variability and uncertainty of the pandemic and governmental response within which they worked, was one way in which CTP demonstrated their

organizational resilience and adaptive capacity as a complex social-ecological-technological system.

I will pause here to acknowledge the importance of human labor in the data collection process. CTP's methods reflect what anthropologists Poirier, Fortun, Costelloe-Kuehn, and Fortun (2020) describe as a "data ideology" (p.212), exemplified by the ways in which data practitioners enact and embed a set of values, including the inclusion of robust, thoughtful metadata to allow for community-wide interoperability and the future comprehension of the data by researchers. Even as state-level COVID-related data became more available and increasingly standardized on their own websites, CTP never automated their collection efforts. They made this decision for multiple reasons. First, state data was sometimes idiosyncratic, and data could both represent different things and be reported in a variety of ways. Human intervention in the data scraping process allowed for acknowledgement and translation to bring all collected data into a standardized baseline for analysis. Second, CTP volunteers sometimes found state data sets to be either opaque or aberrant. As per CTP's Kissane (2021), "lack of clarity was present in most of the metrics we collected, and meant that we spent hundreds, maybe thousands, of person-hours reading footnotes in obscure state PDFs and watching press conferences to try to catch any turns of phrase that would tell us what—and who—was really represented in a given figure" (We produced the most complete section, para. 2). If numbers looked significantly different than usual, the human collector flagged the data for follow-up. Questions would be asked of team members with more experience, research – and sometimes communications with a state health department – would be pursued, and annotations would be made to the data within CTP's repositories and within any public dissemination; they maintained a "a public log of known irregularities in the data" (ibid, para. 3). This last point is crucial to

understand as one of the differences between CTP's work and other, traditional institutions who provided tracking from the same data sets. I describe CTP's communications' tone as humble. They annotated their outputs with their questions, the results of their attempts at aberration resolution, and anything they found notable for ethical and appropriate comprehension. Other institutions, such as Johns Hopkins and the CDC itself, presented the same data as *fait accompli*, not variably resolved. Even if the data reported by every state was unequivocally standardized, CTP would not have acquired the granular information gleaned from human intervention if they had technologically automated their data collection. They knew this, and – despite the significant effort it demanded – maintained the considerable involvement of people in their processes throughout the entirety of their work. This commitment to human intervention, rigorous annotation, and informational description demonstrated a form of care for the data itself. It reflected the prioritization of a multifaceted definition of caretaking within the organization's core values.

CTP members standardized and taught data collection through workshops, a series of self-created training videos, and the use of a meticulously formatted and massively sized shared spreadsheet called "worksheet 2." (This spreadsheet became so beloved that their internal project merchandise store included a shower curtain that displayed a screenshot of "worksheet 2".) Members also instituted a hierarchical data collection process that was consistently enacted during every data collection shift. Which roles volunteers played within the process, and what tasks they were assigned, was highly codified. The most nascent data collectors checked state websites and worked their ways up the ranks to being allowed to check data collected by other volunteers to being the one to double-check and lock data. A select, trained and internally vetted team performed the visualization,

comprehension, and distribution of findings. This highly practiced process created safety nets for both data quality and volunteer support. All participants were set up to succeed as a part of the team, regardless of personal expertise. By the time I observed collections in early 2021, data shift leaders had also instituted a practice of asking a light-hearted beginning-of-shift question that revealed something personal, human, and humane about each participant such as what music or snacks people enjoyed. Even in the most mechanical of processes, CTP culture interwove and emphasized an appreciation for the diversity in personalities and the people behind them.

In addition to the training and support surrounding the data collection, CTP held skill-shares hosted by individual team members. Volunteers ran workshops regarding skills more and less relevant to CTP's central work, both supporting the increase of the overall organizational knowledge base and celebrating the diversity of interests and expertise found within the organization. These workshops happened relatively regularly, and CTP held a full day of intentionally random topics skill share events – as a deliberate mental health support measure – on the date of the November 2021 presidential election. Organizational Slack channels also included regular exchanges of information and expertise, with members' questions ranging from inquiries about what a COVID-related article meant to those seeking information and advice on wider life-related topics.

CARE AS STRATEGY FOR BOTH RESILIENCE AND RESISTANCE

Evidence of "resilience is to be found, first and foremost, in the narratives that people tell about themselves and their surroundings" (Lejano et al., 2013, p. 13). The majority of articles about CTP focus on the co-founders or other select team leaders as an evocation of the overall organization. However, confirmation of how

the team speaks about themselves is represented by a combination of three texts. First, Managing Director Erin Kissane's (2021) project wrap-up article titled "The Decisions We Made." Second, an article co-written by Amanda French, CTP Community Lead and Data Entry Shift Lead, and Nikki Camberg, CTP City Data Lead, (2021) about some of the interior workings of CTP culture. Third, the twitter thread posted to the CTP account at the end of the last night of data collection (COVID Tracking Project, 2021b, 2021c, 2021d). A reading of the combination of these three public-facing texts most closely aligns with the culture I experienced during my months of participant observation. Many of the details of these communications narrate and reinforce topics and tactics I have mentioned earlier in this chapter within other contexts. In addition to providing windows into CTP organizational culture, these narratives support what I think is one of the biggest takeaways from the CTP research—cultures of care increase collective survivability.

Before I move further in this section, I want to pause and acknowledge that I bring personal bias to my belief in the importance of CTP's practices of care. Within my own professional background, I led a team for a high-profile memorial museum design project that told stories of a moment of national trauma. Under high stakes and within multifaceted stressful conditions, I stared at death every day for more than nearly four years. I read historic accounts, listened to recordings of last words and aftermath testimonies, frequently visited the ground zero site where the catastrophe happened, discussed findings with scientists, attended highly charged community board member design review meetings, witnessed the site of unidentified and unclaimed remains, and repeatedly volunteered at the yearly memorial service, amongst many other things. I recall how hard an uncountable amount of aspects of the job were, and I recall just as clearly how many team members were impacted by the weight of it all—some of whom were removed from the project for their own

well-being as they became unable to perform their jobs. When the team first fought to win the project, we were lucky enough to have one of the most esteemed professionals in our field as one of our advisors. She told us that when she led a Holocaust museum project, her team had a therapist on staff. No one can look at death every day, she explained, without incurring significant impact. As they relied on experts for all the other necessities of the project, they knew that – to get through the project in as okay of shape as possible – their work necessitated mental health experts as well. While I have again immersed myself in catastrophic accounts in order to make sense of survivability for this dissertation, I have thought about that advice a lot—including looking back upon how we often failed in our own design team's efforts to do the same. Our advisor's team worked on an important project about a devastating topic at a moment decades after the horror. My team began our project six years after the catastrophe which we memorialized. CTP attempted to make sense of death every day for a year, while it happened.

CTP's Kissane (2021) titles a section of her article with the phrase "We put care at the center of our work," but she could have replaced the actual article title of "The Decisions We Made" with that headline. In the "We put care…" section, she explicitly describes how leadership loosely fashioned themselves as a mutual aid organization, how tasks were set up within deliberate informational and personal infrastructures of support, and how they both enforced mandatory breaks and deliberately planned optional, and often light-hearted, events on holidays and other days when they theorized that pandemic restrictions would make both data collection and isolation the hardest. However, within the rest of the article, Kissane also relays how they set and reinforced their own scope of work, by setting limits upon what they would and would not address, and how they enforced "radical transparency" while doing so. By limiting their remit and wasting no energy on finessing their

findings to be more palatable for some, the organization repeatedly deterred the potentially inevitable well-meaning overextension of their members. Author and social justice activist adrienne maree brown (2019) supports this analysis in her "Pleasure [Activism] Principles" (p. 14). She states, "Being able to say no makes yes a choice" (ibid). Kissane (2021) explains CTP's approach with more nuance:

> Above all, we trusted that our people would, if anything, work *too* hard and sacrifice too many hours of family time or relaxation or sleep. Instead of trying to motivate people, we mandated breaks and time away—and especially in data entry shifts, we routinely reminded people to work more slowly, both to maintain accuracy and to maintain a deliberate and sustainable approach to the work (We put care section, para. 3).

Another sustainable CTP cultural practice was one of humor and joy. Within their organizational Slack, CTP included 2,279 custom emoji, more than 350 of which were variants of the CTP logo (French & Camberg, 2021). CTP members created the equivalent of a visual twins language, that thing that emerges when two children decide to speak only amongst themselves, if twins included dozens and sometimes hundreds of people who shared an internal lingo. Many of my communications with CTP members during participant observation included my stating the phrase "my emoji fluency is that of a toddler" as I enthusiastically attempted to add emotion and context to my texts via CTP cuneiform. Emoji became essential components of workflows, used as labels and signifiers of types of communication and process status. As French and Camberg (2021) relay, the emoji culture was so significant that they went as far as to have an emoji "March Madness bracket to determine the most beloved emoji" (Culture of CTP section, para. 3) reaching a moment of what can only be described as *schadenfreude* when the winner was an emoji representing a personified CTP logo combined with the internet classic "this is fine," dog drinking coffee in the middle of a fire, meme. Was this emojification of language frivolous? I think this nuanced playfulness, representing a wide range of emotions, was essential

to CTP's organizational well-being. My opinion is born from both observation and learning from brown's work. As brown (2019) writes, "I have seen, over and over, the connection between tuning into what brings aliveness into our systems and being able to access personal, relational and communal power" (p. 5).

During the course of my observations, I watched the #emoji Slack channel evolve with near-daily requests for new imagery, ate snacks (mandated for participation) while watching official federal videos about the then-current status of COVID-19 data analysis and text chatting with the data quality team, participated in a "job fair" event where CTP members offered advice and support about the careers from which they hailed and those which they might want to begin, watched the team leaders covertly create an extensive multi-slide presentation and audio tribute to one of the project co-founders for their birthday, and witnessed a multi-page .pdf including a collection of imagery of CTP pets be delivered in honor of the birthday of a member's beloved cat – an animal seen through team video conferences and image posts to Slack. These were only a few of the many, many playful, serious, and seriously playful interactions that I experienced. In the midst of so much data and difficulty and death, I observed an unexpected amount of humor, joy, and multifaceted support within all levels—from leadership through team structures to the general population found within the organizational Slack. As French & Camberg (2021) write:

> We celebrated holidays and birthdays together, helped each other with homework, gave advice on topics ranging from childcare to careers to recipes, and comforted each other through the darkest moments of this pandemic, all while doing meaningful work. Not everyone felt this degree of loyalty and affection all the time: sometimes, some people didn't feel appreciated or useful, some people were overwhelmed, and some people just had more important places to be. But in general, the people who were actively involved in this project will tell you that it was one of the things that sustained and rewarded them during the past difficult and tragic year. We are grateful to and for each other (Thanks section, para. 3)

Though most of the articles about CTP emphasized the incredible leadership (Allsop, 2021; Cohen, 2021; Fausset, 2021), and it was clear to me during my months of participant observation that the extraordinary culture of the organization stemmed from the head, the leaders gave credit to all those who crafted the organizational work and supportive infrastructures. On March 8, 2021, at the end of the last night of data collection, Alexis Madrigal and Erin Kissane wrote the last data reporting Twitter thread for the CTP account. This was after many hours of data collection, communication, and dissemination work performed by the remaining project team leaders and some of the organization's most committed contributors. I observed the work over the course of half a day, sitting in a room in Arizona while contributors worked from locations across the nation. I watched numbers change in a shared spreadsheet and followed questions, answers, progress reporting, and casual chatter in the organization's Slack channels. As per some CTP traditions, I did so while eating snacks. I watched the last Twitter thread develop over multiple rounds of drafting, editing, and discussion. When it was posted, I observed an outpouring of praise and gratitude delivered through countless Twitter replies and quote retweets. And I immediately thought that if those who admired CTP's external work only knew what they were like behind-the-scenes, they would be even more impressed. After providing brief summaries on a year of work, and then outlining thanks to many collaborators and supporters, Madrigal and Kissane provided the slightest peek into their humble, supportive culture. Their last three tweets read:

> Our project's key value is a culture of gratitude, saying thank you even for things that are a normal part of the job. In this year where so much has come to all of us, it has helped to remember that at the very least, we have each other to be thankful for.
>
> In the beginning of the pandemic, [journalist Ed Yong] told us that natural disasters bring people together, but pandemics tear people apart. We like to think that CTP was an active protest against those divisions.

> And—this is [Alexis Madrigal] and [Erin Kissane]—we have to thank CTP's contributors. This project came out of nothing. You became its blood and bones. We know how much you sacrificed—jobs, school, kidtime—and how much it sometimes hurt to handle the numbers that defined this year (COVID Tracking Project, 2021b, 2021c, 2021d).

This thread is one of the only times, in either writing or in conversation, that I personally heard CTP frame itself as an act of protest. The leaders do so in the context of a conversation with Yong, a supporter and informal advisor to the project who proceeded to win a Pulitzer Prize for his pandemic-related journalism. It is through scholar Debra Levine's (2012, 2021) work about her time in ACT UP that I first learned that prioritizing care is an act of protest, specifically an act of both resistance and resilience. In her own dissertation (2012), Levine reframes the heart of ACT UP from one of shared confrontation of danger to a notion of affinity—as acts of disobedience, as reconfigurations of familial structures, as performances of care, and as ways to resist and persist in the face of social and medical stigmatization of the ill.

Informed by my research on and observation of CTP and my attempts to make sense of CTP's work within a broader acknowledgement of ACT UP's work, I hypothesize that the inclusion of practices of care is essential for increasing collective survivability. Whether maintenance as a sustainability practice, agency as acknowledgement of individual and collective humanity, and/or simply crafting and enforcing a culture of appreciation – which is not such a simple thing to do—care matters in both small and large ways.

One of the biggest things I learned from having the honor of observing CTP's work over the last months of their project was that once you see a way that things in the world can operate differently, in a way that prioritizes care rather than competition, collective sustainability rather than individual persistence (even on a daily basis), you cannot unsee it. I discussed this takeaway with multiple CTP

members in informal conversations, official interviews, and to anyone with whom I spoke who would listen to me go on and on about how moved and transformed I was by witnessing CTP.

LIMITATIONS OF DATA-DRIVEN CONCEPTIONS OF THE PRESENT AND POTENTIAL FUTURES

Throughout this chapter, I have contextualized CTP's work in multiple ways, described their navigations of credibility and expertise, and emphasized their prioritization of support and care within their data-driven systems-entangled disaster-response efforts. My focus on CTP is not only about the data. However, their concrete work product centered on the collection and dissemination of numeric data in ways that informed both governmental and public comprehension of risk, uncertainty, and catastrophe. The data, whether through the care shown to data practices by CTP members, as quantification of humans lost, or as attempted representation of the pandemic situation, was deeply entangled with human context. Within this section, I will briefly address their data efforts through three primary points. First, data is never neutral. Second, data contains and is impacted by time, particularly during disasters. And third, non-neutral, time-influenced data informs our conceptions of both the present and potential futures. Within this section, I combine insights provided by CTP team leaders alongside those of scholars from multiple disciplines.

Data is never neutral, and therefore data is limited in its representation.

Data contains values due to human intervention in collection, analysis, dissemination, and design and use of technologies that enable these processes (Benjamin, 2019; Taylor, 2017; Roberts, 2011). Ruppert, Isin, and Bigo (2017) explain that data contains politicized values because data is not only the result of

"political struggles around data collection and its deployments, but how data is generative of new forms of power relations and politics at different and interconnected scales" (p.2). Examples of the politicization of data range from the biased reporting of school-reopening-related U.S. COVID-19 data mentioned later in this chapter (Cartus & Feldman, 2022) to the data practices in Ukraine (Petryna, 2019) and Belarus (Kuchinskaya, 2014) in the wake of the Chernobyl disaster, where nations limited their data collection and reporting due to their prioritization of geopolitical relationships over public health concerns.

Due to the infusion of human influence and politics, data also contain biases and outright injustices (Taylor, 2017; Roberts, 2011; Benjamin, 2019). Aligning with broader social justice concerns, governance scholar Taylor (2017), legal scholar Roberts (2011), and STS scholar Benjamin (2019) all remind us that data are socially constructed in ways which may easily replicate existing unjust cultural and scientific norms. Those injustices lie in the data itself and also may be found within variable access to information, technologies, and skills with which to make sense of the numbers. As per Johnson (2014) and Duarte (2020), informational justice requires both access to data and the distribution of increased widespread capabilities "needed for participation in information systems. This would include both skills and technology" (Johnson, 2014, p.272).

CTP's Data Quality Co-Lead Kara Schechtman and member Sara Simon (2021) describe their experience with U.S. data collection information injustice as the "limitations of reporting systems silently shap[ing] the resulting data" (Test positivity section, para. 4). They explain:

> Though states have electronic reporting systems that can quickly send data from labs to health officials, some public health data reporting still occurs beyond the scope of these technologies. To control for potential problems, some state health departments are deciding to omit non-electronically transmitted data from their own test positivity calculations (ibid).

Schechtman and Simon's experience is of particular concern because of the urgency of data within disaster contexts. However, data collected during disasters is often undercounted. As per data and disaster scholars Soden, Wernimont, and Knowles (2022):

> Deaths caused by disaster go undercounted for many reasons: the limited time and resources available to the public health experts tracking them; complications in categorizing and counting death, which is a complex phenomenon when we think about comorbidities and inequality; and outright governmental misdirection (The count is never the real count section, para. 2).

Undercounting may be the result of informational injustice, political motivations, or procedural, designed, or technological limitations of the systems through which the data is collected. It may also occur because some things are either poorly understood and/or unquantifiable. Soden et al. (2022) argue that "[m]ortality counts also miss the occupational and chronic illness ramifications of Covid—both of which are only beginning to come into focus" (The count is never the real count section, para. 4). They highlight the binaries posed by the kinds of testing, hospitalization, and mortality data with which CTP made sense of the pandemic. COVID-19 has emerged as a pandemic that also inhabits in-between informational spaces, including the inability to quantify those who are sick – or who have prolonged sickness – without a positive test result, those without access to testing, those who were not hospitalized, and those who died from causes which may or may not have been entangled with COVID-19 complications. Wernimont (2018), one of the Soden et al. (2022) authors, also notes that "transactional forms for counting human bodies, whether alive or dead, are at the heart of the modern reality that tables of numbers are poor vectors for the emotional and social impact of human mortality" (Location No. 803). Data is always a reduction of something, and death cannot be entirely reduced. In addition, as both CTP participants and scholars remind

us, disaster data is always incomplete. However, as per Wernimont (2018), the formalities of data presentation – the charts, graphs, and matrices – also make the numbers look like they contain all that matters.

Data, particularly data collected during disasters, contains time.

The fallacy of numeric representation, according to Virilio (2000), is due to technological intervention in a way which we might consider a next-level Wernimont (2018) consideration. Virilio describes the conceptual intervention of the presentation matrix and also the delivery vehicle of that visualization, the internet itself. He argues that internet-enabled virtual connectivity creates perceptual configurations that compress time and space.

> The *matter-time* of the hard geophysical reality of places gives way to this *light-time* of a virtual reality which modifies the very truth of all *dureé*, thereby provoking, with the time accident, the acceleration of all reality: of things, living beings, socio-cultural phenomena (Virilio, 2000, p.117).

Similarly, CTP Data Quality Co-Lead Kara Schechtman (2021), providing pragmatic insights learned from her work alongside Co-Lead Michal Mart (Meyer & Madrigal, 2021), describes data itself as something that "flows at different speeds for different metrics" (Schechtman and Simon, 2021, Test positivity section, para. 3). As per Schechtman and Simon (2021):

> Although positive test results require immediate action from state health officials, negative test results do not require any public health follow-up. As a result, while positive tests or cases (test positivity's numerator) tend to be reported at relatively consistent speeds, the reporting of negative tests (the calculation's denominator) can lag. This difference in speed throws off calculations combining them (Test positivity section, para. 3).

In the last subsection, I summarized how Soden et al. (2022), Wernimont (2018), and Schechtman and Simon (2021) all explained why disaster data may be

incomplete or insufficient to accurately comprehend a moment of the present. Virilio (2000) describes how the notion of data having time combined with the perceptual influences of our internet-enabled collection and delivery methods impact individual and collective visions of both the present and the future.

> To prefer the illusions of networks — drawing on the absolute speed of electronic impulses, which give, or claim *to give, instantaneously what time accords only gradually* — means not only making light of geographical dimensions as the acceleration of rapid vehicles has been doing for more than a century now, but, above all, hiding the future in the ultra-short time-span of telematic 'live transmission'. It means *making the future no longer appear to exist by having it happen now* (Virilio, 2000, p. 94)

Or, as CTP co-founders Meyer and Madrigal (2021) write about CTP's own daily data dissemination charts, "You aren't really looking at the present when you look at these charts—you're looking at four different snapshots of the past" (Data are a photograph section, para. 2). Within CTP's data work, we constantly looked both backwards and forwards to attempt to understand the present.

Data impacts our conceptions of the present and the future, particularly in times of crisis.

CTP's data efforts responded to the need for data in the face of uncertainty. Though initiated as an effort to make sense of the immediate situation, to inform the public and journalists, and to use journalistic publishing about the data to prod the government to collect more and better data, Meyer and Madrigal explained in 2021 why this data was essential for governmental pandemic comprehension.

> *Data* might seem like an overly technical obsession, an oddly nerdy scapegoat on which to hang the deaths of half a million Americans. But data are how our leaders apprehend reality. In a sense, data *are* the federal government's reality. As a gap opened between the data that leaders imagined *should* exist and the data that *actually did* exist, it swallowed the country's pandemic planning and response (para. 6).

As they explain, data was not just a nice-to-have description of reality. To those with the resources and authority to determine the pandemic response both in the moment and for the future, data *was* reality. This inevitably partial and biased information is both believed to describe the conditions of the present and sets the future up as something to be filled in rather than something that materializes. A future imagined to be filled like cells on a spreadsheet is an inevitably prescribed future, rather than one of options, opportunity, and emergence (Adam & Grove, 2007). A prescribed future does not include authoritative systems designed with high degrees of adaptive capacity. Within a to-be-filled future, people and the SETS within which they are entangled have a harder time comprehending variable risk. Practicing multiple potential futures is one way in which individuals and organizations increase their resilience and abilities to effectively respond to uncertainty (brown, 2017; Ramirez & Selin, 2014; Seligman et al., 2016). Highly data-driven perceptions of both the present and future are inevitably incomplete and deter flexibility unless the data is conceptualized as informative without being authoritative on its own.

It is through our use of cognitive maps drawn from our present and our past experiences that we navigate current risk and uncertainty as we also plot potential futures (Seligman et al., 2016; Kemp, 2022). These maps can be acknowledged as sketches that may be revised and iterated upon (ibid). Rather than thinking in regimented matrices, uncertain futures could be imagined as conceptual maps sketched on metaphorical layers of tracing paper which can be reordered and redrawn.

As it pertains to data, I suggest that we can support a shift from fillable to flexible notions of the future in two ways. The first way is one modeled by CTP's own data practices. By including annotations on their own questions, revisions, and challenges with the data, they revealed the human interventions and the complex

contexts within which the data emerged. The annotations, a form of care – as mentioned in the description of data ideologies (Poirier et al., 2020) earlier in this chapter, reinforced the uncertain natures of data while supporting, not deterring, the data's usefulness. The second suggestion for support is one I take from both Soden et al. (2022)'s article on disaster data practices and Meyer and Madrigal's 2021 reflections on what they learned from CTP. Soden et al. (2022) argue that we need to expand what data we collect, particularly during crises. "The accounting and reckoning we do today are what will be preserved in the historical record, and that record informs future disaster policy and emergency management funding," they write (Soden et al., 2022, Accounting for care section, para. 3). Meyer and Madrigal (2021) add, "We have learned that the country's systems largely worked as designed. Only by adopting different ways of thinking about data can we prevent another disaster" (para. 8).

In this day and age, data is a key actant in the management of crises and a primary mode of sense-making for individuals and the collective. CTP's approach to and understanding of data exemplify another ethos and system by which to harness data for greater good—even when gleaned from and in interaction with systems designed for limited protections.

SURVIVABILITY SCHEMATICS: SYSTEMS OF ALLOWABLE SACRIFICE

In the last chapter, I described how Georgia O'Keeffe's construction of a nuclear fallout shelter at her home and studio in Abiquiú, New Mexico, was not representative of her overcompensation for governmental sociotechnical failure to protect her as an U.S. citizen. Instead, her actions aligned with civic, sociotechnical imaginaries of her participatory role in collective survival. Members of U.S. governmental leadership made deliberate decisions, reflected in budgets and

policies, to create defensive architecture for a minimal elite population, not all Americans. In the face of potential annihilation as the result of nuclear warfare, widespread safety relied – and still relies today – on individual and community acts of self-protection. The relevant SETS' designs inscribe survivability as perseverance for some, not all.

In the first chapter, I described how one of the differences between complex systems notions of resilience and robustness is that robustness includes an explicit designation of what aspects of a complex system might be allowed to cease operating, and/or incur destruction, and what components are necessary to continue essential system operations (Anderies et al., 2004). If we perceive the U.S. government's response to nuclear warfare through this robustness lens, we understand that the system prioritizes the persistence of those involved in governance and/or considered elite enough to garner entry into the limited, government-funded defensive architecture infrastructure. Others are encouraged and supported, through propaganda and information, to provide for their own well-being, but the design of America's civil defense system indicates that the persistence of the larger population is optional for sociotechnical system persistence.

When I additionally take into consideration the context of governmental response to the AIDS epidemic and the work of other communities who attempt to protect themselves in the face of social-ecological-technical danger, I arrive at a similar conclusion about U.S. public health systems. CTP did not respond to governmental sociotechnical public health system failure. The organization responded to systems designed to deliberately not protect many because the system's survivability is conceived as the persistence of some, not all. During the AIDS epidemic, high risk populations – such as gay men, sex workers, and intravenous (IV) drug users – were considered allowable sacrifices for sociocultural

reasons. During the COVID-19 pandemic, public discourse has debated the degree of allowable sacrifice of the old, the young, the frontline workers, the disabled, and the immunocompromised. As public health expert and ACT Up alumnus Dr. Greg Gonsalves wrote in 2021, "We are in the midst of another epidemic of disposable people" (p. 4).

Gonsalves, in the same article (2021), also outlines a history – tracing back to the country's origins – of U.S. public health choices that conceive of survivability as a notion for some, not all. Our long-term collective hallucinations that the U.S. protects its own, he argues, realistically kills U.S. residents in the context of the COVID-19 pandemic. Gonsalves's explanations separately, briefly encapsulate legal scholar Dorothy Roberts's (2011) extensive documentation of how the U.S. history of eugenics and slavery are at least two source points for the allowance of increased BIPOC and poor deaths in both medical and public health systems design. Similarly, legal scholar Kimberlé Williams Crenshaw, concludes her May 2020 *New Republic* article with a plea:

> [W]e must also absorb the bone-chilling truth that the rapid spread of Covid-19, and disproportionate death rates, among Black Americans is a product of the everyday disregard for our lives. This involuntary sacrifice of a predictably vulnerable population does more than shore up a grossly inequitable economy and distribution of power. It has to be squarely confronted for what it is: One more chapter in the annals of American racial power, in which the bodies of some are sacrificed en masse for the privilege and convenience of others (para. 14).

Whether the allowance of death is racialized, class-based, homophobic, xenophobic, or based in any other prejudices, sacrifice allowance is designed into U.S. SETS in forms such as the inhumane incarceration of asylum seekers (Bogado, 2020), the perpetuation of environmental injustice (Pellow, 2018; Walker, 2012), and the repetition of scientific and technological anti-minority biases (Roberts, 2011; Benjamin, 2019). Sociologist Nikolas Rose (2001) explains that the governance of

bodies is deeply entangled in legal and social architectures of advanced liberal democracies. "Within this complex network of forces and images," he writes, "the health-related aspirations and conduct of individuals is governed 'at a distance', by shaping the ways they understand and enact their own freedom" (p.6). Philosopher Achille Mbembé (2003) additionally writes that the "subjugation of life to the power of death" (pp. 39-40), particularly as codified through the acts of a nation-state, may be understood as necropolitics—a form of governance built upon sacrifice and death. A comprehensive review of the design of sacrifice into systems' notions of survivability is beyond the scope of this dissertation. However, I feel that it would be egregious to not acknowledge this case study's deep-rooted context.

As I write this chapter in the Spring of 2022, the United States continues to experience death tolls that equal more than 1.5 times the amount of 9/11 deaths every week ("Coronavirus in the U.S.", 2022). This happens despite the existence of a vaccine and considerable knowledge about effective deterrents to airborne transmission, and – 2 years into the pandemic – the amount of death now rarely makes the news. The CDC, federal, and state governments all now encourage decreased lengths of isolation for those who have COVID-19, and mask mandates are expiring in even some of the most public health cautious of states. Due to variable vaccination rates, the appearance of more contagious disease variants, and the slowly increasing knowledge that even surviving the disease may be debilitating to many, those publics deemed allowably sacrificial remain only incrementally less in danger than when CTP ceased their data collection a year ago.

COVID-19 data is not in itself a weapon against death or disability. In their extensive analysis of economist Emily Oster's use of COVID-19 data to argue for school openings and to claim lesser disease impacts on the young, public health experts Cartus and Feldman (2022) outline ways in which Oster's experimental and

unconfirmed data analysis promotes particular political priorities. They unpack her use of her own COVID data dashboard as egregiously partisan in ways they claim are potentially mortally risky for those who follow its findings (Cartus & Feldman, 2022). Though the governmental actions may not have been deliberately pernicious, CTP co-founders Meyer and Madrigal (2021) also explain that the data used by government agencies to assess school re-openings was woefully incomplete due to value-laden structural design and lack of improvement of the government's own pandemic data systems. I argued throughout this chapter that no data use is neutral. As the Oster example indicates, not all pandemic data engagement even strives for increased survivability.

Within her texts *Precarious Life* (2004) and *Frames of War* (2009), Judith Butler asks what lives are considered worthy of grieving, and she expertly frames the visual and sociocultural politics that inform and reflect our answers to that and associated questions. Butler's central inquiry spans beyond the scope of this dissertation, and it could be a dissertation in itself in how it applies to each of my case studies, but I raise it here because it is an important one to consider when making sense of CTP's work through the lens of survivability. Earlier in this chapter, I addressed implications of attempting to turn ill and dead bodies into abstract, datafied forms.

CTP was originally designed as a stop gap measure to produce, comprehend and disseminate pandemic-related data in ways which could allow both the media and the public to make sense of the evolving crisis. They did this because what seemed like a perfectly reasonable thing to expect from state and national public health agencies, reliable and coherent data, did not exist at the time of CTP's founding. I hypothesize that the CTP co-founders, members, and those who responded so positively to CTP's work as a response to perceived governmental

failure all expected more from governmental agencies due to both perceived health agency responsibilities (Birx, 2022) and a civic imaginary derived from political expectations of U.S. participatory engagement with government (Ezrahi, 2012; Scott, 1998). However, whether or not these expectations were realistic and appropriate, given U.S. constitutional and institutional remits, is also beyond the scope of this dissertation. It is nonetheless important to note for two reasons. First, CTP co-founders Meyer and Madrigal write in March 2021 that "We have learned that the country's systems largely worked as designed" (para. 8). This mildly devastating notion, one nonetheless aligned with the arguments provided in this section, did not deter them from conceiving of and deploying CTP. And, second, as Scarry wrote in *Thinking in an Emergency* (2011), which I referenced extensively within the O'Keeffe chapter, we may live within national sociotechnical imaginations, but – particularly in the ways in which we choose to take care of others and ourselves - we are not powerless. One way in which we may choose to gain information and agency, as demonstrated in the work of both ACT UP and CTP, is through engagement with data, evidence, and epistemologies of expertise.

CONCLUSION: INSIGHTS ON INCREASING COLLECTIVE SURVIVABILITY

As a result of my research, I summarize some of the most important things we can learn from CTP about increasing survivability as four top-level insights. Each insight appeared within interwoven threads throughout this chapter.

First, the allowance for adaptive capacity within organizational structures and processes is essential for increased survivability. By limiting their own project/system scope, CTP allowed their work to breathe and grow in ways that became more grounded and complex rather than simply expansive. Their comprehension transparency, CTP's thinking and learning in public, showed the

thoughtfulness of their work and how the work – and their understanding of that work – evolved. Both the organization and larger publics benefited from their transparency in ways that placed the data efforts in the context of larger questions and systems. This transparency also acknowledged layers of uncertainty within both the data and the pandemic, and this was a strength of their communications that increased their credibility amongst both scientific and lay populations. CTP demonstrated that making sense of uncertainty, the fact that there's always more to learn, is an opportunity to improve how, why, and where you do so.

Second, system transformation arises from structures of culture and support. As ACT UP demonstrated before them, CTP affirmed that interdisciplinary collaboration is not only useful but essential for increased survivability. CTP's knowledge systems, designed for varying types and levels of expertise, benefited all who participated in their efforts. Their data dissemination designs, which included all the knowledge related to that data in both comprehensive and comprehensible ways, aided their accountability efforts and improvement both within the organization and governmental systems.

Third, an extension of the second, a culture of care is essential to protecting more, not some. When everything else was uncertain, CTP made their organizational culture one of reliable care. Their internal networks responded together as a multifaceted, complex, unified, supportive whole. For many of us who witnessed an inspirational, humane way in which teams can work together with care, it is now hard to unsee the possibilities of operating differently in the world both individually and collectively.

And fourth, conceptions of the future based on data can only be partially imagined. As many scholars remind us, data is never neutral; it always comes from somewhere, is entangled in human decisions, and contains politics, limitations, and

opportunities. Therefore, our data-driven future visions are always partial inventions. Also, as per CTP'ers Schechtman and Simon (2021), "Data flows at different speeds" (Test positivity section, para. 3) in ways which impact metrics and sociotechnical imaginations. CTP demonstrated that acknowledging and accounting for uncertainty allows us to become more expansive in our employment of data towards the present and potential futures.

In their explanation of what data and disaster scientists can do better in within our next emergency, Soden et al. (2022) write, "In our public discourse, there is widespread knowledge of mortality and infection data, but we know woefully little about the work that our communities and neighbors are doing every day to help each other through this slow disaster" (Accounting for care section, para. 1). CTP is only one instance, and this chapter is evocative rather than exhaustive about their efforts, but there are nonetheless lessons we can learn, take forward, and adaptively transform into new tactics in the face of social-ecological-technical uncertainty.

CHAPTER 4

FUTURES, IMAGINED

"And, with time, it became painfully obvious to the eight of us that most media reporting missed a most crucial point: it was above all else an experiment. We built Biosphere 2 not to demonstrate what we knew but to find out what we didn't know, to learn from our mistakes and what the facility, with its complex ecological systems, would teach us" (Alling et al., 2020, p.34).

"Perhaps, even as we studied ecological science and politics every day, we loved the mystique of the past because we knew that studying wasn't enough. We knew that the biospherian missions had gone interpersonally haywire, but we were still drawn to that original spirit lying dormant amid the tangle of plants under huge glass pyramids: the wild hope that even on a troubled and polluted planet, a new world was possible" (Reider, 2009, p.271-272).

"Everything we think we know about the world is a model" (Meadows, 2008, p.86).

Biosphere 2 (B2) is a 40-acre campus located outside of Oracle, Arizona. Named to reflect a synonym for the Earth – the biosphere (1), B2's facilities contain a distillation of global ecologies. The primary, interconnected buildings house a four-story rainforest, a savanna grassland, mangrove wetlands, a desert, and the largest controlled ocean environment in the world. Completed in the early 1990s, the biomes were intricately crafted, connected to sustaining technologies, and equipped with monitoring systems. Biospherians and collaborating scientists have employed the environments for controlled experimentation ever since. A private group originally designed B2 for closed system "missions" to explore the feasibility of establishing sustainable habitats on other planets. Throughout this chapter, I refer to this era as phase 1 (1984-1994). After the mission era, in what I call phase 2 (1996-2003), Columbia University utilized the biomes to undertake research that would extend the capabilities of their existing environmental science labs and educational programs. Currently, in phase 3 (2007-ongoing), the University of Arizona (UA) maintains B2 as local and global scientists perform complex adaptive Earth systems science research

at field scale using lab controls. From the moment the facilities' construction began, project founders and Biospherians explored survivability and practiced potential futures. The ways in which different phases of multidisciplinary scientists have continued to pursue concepts related to survivability – as well as the scientific, institutional, and global climate contexts within which scientists of different phases have understood their work – have both persisted and evolved in their uniqueness in concerns, methods, and comprehension.

Within this chapter, I address the evolving notions of who and what are deemed essential to the survivability of B2 systems as demonstrated by three eras of scientific practice. I also examine the institutional and public imaginaries that influence both experimentation by B2 scientists and public perceptions of B2. Throughout its more than 30-year history, I identify shifts in B2's institutional identity and priorities from lay person involvement with scientific institutions (in phase 1) to increasingly scientific institutional configurations (in phases 2 and 3), particularly as the shifts entangle with notions of credibility and expertise across local, national, and international collaborations and transform institutional and public conceptions of survivability.

B2 was designed for the performance of complex adaptive systems (CAS) science research even before this type of experimentation was valued by the academy and prestigious funding bodies. The comprehension of the usefulness of CAS research has changed over time. One of the things that has not changed is the extraordinary ways in which B2 itself is comprised of completely integrated social-ecological-technical systems (SETS). Networks of scientists, of variable institutional affiliation and interpersonal entanglements, perform research in and with the B2 environments which are supported by scientists' control of the facility's ecological-technological infrastructure that both maintains the environments' needs while

allowing scientists to monitor and manipulate the environments' conditions. Each of the three phases of B2 leadership have identified different combinations of B2's SETS subsets as more or less valuable for both their experimentation and survivability purviews—what is deemed as essential for persistence of the B2 SETS systems. Leaderships have similarly differently prioritized the importance of CAS and SETS to their B2 institutional identity. Within this chapter, I sometimes disentangle CAS and SETS, by identifying specific complex adaptive configurations of social-ecological, sociotechnical, and ecological-technical systems, and at other times allow a lack of institutional differentiation to provide a backdrop to addressing other dissertation through-threads.

Finally, B2 has always been about the future, in that it is a vehicle, a culture, and, as I will argue, a new form of scientific institution through which to practice the future. Within all its phases, through its unique modes of controlled, embodied, CAS experimentation and different approaches to SETS survivability, B2 scientists have provided potential future visions and exercised future practices in ways always tied to how we navigate risk and uncertainty within the present.

SCAFFOLDING ANALYTICAL FRAMES FOR COMPREHENDING SURVIVABILITY

Throughout this chapter, I continue to seek to unravel how artistic, civic, and scientific imaginations inform conceptions of agency and survivability in the face of social-ecological-technical uncertainty and multiple potential futures. I investigate how expertise and credibility are gained, challenged, transformed, and demonstrated by both laypeople and scientists through collaboration with scientists and scientific institutions within urgent conditions. I identify ways in which protagonists acquire information, skills, and agency within their situations through their inter-personal collaborations, use of technologies, and intersections with civic and institutional

processes. I continue to ask whether or not the foci of my case studies teach, learn from, and care for one another, and – in particular – how these acquisitions and exchanges inform their notions of survivability. Within this case study, I explore these inquiries through field research, document study, literature review, and semi-structured interviews. With this research, I contribute to three analytical frames found throughout this dissertation: (1) who and what are deemed essential within the survivability design of the case study systems, (2) affirmation, negotiation, and transformation of expertise and credibility, and (3) the agency to imagine increased survivability. My ongoing examinations of collaborations appear within and inform all three of these frames. I begin this chapter examining each of the three historical phases and then addresses B2 through conceptual, cross-phase themes. For each phase, I describe my source materials and then explore the phase through each of the three analytical frames—described in additional detail below.

First, in each B2 phase summary, I address who and what is deemed by institutional priorities to be essential for systems persistence and who and what may be an allowable sacrifice. These examinations add to my findings in the previous two chapters. In the O'Keeffe case study, I discussed how her build of the fallout shelter was both considered good citizen participation in civil defense and the result of a lack of civic defense infrastructure for all but the government elite. Her shelter construction, alongside the build of her garden, increased her agency in the face of nuclear danger and strengthened the survivability of her home and studio SETS. In the COVID Tracking Project (CTP) chapter, I argued that CTP's work was not the result of governmental sociotechnical failure, but CTP instead responded to government sociotechnical design that only protects some, not all. US public health systems, and the people involved with them, determine some people as sacrificeable. In these previous chapters, I tied explorations of allowable sacrifices to

the concept of robustness within the complex systems context within which I have framed this dissertation. The concept of robustness, in contrast to broad notions of resilience – which are the ability to survive disturbances – can be used to specifically identify and operationalize who and what is deemed essential for systems functions to persist in the face of systems' disruptions, danger, and threat contexts. Survivability is the assessment and design of systems' abilities to persist despite threat. Identifying who/what is deemed essential, deemed valuable, to a system explains institutional attitudes about whom/what they feel is worthy of survival. Within this chapter, I focus upon B2's shifting survivability purview as it pertains to B2 SETS, including the ecological-technical infrastructure of the facility and the shifting institutional and research priorities.

Second, credibility and expertise are two intertwined concepts that are central to my case studies. Within the O'Keeffe case study, I highlighted her autodidacticism and ways in which her immense credibility in one field translated to access to information and intellectual exchange in another. In the CTP case study, I explained how the CTP members navigated and negotiated scientific, data science, and public communications credibility through their relationships, the details of how they released their work, and their maintenance of relationships to each other and external institutions. CTP, as with members of ACT UP before them, were largely self-taught in pandemic, epidemiological, and data sciences. B2's phase 1 founders and participants were also mostly autodidactic in their acquisitions of project-relevant knowledge. B2's involvement with expertise and credibility arises in two forms. In phase 1, the project creators intersected with multifaceted credibility economies – negotiation of signifiers of valid credentials such as educational bonafides, publications, and institutional affiliations (Shapin, 1995) – tied to traditional scientific institutions. These creators gained expertise, and variable levels

of credibility, through their acquisitions of information from and relationships with scientific luminaries. However, the unusual backgrounds and intensely questioned motivations of the project founders haunted the evolving B2 institution for decades after their involvement. The more traditional institutional administrators, Columbia University (phase 2) and University of Arizona (phase 3), have navigated credibility and expertise in ways which rely on their uses of traditional notions of credibility establishment within scientific knowledge economies (Shapin, 1995). The credibility of the rigorous research phase 2 and 3 scientists have performed within the facility has depended upon the relevant administrators' negotiations of both the institutional history and repositioning of B2 within credibility economies. Within this chapter, I analyze how these negotiations include the acquisition of financial research support from notable funding bodies in both the US and the European Union, extensive publications in highly regarded peer-reviewed scientific publications, and a necessary shift in both views on complex systems science research and how the facility is perceived by scientific researchers.

Third, again contributing to an ongoing dissertation frame, in this chapter I address contextual imaginations and imaginaries. My definitions of these terms, as used throughout this dissertation, are grounded in the work of Taylor (2002), Marcus (1995), Jasanoff and Kim (2009, 2013). Social imaginaries are the product of multidirectional influence that occurs between individuals, economies, and the state towards collective buy-in on ideas, assignments of value, notions of risk and its management. Sociotechnical imaginaries specifically describe the ways in which society, science, and technologies influence and form one another in reciprocal relationships (Jasanoff & Kim, 2009, 2013), while technoscientific imaginaries additionally include the roles of science, scientists, and relevant institutions within these entangled interactions (Marcus, 1995). Within the O'Keeffe chapter, I outlined

relevant artistic, civic, and scientific imaginaries that provided insights that positioned O'Keeffe and her actions within mid-20th century nuclear threat imaginaries. In the CTP chapter, I provided information on scientific, technological, and civic imaginations that informed and interacted with CTP's work. Within this chapter, I identify a broad range of social, ecological, technological, and scientific imaginaries from which the B2 project emerged and in the context of which B2 has continued to transform. B2 is also a location, institution, and scientific lab space that contributes to collective imaginations. B2's intersections with artistic, civic, technological, and scientific imaginaries have informed both researcher and public conceptions of agency and survivability in the face of social-ecological-technical uncertainty in multiple ways. I investigate how these ways vary depending on B2's historical phase, perception of the site by both scientists and general publics, and the means through which scientists and credible institutions perceive and leverage – or not – the resources that B2's construction as an ecological-technical cyborgian system provides to scientists within evolving perceptions of institutional credibility.

This chapter also contributes to the dissertation's ongoing interrogation of collaborations as a means through which to achieve increased collective, SETS survivability. In the O'Keeffe case study, I focused on her multifaceted collaborations with scientists. In the CTP case study, I discussed forms of collaboration internal to the organization and ways in which CTP engaged with scientific institutions, media bodies, and experts. This case study is notably different than the O'Keeffe and CTP case studies in relation to questions of information, skills, and agency acquisition in that the phase 2 and 3 scientists are credentialed researchers trained through traditional forms. B2 collaborations are also unique in the ways in which they leverage the facility's SETS and that B2 research design includes both unusual collaborations and SETS-entangled knowledge systems that include similarities to the

previous two case studies. B2-enabled collaborations provide new means by which B2 scientists and greater publics may comprehend our present, our potential futures, and how we might practice and gain agency in the face of social-ecological-technical uncertainty.

In this chapter I investigate all three phases of B2's history, and I draw from distinct data and evidence for each. Within each phase section, I provide a brief overview and analyze how these three themes are negotiated, contested, and transformed. After the analytical frames are outlined and analyzed for each phase, I then synthesize findings across the phases that lead to new understandings about survivability that build in explicit concern for SETS complexity.

I include discussion of B2 SETS throughout the phase descriptions, and I return to larger cross-phase discussions of SETS afterwards. SETS are fundamental within the construction and operations of B2's physical and informational systems, and – as I will discuss throughout this chapter – they appear in multiple configurations. The social-ecological systems of B2 research include the biophysical contexts within which the institutional rules and norms of the B2 scientific research happens which are tightly coupled with the socio-technical systems – local and global – upon which B2 is built. B2 environments themselves are ecological-technical systems, in that the environmental components are reliant on B2 machinery for condition-setting, monitoring and maintenance. The primary building complex itself is also an ecological-technical system, utilizing dynamic structures, called "lungs", to balance the building's air pressure in response to significant outdoor temperature changes' impacts upon closed-system conditions. The ecological-technical systems are inextricable from human involvement in the forms of co-existence (as in phase 1), human research upon the environments (in phases 2 and 3), and ongoing monitoring of the B2 environmental conditions through the use of technological tools

(all phases). Some operational B2 SETS aspects never change, but the specific ways in which B2's SETS are perceived and utilized within scientific research transform alongside shifting notions of survivability priorities over time.

A considerable amount has been written about B2 history by both B2 participants and scholars (Allen, 1991; Poynter, 2006; Allen, 2009; Reider, 2009; Carson, 2015; Nelson, 2018; Alling et al., 2020; Luke, 1997; Höhler, 2010; Koch, 2021; Baudrillard, 1992/1994). Within this chapter, I do not set out to provide an exhaustive chronology; history is the backdrop rather than the point of this case study. Despite the considerable time I spend on describing B2 through its chronology in order to provide the reader with essential background components, I concentrate less on providing exhaustive historic descriptions than on this dissertation's inquiry threads which run through – in conversation and at times in opposition within – the timeframes, leadership, and contexts of the place. Before I provide a broader analysis of this case study, I outline key components and provide focused analysis of each phase using the three analytical frameworks, including the research approach to survivability design, credibility and expertise of the phase researchers, contextual imaginations that informed that phase's work alongside contemporary public imaginations of B2, and the source materials I referenced in my understanding of that phase in B2's history.

PHASE 01: ORIGINS AND MISSION ERA AS A THEATER OF POSSIBILITIES

An interdisciplinary group of artistically committed and variably academically trained collaborators envisioned and built B2 as a private venture. The founders focused on research and development for space colonization that could reveal insights on Earth systems and result in marketable product solutions that would provide returns on facility investments and funds for future enterprises. The decision

to create B2 occurred in 1983, and construction began in 1986. During phase 1, they acquired ecological source materials from all over the globe, designed biomes and maintenance systems in collaboration with scientists based at multiple credible institutions, and performed the first two of what was intentioned to be 50 missions held over 100 years. Within each mission, a small number of those who became known as Biospherians lived within a locked, closed system, where they grew their own food and maintained the five biomes and the technosphere – the massive, machine-filled basement. While locked inside, Biospherians collected data, performed research, wrote memoirs, participated in networked art events, spoke to classrooms, and waved at visitors through the building's glass. The first mission ran from 1991 to 1993, and the second lasted for six months in 1994 (Allen, 1991; Allen, 2009; Nelson, 2018; Alling et al., 2020; Poynter, 2006; Reider, 2009).

The project founders, and many of the Biospherians (some, but not all of whom, were project founders (per Ruiz in Bugaj, 2021)), did not hold academic and occupational backgrounds which one might presume of those setting out on a major social-ecological-technical exercise. Instead, they were artists who collaborated within experimental living environments. Many were members of the performance troupe named Theater of All Possibilities. Many of the Theater of All Possibilities members also lived at the communal Synergia Ranch outside of Santa Fe, New Mexico. Ranch members were sometimes called Synergists. Some members of the Theater of All Possibilities and some residents of the Ranch were involved with the Institute of Ecotechnics, a science-focused organization that held intellectual conferences, created a publishing house (still operating in 2022 as Synergia Press), and built and maintained multiple worldwide locations including an Australian Ranch, a Himalayan Hotel, a rainforest site in Puerto Rico, and a homemade ocean-going research vessel. John Allen was a leader within all three of these groups. Allen held

degrees from the Colorado School of Mines and Harvard Business School; he worked for the mining industry before he embarked on a more counterculture existence focused on ecological concerns and space colonization. One of Allen's collaborators was Ed Bass, a billionaire who funded the B2 project. For the B2 project, Bass incorporated as Space Biosphere Ventures (SBV) – "to indicate the threefold nature of the enterprise" (Allen, 1991, p.18). SBV was the financial arm of the B2 management organization. In his 1991 book-length encapsulation of the project, Allen identified the 1983 envisioning team as eight people. He then identified four key leaders for the built project. Allen described himself as Director of Research and Development, Margaret Augustine – also frequently credited as leading the architectural build and running daily management – as the C.E.O. and co-designer, first mission Biospherian Mark Nelson as Director of Space Applications, and Ed Bass as Chairman of the Board.

By the time they reached six months in to the second mission, relationships had fractured between Allen, Augustine, and Bass. As a result, the first mission Biospherians split into two factions. Some sided with Allen — with whom Augustine also aligned, and others united with Bass. Biospherians who allied with Allen broke in to the sealed second mission facility to allegedly warn locked-in Biospherians that management endangered their lives. Bass subsequently shut down the mission, evacuated Biospherians from the facility, and sent in the U.S. Marshals to escort Allen and his collaborators out of the B2 campus. The dissolution of the project occurred in 1994. Bass maintained his ownership of B2, through rental agreements with Columbia University and the University of Arizona (UA) in phases 2 and 3, until his donation of the facility to UA in 2011. Allen and Nelson presently continue their collaboration, as well as their involvement with the Synergia Ranch and Institute of Ecotechnics.

Source Materials for this Section

Biospherians' memoirs informed this section. Other phase 1 sources include multiple, scientific publications written by Biospherians and collaborators, peer-reviewed publications written by scholars of multiple disciplines, and both documentary films and journalistic publications spanning from the time of phase 1 to 2022. These materials include multiple literature groups. Phase 1 was controversial, and the following four groups – for which I provide some example references – exemplify a range of perspectives from within and about the project. I do not describe phase 2 and 3 source material sections in this extensive detail, but – in part because phase 1 narratives influence all subsequent phases – I map this landscape to provide a through bedrock from which to make my arguments throughout this chapter.

The first group of perspectives contains literature that explains the project as told by Biospherians, Three of the four memoirs I read, published from 2006 through 2020, are written by ongoing collaborators with Allen's Institute of Ecotechnics. (Allen, 2009; Nelson, 2018; Alling et al., 2020). As mentioned in this section's introduction, phase 1 protagonists split into factions, so B2 contains more than one history. One memoir, written by first mission Biospherian Poynter (2006) who sided with Bass in the split, represents different views in regard to the dissolution of the project. In addition to the memoirs, Allen (1991) wrote a project summary book, published at the onset of the missions, titled *Biosphere: The Human Experiment*. Scientific papers published about the first mission are also the work of Allen and his ongoing collaborators. The publications I read spanned from 1991 to 2020.

The second group of source materials includes publications by seemingly neutral observers. Within my literature set, I read two history books written by people not involved in phase 1. The first, a "scientists in the field" book aimed at

young adult readers, explains the project's origins but concentrates more on present day (Carson, 2015). The second is what I consider to be the most nonpartisan, in-depth history of the mission era, written by Rebecca Reider (2009) as a result of her academic ethnographic research. Reider (ibid) developed her book, *Dreaming the Biosphere: The Theater of All Possibilities*, with mentorship support from STS scholar Sheila Jasanoff, and her perspectives were informed by her undergraduate and graduate degrees in the history of science and environmental studies (p.ix). Reider's narrative spans from project origins to the sunset of phase 2. Later Biospherian memoirs, such as Mark Nelson's 2018 *Pushing Our Limits: Insights from Biosphere 2*, use Reider's book to buttress their arguments about the scientific and public credibility they felt the project should have had but did not acquire during phase 1.

The third literature group focuses on B2's phase 1 rise and fall within major media outlets' narrations. Journalistic articles from this era may be sorted into two categories, excitement around the project and evisceration of the whole enterprise. Some considered B2 a unique and extraordinary opportunity, going as far as calling it one of the 50 must-see "Wonders of the World" (Araiza, 2011). Others, such as Cooper (1991) in the *Village Voice*, wrote investigative journalistic pieces dismantling the notion that B2 was anything other than the pet survival project of an apocalypse cult run by an abusive charismatic leader. Though I needed to track down Cooper's (1991) most notable article, "Take This Terrarium and Shove It" through Interlibrary Loan because it has fallen so far out of any kind of circulation, it remains consistently cited by those skeptical about B2's origins (Koch, 2021), or – in the case of Reider (2009) – those who attempt to present a balanced view.

The fourth source materials group includes publications by scholars of multiple disciplines, including design (Pasquero & Poletto, 2016), performance (Franinović & Kirschner, 2020), STS (Höhler, 2010), political science (Luke, 1997)

and geography (Koch, 2021). This fourth set includes but often extends beyond phase 1, and it consists of a range of attitudes about the project. Literature foci span from inspiration found in the unique SETS design (Höhler, 2010; Pasquero & Poletto, 2016; Franinović & Kirschner, 2020) to disdain for B2 as an eco-Disneyland (Baudrillard, 1992/1994; Luke, 1997) and a product of colonialist desert imaginaries (Koch, 2021).

Survivability Systems Design Analytical Frame

The original Biosphere 2 mission reads, "Biosphere 2: an aid to dealing with the problems of the environment; an experiment to understand the laws of biospherics; and a prototype for a space colony" (Allen, 1991, p. 1). Additionally, B2 "inventor" John Allen (2009) says, "I designed Biosphere 2 to sustain a one-hundred-year 'human experiment' in order to see how humans deal with relatively long-term life systems" (p.161).

Though the B2 facility is a very terrestrial affair, phase 1 narratives concentrated on prototyping a space colony on Mars. Communications about the missions referenced environmental problems and increased comprehension of Earth systems, but the mission literally ends where phase 1 notions of survivability were focused—outer space.

As I describe multiple places within this chapter, B2 was designed as a deeply entangled SETS facility. However, even within the design of the B2 environments themselves, humans – and specifically the Biospherians – were the survival priority. Despite romanticized language about interconnections between human biology and ecological sustenance, flora and fauna were deemed in service to the sustenance of the enclosed human mission participants. Allen titled his 1991 project summary *Biosphere 2: The Human Experiment*.

According to Cooper (1991), a journalist critical of the B2 project who wrote for the *Village Voice*, Allen and his close collaborators were an apocalypse cult. Cooper's B2 narratives read as the work of an alarmist, but his work nonetheless appears to be that of a credible researcher. Cooper based his perspectives in the anthropological the work of "counterculture expert" (p.25) and then University of California professor Laurence Veysey. Veysey lived at Allen's Synergia Ranch in the early 1970s and documented what he described as Allen's apocalyptic notions as born from nuclear fear. Cooper (ibid) claimed that Allen conceived of a massive structure through which to practice and enable Earth escape. Despite the nod to contemporary notions of environmentalism in the phase 1 B2 mission, Cooper argued that B2 was not designed to operate in ways which might increase survivability systems on Earth. Instead, as the mission directed, project intention was for off-world existence, and it was the Biospherians alone who would escape environmental catastrophe and nuclear war.

Within their memoirs, mission Biospherians (Nelson, 2018; Alling et al., 2020; Poynter, 2006) and Allen (2009) described overloading the biomes with additional plants and species. While they knew that some flora and fauna would inevitably die throughout the experiment run, the rate of death was only a speculation. Alling, Nelson, and Silverstone (2020) described bets the Biospherians made with scientific advisors on the predicted percentage of non-human loss. The scientists predicted an 80% loss of initial species, a Biospherian predicted less than 20%, and the authors indicated that the resulting loss was a pleasant (less destructive) surprise to the scientists. The authors did not provide a survival percentage. As per Alling et al. (ibid), this lesser loss was in great part due to human intervention.

> The biospherians took regular walks through the wilderness biomes to check their overall health and the health of individual species, as did John Allen on the outside who would report his observations to Gaie daily. In many of the

> biomes there were organisms which served as 'biological indicators', a sort of early warning device of emerging problems. With dozens, if not hundreds of potential disaster scenarios, we had to be continually alert: in a small closed system, things happened with amazing speed (Alling et al., 2020, p. 109-110).

Biospherians wanted the environments to thrive, but non-humans within the biomes were deemed allowable sacrifices from the outset. They were sacrificeable as long as their demise did not indicate dangerous conditions for the Biospherians themselves.

Luke (1997), a political scientist writing in the midst of the transition between B2's phase 1 and phase 2, referred to B2's original design as a cyber-mechanistic "high-tech designer planet, drawn to omit the pests and weeds its inventors have decreed to be dispensable" (p. 113). He countered the notion that B2 was designed with any significant resemblance to actual Earth environments, which is a topic that I will return to later in this chapter. Instead, he argued, B2's biomes were envisioned as idealized ecosystems compiled and controlled specifically for increasing ecological engineering knowledge, experimentation, education, product design, and future commodification towards persistence of upper-class dystopian-visioned survivalists in the midst of potential social, economic, and/or environmental collapse. B2's phase 1 survivability systems may have been designed as a means by which to increasingly comprehend and achieve human-ecological balance in the face of social-ecological-technical uncertainty, but phase 1 notions of robustness considered only those elements necessary for human persistence as absolutely essential for persistence of B2's SETS within the ecological threat context within which the project sat. Biospherians may have, in part, pursued insights into how to live more sustainably with the planet, but B2 was also a project through which to learn how to survive an End of Days scenario.

Epistemologies of Expertise Analytical Frame

Despite B2's status as an ecological icon, it is within its human relationships that its legacy will be negotiated. I revisit the themes of credibility and expertise throughout this chapter, but it is important to note here that credibility and expertise were, and remain, some of the most contentious aspects of the external perception of phase 1. Also, in this phase, the perception of project and participants' credibility was inextricably tied up with notions of expertise and configurations of collaborations.

Whether or not one may deem Allen and his collaborators' partnerships with additional institutions and experts successful likely depends on whose B2 narratives one reads. According to Allen and the Biospherians, they pursued partnerships because their cohort fundamentally operated through collaboration and because they needed a wide range of expertise to execute this massive undertaking. Multiple B2 team memoirs claimed that notable institutional scientists hailing from a wide range of disciplines consulted on the research design, construction of environments, and throughout the entirety of the missions (Nelson, 2018; Alling et al., 2020; Poynter, 2006; Allen, 2009). According to project critics, collaborations were solely means through which Biospherians gained credibility for their project. Cooper (1991) claimed that Biospherians often ignored experts' recommendations, while Biospherians simultaneously gained legitimacy by association. Cooper additionally wrote that B2 leaders hooked scientists through promised financial support for the scientists' own research projects rather than through the persuasiveness of the B2 vision.

Within their internal expertise negotiations, the phase 1 team appeared to value relationships and experience more than standard accreditations. Only two of the first mission Biospherians held advanced scientific degrees. Abigail Alling had a

master's degree in environmental studies and Roy Walford was a M.D. and professor from UCLA; Wolford was not a member of any of Allen's three pre-B2 organizations. However, multiple mission participants spent time working within various global research outposts relevant to the B2 environments. This note about work-study is relevant because the Biospherians argued that the necessary mission skills required tacit knowledge as much as simply book smarts. They grew their own food, maintained machines, ran experiments, and served as informal science communicators to a wide range of public audiences. Each Biospherian held their own area of responsibility within the facility, and they collaborated and overlapped on their duties as their lives under the glass required. Two of the first mission Biospherians went on to acquire PhDs after their time at the facility, and both focused on research built upon experience they acquired within the closed system (Nelson, 2018; Alling et al., 2020). These later, advanced degrees may have given some phase 1 participants greater legitimacy in the long durée of B2 narratives, as they began businesses and continued to publish about their B2 findings in the decades after their B2 residency.

The legitimacy of the phase 1 experiments was, and continues to be, challenged, particularly as mainstream media outlets persist in labeling the project a failure. In addition to questions around the validity and rigor of the science performed during the missions, the Biospherians themselves broke their own, advertised rules. According to author T.C. Boyle, in a talk he gave about the B2 origins of his 2016 novel *The Terranauts*, the Biospherians' rule-breaking is when he and many other initial fans felt betrayed by the Biospherians' actions and stopped following the first mission's progress (Politics and Prose, 2016, 4:30). Mainstream media identified rule-breaking instances as evidence that the great experiment was a sham (Cooper, 1991). According to their memoirs (Allen, 2009; Nelson, 2018; Alling

et al., 2020), first mission Biospherians did not perceive their aberrant actions as anything significant. Biospherians modified their conditions three times within the first mission, and the second mission abruptly halted early due to system sabotage caused by management strife (Allen, 2009; Poynter, 2006; Nelson, 2018; Alling et al., 2020).

According to the project conception, the SETS were designed to be entirely self-sustaining, and the building was to be sealed throughout the mission. However, the first mission occurred with a few caveats to the Biospherians' own rules. First, some edible dry goods were stored within the building before the mission began. Second, the building seal was broken so that Jane Poynter could be taken to the hospital to mend a deep cut in her hand. She returned later the same day, and she returned with a bag that she took with her into B2; much speculation occurred about the bag's contents. Third, when carbon dioxide (CO2) levels rose dangerously, initially inexplicably high within the facility, management made the choice to pump in additional oxygen for the Biospherians' health. Were these occurrences failures in the experiment? Were they inevitable results of experimentation? Were they purely managerial and technical aberrations, or breaks from the project's closed SETS survivability design? Answers to these questions depend upon how one frames an understanding of the project itself.

According to sociologist of risk Perrow (1984), complex systems – such as his examples of nuclear power plants and aircraft control systems, and – I argue – the SETS of B2 – contain inherently high risks for what Perrow describes as "normal accidents". Unexpected, even detrimental, outcomes may arise within systems which are complex beyond omniscient comprehension. B2's SETS may have been simplified and stripped-down versions of their purported external ecological counterparts, as per Luke (1997) and Baudrillard (1992/1994), but they nonetheless remained

complex adaptive systems. As is the case of other complex adaptive systems, systems may additionally evolve beyond their initial states. However, according to Perrow (1984), unexpected occurrences do not equate to failure. Nor do these occurrences indicate that complex systems are beyond our ability to navigate partial information and uncertainty.

Acknowledgement of B2 SETS's complexity additionally nods to B2's place within thinking about complex adaptive systems. The ability to perform controlled, complex configurations of experiments at field scale with lab controls has always been a facility strength, and this opportunity has been a B2 characteristic that proved continuously advantageous for phase 2 and 3 scientists. However, historically, and particularly within 20th century America, science has been traditionally viewed and funded as narrow bands of concerns. Whether or not the phase 1 Biospherians performed their experimentation with the training and rigor with which more institutional scientists would have demanded and designed, I argue they expanded our visions of what scientific experimentation could look like—within both scientific and public imaginations.

Contextual Imaginations Analytical Frame

Within phase 1 the ways in which Biospherians performed science was not entirely unique, but it was unusual for its size and complexity. B2 founders knew of and worked closely with Russian scientists who had spent years designing and testing closed-system habitats also aimed at space travel. According to Allen (2009), "Without access to this Russian data, Biosphere 2 would hardly have been possible, because starting from scratch would have taken years to prove that sealed-life systems did not pose severe, unacceptable, risks to human health" (p.144). Biospherians also consulted with the National Aeronautics and Space Administration

(NASA) on NASA's own human and architectural experimentation (Allen, 2009; Nelson, 2018; Alling et al., 2020). However, as much as B2 was an experiment in off-world colonization, it also cloaked itself in notions of environmental science and traditional scientific institutions. The scale, complexity, and open-ended emergent nature of B2's experimentation was not how science was seen to be performed in the U.S. in the 1990s (Reider, 2009).

As mentioned earlier in this chapter, B2 founders were believed by some to be an apocalyptic cult born from nuclear fear. If this was the case, then they were as much a product of the Cold War as the space race itself. In the O'Keeffe chapter, I examined the proliferation of mid-20th century public narratives about catastrophic decimation due to nuclear weapons. Between the 1960s era of the O'Keeffe case study and the creation of B2, Americans also experienced the Three Mile Island nuclear power plant disaster (1979) and contentious clean-up (1979-mid-1980s). In 1986, the Chernobyl nuclear power plant disaster occurred in Ukraine but could be identified in the atmosphere of Europe and was reported worldwide. Nuclear fear was not a historical note, in either fiction or reality.

In addition to the persistent presence of nuclear fear, an increased apprehension about climate change arose within the second half of the 20th century. The impacts of CO2 on environments were studied as early as the 1950s (Oreskes, 2021; Sepkoski, 2020). In the 1960s and 1970s, scientists articulated concepts such as ecosystems and the biosphere in both scientific and public dialogue. These terms represented an emerging comprehension of human-environment interconnections, as well an evolution in ideas connecting both biological and cultural diversity to stability (Sepkoski, 2020). Diversity was described as "adaptive flexibility," a concept similar to that of adaptive capacity, which I discuss in previous chapters. According to Sepkoski (2020):

> (T)his is one of the later twentieth century's most important (if often unexamined) cultural notions: that any complex collection of biological entities—whether a genetic population, an ecological system, or a human society—is made stronger and more resilient to change by having a 'storehouse' of variability. Diversity, in other words, became reconceived as an inherent property of healthy collectives, and therefore came to hold an inherent positive value (p.159).

Contextual imaginaries for B2's phase 1 included great nuclear and escalating ecological catastrophic anxieties. During this time, potential key notions for increased collective survivability emerged alongside heightened awareness of existing and likely future threat conditions. Per historian of climate science, Paul Edwards (2010), scientists gained consensus on the existence and emerging dangers of climate change by the early 1990s, but scientific consensus did not deter controversy in public and policy venues. Contestation was the result of politics, not scientific evidence. However, in 1988, James Hansen, head of the NASA Goddard Institute for Space Studies, testified before congress about the "human fingerprint" of climate change. *The New York Times* subsequently ran the headline "Global Warming Has Begun, Expert Tells Senate" on its front page the next day (Oreskes, 2021, p. 407).

Concerns about ecological destruction both arose from and were entangled with nuclear fear, as the 1980s included public, science-inspired narratives led by notable scientists such as Carl Sagan about the possibilities of "nuclear winter," an ecological catastrophe resulting from nuclear war. The 1980s additionally included an escalation of the Cold War, as the Reagan administration began the MX Missile program and lobbied to build a space weapons initiative. Both humans and their habitable environments were under threat—from themselves. Also, given the looming approach of the millennium, other possible catastrophic SETS occurrences – such as the Year 2000 (Y2K) bug, where technological experts expected widespread information systems' disruptions, or millennial doomsday cult predictions – may have

been in the catastrophic imaginaries' midst. An off-world option allowed for a certain kind of survival, as tied to escape.

The second half of the 20th century was also one dominated by notions of what McCray (2013) calls visioneering. Visioneering describes a particular approach to futures thinking that asserts engineering and technological solutions as ways forward in the face of uncertainty. By providing tangible solutions to future potential challenges, the future becomes both prescribed and led. Visioneers themselves were typically charismatic men with strong technical educations, perceived as leaders towards bright, clear futures. McCray only mentions B2 once within his text *The Visioneers: How a Group of Elite Scientists Pursued Space Colonies, Nanotechnologies, and a Limitless Future*, in that another visioneer on whom he focuses held a meeting there. B2 was considered a site of vision and possibility, and – whether or not he actually had the technical chops – Allen could have been seen by some as one of McCray's charismatic figures.

B2 also emerged during the rise of neoliberal capitalism during the Reagan presidency in the US. This is relevant for two reasons linked to individual responsibility and roles of industry. Allen (1991) noted that Bass named his company Space Biosphere Ventures to represent the three components of the B2 project—space colonization, biosphere research, and product/business development. B2 was built with private money to protect private people while making money to both sustain and profit those people who funded and participated in the project. Though within all three dissertation case studies I have discussed ways in which governmental sociotechnical systems are deliberately designed to not protect all from harm, B2 phase 1 was an era within which individual actions and narrow selfishness were notably, fervently encouraged.

Neoliberalism posits that individuals should take care of themselves, and that larger sociotechnical infrastructures built for the collective good should be deprioritized. Rise of neoliberalism or not, if we already consider B2 as a possible legacy of nuclear fear, we might also consider it within the unchanged contexts within which O'Keeffe built her fallout shelter in approximately 1962. Civil defense for those not in the upper echelons of government were the responsibility of individual citizens and their communities. Providing for one's own protection was a way in which to fulfill one's duties as a U.S. citizen. The B2 facility could be similarly understood as a maximum-level bunker inspired by such post-O'Keeffe-era popular film narratives as *Silent Running* (Trumbull, 1972) – a lush environment sustained on a spaceship – and *Logan's Run* (Anderson, 1976) – a society of only the young, maintained by computers, contained within buildings after some sort of apocalyptic event. Connecting also to my second case study, the COVID Tracking Project (CTP), the B2 project could also be considered a for-profit predecessor for a non-governmental, collective response to tangible and existential threats. It is important to underscore that B2 was not an altruistic venture; it was an incubator for both scientific evidence and products that could be spun off of the project and sold. This B2 commodification scheme was to be a self-sustaining economic support for the experimentation, which the founders originally envisioned would occur for 100 years. The organization was not a grassroots, mutual aid-inspired response in the vein of CTP. SBV was a money-making venture for billionaire funder Ed Bass and Allen's other adventures. B2 did not model all peoples' survival. It was an experiment towards protecting a select few in ways which might benefit others and should contribute to the founders' own wealth.

B2 was also created in a way in which geographer Koch (2021) argues is consistent with western desert imaginaries and settler colonialism because its

inception treated the facility's site outside of Oracle, AZ, as one without history. Though, when standing inside of the B2 buildings, one views surrounding landscapes as backdrops to B2's constructed environments, the founders' B2 design treated the biomes as outside of space and time.

"[E]nvironmental imaginaries about deserts are geopolitical imaginaries, actively constituting and constituted by relations, identities, and potentialities across time and space," Koch writes (2021, p.87). She (2021) describes 20th century desert imaginaries as including the "frontier masculinity and modern violence of subverting nature to the will of man" (p.87). Kuletz (1998) and Voyles (2015) additionally explain that U.S. southwestern environments are perceived as valuable to the state because military, science, and industry players deem the locations to be pollutable, expendable, and sacraficeable. Especially given this description's stark contrast to the same landscapes' rich mineral resources and frequent cultural value to Native American tribes, Kuletz (1998) refers to this sacrifice-for-the-state dynamic as internal colonialism. As per historian Blackhawk (2006), the U.S. southwestern region cannot be understood in contemporary comprehension outside of socially and environmentally constructed layers of settler colonialism, particularly those which treat locations as empty other than Native Americans. Native Americans, Koch argues, are not recognized in B2's conception. As she notes, tribal members who participated in phase 1 artistic and celebratory events were chosen from far rather than proximate tribes, and they were treated as primarily symbolic mascots within public events to signal a connection to an ethical approach to environment for a project that primarily fore-fronted middle- and upper-class white people. Though, unlike Koch (2021), Blackhawk (2006) does not write specifically about B2's origins, he nonetheless explains that, broadly, narratives of southwestern ecological reclamation – B2's version being more audacious than most – fit within long histories

of frontierism and manifest destiny. I last mentioned these desert imaginaries as contextual imaginaries within the O'Keeffe chapter, and this provides yet another through-thread for the underpinnings of influences upon how the protagonists of potentially seemingly disparate case studies imagined their futures.

As described as project context and potential motivations throughout this section, the phase 1 B2 future imaginary was one of potential global devastation on Earth, alongside visions of extensive space-bound travel and colonization. B2's future imaginary stretched far into the future—even if the Earth became itself no longer inhabitable. B2 was designed to provide sustained food, water, energy, and financial support for a select few people and a subset of hybrid environments born of real flora and fauna, on planet while serving as a prototype to take people into the stars.

However, this future imaginary was not necessarily the way in which B2 was perceived by its visitors and observers. Baudrillard, in his book *The Illusion of the End* (1992/1994), derided B2 as an ecological Disneyland, an edutainment experience about survival. He described B2 as "not an experiment, but an experimental attraction," (p.85) and "the first zoological gardens of the species, to which human beings come to watch themselves survive, as they once went to watch apes copulate" (ibid). Baudrillard's (1992/1994) critiques are ironic; I learned through informal conversations during field research that the phase 1 visitor experience was designed by Disney. His B2 critiques were also snarky, but – when placed in the context of his perspectives on potential devastation in his text *The Illusion of the End* (1992/1994), they were also not superficial.

Baudrillard (1992/1994) has strong opinions on how western societies imagine both catastrophe and survival. He explains catastrophe as three progressive stages. The first stage of catastrophe is one which is "natural and unforeseeable" (p.71); this is a type of catastrophe that happens before human intervention. He

describes the second stage as manufactured; this, due to human intervention in the world, is "imminent and foreseeable" (ibid). The third, which he – contextualizing his B2 critique – describes as "pre-programmed," is a type of catastrophe that he feels is so human-driven that it is "deliberate and experimental" (ibid). Humans not only create our own catastrophes, he explains, but people do so in ways that evoke delusional visions of survival because visions of survival taken to such extremes as the B2 experience are detrimental to humanity's ability to navigate the unknown. Performative experiments which promote narratives of ultimate self-determination deter our societal abilities to grasp and navigate uncertainty, and even potential demise, as part of natural life cycles.

Natural life cycles in B2, as both Baudrillard (1992/1994) and Luke (1997) argue, are not even those found in nature. B2's phase 1 environments were of the creators' own sanitized and controlled construction. They were located in frontier "empty spaces" of manifest destiny, as per Koch (2021), Kuletz (1998), and Blackhawk (2006), made "clean" by the presence of white people and their technological innovations (Kuletz, 1998; Voyles, 2015). The mess, the death, and acknowledgement of uncertainty, Baudrillard (1994) and Luke (1997) argue, are all missing from B2 in phase 1. "(N)ature is also germs, viruses, chaos, bacteria and scorpions, [all which are] significantly eliminated from Biosphere 2 as though they were not meant to exist" (Baudrillard, 1992/1994, p.81).

However, B2's communications about aiming for ecological, SETS-entangled equilibrium within the facility were seen by its protagonists as part of a larger narrative about the possibilities for ecological harmony and a different path forward. Allen (2009) wrote of his reaction to the completion of the first mission, "I felt that this moment's taste of the harmony of technics, life, and culture intimated how life

should and could taste for all humans – at home in their cosmos, their biosphere, at peace with their destiny" (p.180).

Vastly different perceptions of B2's utility aside, the locked-in Biospherians nonetheless communicated with a plethora of classrooms around the globe, as they also waved through the glass and sometimes provided demonstrations for the hundreds of thousands of visitors who travelled to witness the project at the site. Edutainment or valid science, stories about B2's missions instilled themselves into public imaginations for better and worse, and they remain part of public narratives long past their time. In 2016, acclaimed author T.C. Boyle published *The Terranauts*, a research-informed fictional take on a Biosphere 2-esque mission that was loosely veiled under the name Ecosphere 2. Boyle was transparent, even exuberant, about B2 providing his inspiration. In a promotional event, Boyle describes B2's phase 1 as a project of "tremendous chutzpah" (Politics and Prose, 2016, 5:40), and his research fascination in its origins as relevant to his overall interests in survival. Popular media narratives about B2 phase 1 increased around Boyle's novel publication. An article in the future-focused tech magazine *Wired* described the missions as "a rare look at where science and cultishness intersect" (Locke, 2016, para. 2), perhaps echoing – independently, and more than 20 years later, Cooper's 1991 claims. As recently as 2020 saw the release of a documentary film about the first mission, titled *Spaceship Earth* (Wolf, 2020). Primarily informed by and including interviews with Allen and first mission Biospherians, the film does not appear to be self-aware that it presents a partial view. However, it nonetheless introduced new audiences to legendary B2 stories from Biospherian, rather than detractors', perspectives.

The film was favorably received by critics (Zoeller Seitz, 2020; Bradshaw, 2020; Fear, 2020) and held particular interest to audiences who found themselves in

a new form of lockdown isolation due to the pandemic. I watched the film on my laptop through a streaming service. As I sat alone in my apartment in Phoenix, I witnessed an online discussion between the filmmaker and multiple first mission Biospherians that was hosted by the actor, and beloved *Star Trek* veteran, LeVar Burton. The filmmaker noted that his interest in B2 had been sparked by seeing a photo of the first mission Biospherians in their jumpsuits. Fashion curiosity was his initial way into the story, not the interdisciplinarity or ecological explorations or B2's ongoing scientific efforts. Burton asked thoughtful questions about the film and the Biospherians' experiences, and Burton described B2's larger story as one of scientific experimentation. This emphasis, and reframing in the public imagination, continues to be necessary, as *Rolling Stone* subtitled their 3.5 star, reasonably glowing film review as a documentary about "one of the eco-science community's most noble failures" (Fear, 2020). If viewed as an experiment, noted both Burton and the Biospherians during the panel discussion, perceptions of B2 transcend a binary of whether or not the phase 1 activities were a success.

In a 2021 podcast interview, current (phase 3) B2 Director Dr. Joaquin Ruiz discussed his attendance at the *Spaceship Earth*'s premiere at the Sundance Film Festival in 2020. Aaron Bugaj, a B2 researcher and the podcast host, asked Ruiz for his reaction. The film was about the Biospherians, Ruiz replied, "It really wasn't about Biosphere 2." He clarified the public misidentification of the film's focus, "the Biosphere [2, itself] was an afterthought; it was [presented as] a tagline for what these people had done" (Bugaj, 2021, 36:14).

PHASE 02: A LAB FOR CONSTRUCTIVE DECONSTRUCTION

Columbia University ran B2 as an Earth sciences research lab from 1996 – 2003. Before 1996, Columbia scientists were involved in phase 1 consultations and

first mission troubleshooting (Reider, 2009; Downey-Mavromatis, 2018). They were also involved with the between-phases envisioning process, initiated by B2 funder Ed Bass, of what B2 could become. According to phase 3 Deputy Director John Adams, who began his own relationship with B2 as a phase 2 researcher, Columbia scientists performed research on-site as early as 1995 (Downey-Mavromatis, 2018).

Columbia named B2 its Columbia University Biosphere 2 Center and associated the facility with its prestigious Lamont-Doherty Earth Observatory. Columbia utilized B2 in three ways. First, B2 was a West Coast outpost site for complex Earth science research performed in a controlled, but no longer completely closed, set of ecological-technical systems. During this period, Columbia performed and published seminal research on the impacts of climate change on ocean and rainforest habitats. According to a 2005 news summary (Flinn, 2005), Columbia published 25 peer-reviewed journal articles during their tenure; a 2018 *Columbia Spectator* article states that 39 articles were published between 1997 and 2006 by the Biosphere 2 team (Downey-Mavromatis, 2018, Chapter 3 section, para. 9). Second, Columbia established semester-long, educational "away" programming for both Columbia students and undergraduates from other universities. Before ceasing their administration, Columbia had additional plans to establish an educational policy master's degree program on-site. Third, B2 remained an edutouristic, money-making venture. As I will discuss later in this section, the narratives tourists found upon arrival at B2 changed from the phase 1 days, but the tourist dollars remained an income stream to fund both research and facility maintenance. Notably counter to evidence I found about phases 1 and 3, artistic collaborations do not appear to have been included in Columbia's phase 2 vision.

Columbia rented the facility from Ed Bass and his companies. Repeating aspects of the end of phase 1, the era closed in controversy.

Source Materials for this Section

Though global scientific collaborations occurred within this phase, and public edutourism was a priority for Columbia University, this second phase was the least public facing of the three. As with phase 1, this phase also concluded in a dispute. The materials I referenced to understand phase 2 include research articles published within peer-reviewed scientific publications, communications by Columbia University-related publications spanning from the time of their announcement of the partnership (Columbia University, 1995) to a relatively recent reflection about the institution's B2 history (Downey-Mavromatis, 2018), and contemporary journalistic media accounts about the lab—including narratives about the dissolution of the relationship between Columbia University and B2 funder Ed Bass, ending in a lawsuit (Herszenhorn, 2003; Arenson, 2003). I rely substantially on Reider's (2009) accounts of this phase as learned from her extensive ethnographic research. Parallel to her accomplishments with phase 1 participants, and perhaps in part because she began her research as a result of participating in a Columbia educational program while a Harvard undergraduate student, Reider gained the trust and support of Columbia leadership. Her text *Dreaming the Biosphere* (2009) includes exclusive interviews and insights not documented elsewhere.

Survivability Systems Design Analytical Frame

One of the largest shifts in character between phase 1 and phase 2 attitudes, Reider (2009) notes, was in administrative attitudes regarding whether the biomes were to be maintained or deliberately destroyed. Phase 2 research (phases are my delineated terms, not hers) primarily focused on comprehending potential environmental destruction—destruction which could not be safely simulated in exterior environments. In particular, she describes Columbia researchers'

prioritization of seminal CO2 research in both the rainforest (Cohn, 2002; Poynter, 2006) and ocean biomes (Langdon et al., 2003; Cohn, 2002; Kolbert, 2006; Poynter, 2006). This constructively destructive research focused on the impact of CO2 levels on ecological systems, and in doing so both produced seminal data on the potential impacts of global warming while simultaneously pivoting a contentious phase 1 narrative – the increase of CO2 within the closed system during the first mission – into a scientifically rigorous reframing. Columbia scientists' research pursuits were themselves charismatic, in that they told an easily understood story of B2 facility usefulness, while they proved essential in emerging comprehensions of global environmental impacts due to climate change. In phase 2, B2 was not a place within which to survive catastrophe, but rather a place through which to understand how ecological devastation could unfold.

In this, Reider (2009) infers – since survivability is my concern, not one which falls within her scope – that planetary and institutional survival were deemed more essential than survival of the B2 environments themselves. Flora and fauna of the B2 facilities were allowable sacrifices, and humans were no longer visibly, persistently present within the environments. B2 environments were no longer just secondary elements of human-driven experiments. They were the singular foci of research agendas wherein humans' environmental impacts were represented by disembodied changing conditions, such as the rise of CO2.

Within Columbia's phase 2 research, the social system parts of B2's SETS appeared in three configurations. First, human influence upon environments was inserted as impacts, as described above. Second, scientists performed science upon, rather than within, the environments. And third, humans were the audiences for edutouristic and Columbia's institutional educational programming. B2 transformed into a site that taught students and public audiences about devastating impacts of

their actions, in part through scientists enacting devastating actions upon B2 environments. In phase 2, B2's ecological systems shifted from second priority to targets for demise in ways in which Columbia researchers justified would increase survivability within broader global SETS as understood through formal Earth science worldviews. Unlike phase 1's focus on the off-world future, phase 2 worldviews investigated understandings of the present in ways which involved potential climate-altered near futures.

Epistemologies of Expertise Analytical Frame

These deliberately catastrophic, CO2-focused experiments were one way in which Columbia's researchers and administration navigated and negotiated what I can only describe as a crisis of credibility. They deliberately attempted to push the site's controversial origins behind them through traditional signifiers of the scientific "credibility economy" (Shapin, 1995). As Reider (2009) writes, "Just as the resonance of the word *science* had been used to tear down Biosphere 2's reputation, now that word would be used to build it up again" (p.222). This rebuilding of "science", and for my purposes, a window into negotiations around expertise and credibility, occurred in four ways. First, Columbia's choice of leadership for the project signaled scientific prestige. Second, the adoption of a traditional publish-or-perish research model particularly emphasized the necessity of publishing in not only peer-reviewed but also top-ranked scientific journals. Third, the pursuit of funds and research partnerships leveraged the first two points. And fourth, Columbia invested in both the revision of educational outreach as edutourism and the establishment of academic "away" semesters and degree programs on site.

First, Columbia's choice of leadership for the project signaled scientific prestige. In the moments between phase 2 and phase 3, B2 funder Ed Bass brought

on Bruno Marino, a PhD-holding, isotope geochemist from Harvard University, to serve as scientific advisor, and Marino became the first phase 2 science director. Columbia scientists were one cohort present within inter-institutional conversations convened to imagine the next stages of the project, and it was this pre-existing relationship that allowed for a relative ease in transition to phase 2 facility overhaul, management, and educational expansion. A key player within this transition and subsequent leadership was geochemist Wallace Broecker. Broecker consulted with Bass and his team during phase 1 missions, as one of the scientists who determined how to respond to rising CO2 levels within the facilities. Allen (2009), in his summary of his vision of the success of the first mission, quoted Broecker as saying, "No one who has experienced Biosphere 2 can help but marvel at its technological achievement" (p.179).

Broecker, who held the largest federal funding track record of any scientist of the time, remained involved with B2 even when not officially positioned as Columbia's top B2 administrator. In addition to Broecker's leadership and the establishment of B2's direct institutional affiliation to Columbia's prestigious Lamont-Doherty Earth Observatory, subsequent facility leaders included former National Science Foundation (NSF) employees. The B2 project may have begun phase 1 with a rag-tag group of variably traditionally trained expert leaders, but phase 2 clearly signaled a new, credible era of prestigious affiliation at both individual and institutional levels. As per Reider (2019):

> Biosphere 2 had once been attacked as "unscientific," largely because of the personalities involved in the project; now, in the project's reinvention, the definition of 'science' was still tied less to what was being said than to who was doing the talking (p.226).

Second, the transformation depended on who spoke and within which venues. The phase 2 adoption of a traditional publish-or-perish research model additionally

prioritized the necessity of publishing in top-ranked, peer-reviewed scientific journals. Reider (2009) described Columbia B2 leadership as emphasizing the necessity to publish in journals such as *Nature* and *Science*. The leadership emphasized "good" science, particularly highly visible and cite-able science, where scientists published their research as much and as soon as possible.

Reider (2009) described a phase 2 within which the emerging research program may not have entirely aligned with the strengths of the facility. Scientists acknowledged that the facility was best suited for complex, entangled, long-term observational science. Leadership expressed an urgent necessity for prestigious peer-reviewed publications, as one strategy, to push the institution beyond its phase 1 past. As she notes, the "new leaders, desperate to prove themselves, did not have a long time for 'humbly watching'" (Reider, 2009, p. 225).

Third, the pursuit of funds and research partnerships leveraged the first two points. Columbia's B2 leadership chased federal funding, federal agency partnerships, and institutional partnerships. Columbia's own Ivy League status alongside the leadership's prestigious pedigree were seen as credibility indicators that should have been able to pull in a maximum of funds through traditional channels. As per both Reider (2009) and Downey-Mavromatis (2018), this presumption proved to be only partially true. Without a significant track record of established, published research at the site, funding bodies were reticent to back new research. The typologies of funded science also proved to be a challenge, as phase 2 occurred within nascent days of NSF programs focused on interdisciplinary science (Reider, 2009). B2's facilities supported interdisciplinary complex systems science research, whereas institutions solicited proposals for narrow foci. Without significant funding opportunities, scientific partnerships also often stalled at brainstorming

phases, and corporate partnerships – such as an exhibit funded by automaker Volvo – were deemed acceptable (Reider, 2009; Poynter, 2006).

Fourth, though phase 1 B2 was often derided by critics as edutourism, Columbia invested in revision rather than deletion of this aspect of the facility. As with their predecessors, Columbia envisioned edutourism as a source of financial support. Leadership of all B2 phases have worked towards facility financial sustainability without the need for Bass's additional ongoing supportive funds. However, the focus of the phase 2 educational experience changed in two ways. As mentioned in the survivability subsection, narratives shifted from environmental equilibrium to the perceived influence of the roles of personal decision-making within environmental impacts. Scientists and the performance of science were also deemed central. Reider (2009) described a shift in narrative imagery throughout the facility to one which foregrounded scientists in lab coats, scientific instrumentation, and explanations for the scientific method and experimentation.

In addition to edutourism, Columbia deemed B2 their West Coast, environmental studies outpost. They developed two semester-long "away" programs, modeled on typical study-abroad formats, which focused on environmental studies and astrophysics. Downey-Mavromatis (2018) quotes former participants who described the experience as uniquely immersive in both hands-on learning and research opportunities. This, they stated, was the result of both the facilities' opportunities and Columbia's understaffing of B2 research projects in ways in which those opportunities also put young scientists into possibly inappropriate levels of research responsibility. The programs were offered to Columbia students and students from other institutions. Though reliably attended, registration did not reach what was deemed acceptable levels by Columbia leadership. Before Columbia's

shutdown at the facility, plans for a master's degree in environmental public policy, a revision of an existing New York City-based Columbia program, were in the works.

In their 2018 reconsideration of Columbia's B2 history, published within a Columbia-associated online publication, Downey-Mavromatis argued that Columbia abandoned the B2 project because the institution failed to adequately achieve the above goals towards credibility transformation. Phase 2 scientists did not bring in enough money or partnerships, did not publish an adequate number of scientific papers as a result of the research, and the educational programs did not attract enough students or money. Reider (2009), who witnessed multiple phase 2-era collaborative meetings between government agencies, international scientists, and Columbia's B2 leadership, noted that she repeatedly observed ways in which scientists liked to imagine what research could be accomplished at B2 but did not want to potentially risk their own credibility in order to perform the research themselves. She described a B2 that was increasingly acknowledged as a place for possibilities, but which simultaneously could not shake the public and institutional perceptions that it was too risky a venture for sustained investment.

Both authors also hinted at another point of failure which may have had nothing to do with B2 itself. Columbia's default on contract, a result of institutional pull-out from commitments, occurred at a critical period of change in Columbia's leadership. The new president in 2003, Lee Bollinger, claimed that he saw no value in persisting with the B2 project at a time when the project's most committed advocate, Michael Crow, left Columbia to become president of Arizona State University. In my years on-site at B2 during the phase 3 era, I encountered multiple people who worked with Crow during phase 2. The anecdotal story I repeatedly heard about Columbia's withdrawal from B2 involved the complicated relationships between the new leadership and Crow. I hypothesize that all these items may

simultaneously be true; the metrics for success may not have advanced quickly or specifically enough in the new leadership's eyes, and interpersonal politics may have been a factor. As I argue throughout this dissertation, assessment of systems' survivability requires acknowledgement of both the systems and the people involved. As first-mission Biospherian and Bass supporter Poynter (2006) wrote about the dissolution of the phase 2 era:

> The details of the endless dramas are unimportant here, suffice it to say that, as in the first regime, [phase 2] egos ran amok and intrigue was rampant. For those of us watching from afar, the similarities between the two regimes were striking, all the more ironic as the two groups held opposing views on almost everything except the value of Biosphere 2—after all, the first group was antiestablishment, Columbia University is the establishment (p. 335).

Contextual Imaginations Analytical Frame

As mentioned in the last subsection, Columbia's entrance, execution, and exit from B2 involvement was mired in historical baggage. The establishment of academic scientific credibility was in constant conversation with, and opposition to, perceived notions of phase 1's undisciplined participants' lack of rigorous expertise. This overarching narrative persisted throughout the phase.

Contemporary journalistic accounts of the relationship dissolution between Columbia and Bass (Arenson, 2003; Herszenhorn, 2003) claim that the break happened for two different reasons. The first reason was that Bass sued Columbia for breach of contract, which is a fact. The second reason was that Columbia pulled out because B2 was an inoperable facility not suitable for research—despite having performed research at B2 for nearly a decade at that point. This second story persists. At the end of Downey-Mavromatis's (2018) article, they quote John Mutter – a former Lamont-Doherty affiliate to B2, "When Mutter reflects on the legacy of Biosphere 2, he is blunt but honest. 'There's nothing to shout about,' he says, laughing. 'There's nothing to be proud of'" (Chapter 5 section, para. 19). This, I feel,

perpetuates inadequate comprehension of the complexity of attitudes, relationships, and opportunities at the site in ways that then continue through additional credible channels. In her 2021 article regarding what she considers to be B2's colonialist establishment, Koch argues that no research – of any phase – has ever been adequately valid to scientific institutions. In continuing the talking points of scientists such as Mutter, geographer Koch denies the importance of seminal research of both phase 2 and phase 3 eras, including the phase 2 ocean and rainforest CO2 research which proved essential to subsequent comprehension of global warming by both the public and scientific communities.

In this, academic observers such as Mutter and Koch attempt to degrade the constructive aspects of B2 legacies. This is particularly ironic in the context of phase 2 research, as the B2 science of the time was considerably focused on comprehending destruction. Phase 2 science fell within the legacy of studies regarding increased CO2 levels' potential impacts on ecosystems which occurred in U.S. scientific establishments from the 1950s onward. The research also occurred within the context of the emergence of the Intergovernmental Panel on Climate Change (IPCC). The second IPCC report was published in 1995, the year before Columbia signed their B2 agreement, and the third in 2001, two years before they departed. As per climate historian Edwards (2010), "tentative scientific consensus achieved by the early 1990s has grown steadily over time" (Location No. 8163) until the early- to mid-2000s. One example of this shift can be found in the establishment of the Earth Systems Modeling Framework, an open-source data initiative led by the National Center for Atmospheric Research (NCAR) with the involvement of the National Oceanic and Atmospheric Administration (NOAA), NASA and others, in 2002. Phase 2 scientists performed their research in the midst of a sizeable increase in

Earth systems data collection and collaboration, set against the dawn of the articulation of the concept of the Anthropocene (Crutzen, 2002).

Towards the end of this phase, B2 could be labeled as a project of the Anthropocene, an effort to more deliberately control and manage limited natural resources and a planet in peril. Atmospheric chemist Paul Crutzen first defined the Anthropocene in a 2002 article published in the highly regarded scientific journal, *Nature*. Crutzen (2002) describes the Anthropocene as the era within which human intervention in the environment, due to technological innovations and evolutions in ways of living, became impactful enough to force significant ecological change. Phase 2 B2 scientists utilized B2's innovative technologies to study ongoing anthropocentric repercussions.

PHASE 03: AN ICON FOR EXPANDED POSSIBILITIES

After Columbia's departure in 2003, the site lay dormant until 2007. During that time, Bass considered razing the facility and selling the land. As with the phase 1 to phase 2 transition, Bass again convened envisioning sessions that included scientific luminaries from credible institutions. Phase 3 Director, UA geochemist Dr. Joaquin Ruiz, was in attendance (Bugaj, 2021). In 2007, Bass, his companies, and the University of Arizona (UA) committed to a rental agreement through which UA would operate the facility much in the way in which Columbia modeled operations in phase 2. B2 became an Earth science research lab for UA, but now the committed academic overseers resided a 45-minute drive, rather than a cross-country flight, away. In 2011, Bass and his corporations donated the site to UA and gifted a substantial endowment intended for ongoing facility maintenance (Hijazi, 2011; Pallack, 2011). The 2011 transition built upon four years of successful scientific

administration of the site, and the UA-led research and programming has continued to expand.

UA's leadership utilizes B2 in a variety of ways. First, Phase 3 scientists operate B2 as a complex Earth science research lab. In this, they build upon the work accomplished in phase 2 and expand upon the concentration, concerns, scale, and methods within which Columbia performed their work. Second, they use the facility for educational programming for multiple disciplines and interdisciplinary initiatives at multiple academic levels at UA, and they also participate in collaborations with other institutions. Third, B2 remains an edutouristic site. Visitors' admissions remain a major source of financial support, and B2 is an educational destination for school groups from Arizona and northern Mexico. In addition, B2 now has a research "institute" for addressing big challenges, and B2 serves as a supporter of and incubator for emerging technologies aligned with their complex systems and sustainability-focused mission. Using facilities built during the phase 2 era and maintained in phase 3, they host conferences and events as another funding stream and a way in which to connect B2's history, present, and future to unexpected audiences in the arts and other non-science disciplines. B2 environments are overseen by UA research scientists and on-site B2 scientific and maintenance staff, but research performed at B2 is led by a combination of local and global scientists—often in multidisciplinary collaborations to address complex topics through research that could not be performed in the same way anywhere else in the world.

Unlike phase 2, phase 3 leadership do not divorce themselves from the site's origins. Instead, phase 1 has been increasingly integrated into larger narratives of B2 as a catalyst for the evolution of innovative scientific practice that's critically relevant within increasingly urgent threat contexts. Some B2 leadership, such as Deputy Director John Adams, have worked through multiple phases. He began his B2

tenure as a researcher in phase 2. B2's current cohort steward 30-year-old environments and decades of knowledge towards increased comprehension of current and future climate conditions, seeking information and interventions towards increased SETS survivability.

Source Materials for this Section

This contemporary phase of Biosphere 2 history is the longest and least controversial. Possibly due to this, alongside access provided by my personal relationship with current B2 leadership, a wide range of source materials informed my understanding of this phase. For this section, I referenced peer-reviewed scientific publications written by B2 scientists, B2's own communications – as texts, videos, and podcasts, and journalism about current research and the overarching facility legacy. In addition, I performed site visits for field observations, and I held informal conversations and semi-structured official interviews.

I began spending time at B2 and in conversation with B2 scientists as a professional collaborator from 2016 – mid-2018. I resumed observations and conversations as a PhD student, then candidate, from 2018 – 2022. This period included sanctioned access to non-public areas of the complex and ongoing informal conversations with B2 scientists, my attendance of public tours of and events held at and related to B2, and a small number of formal interviews with members of B2 leadership. My field work documentation included written notes, photographs, and audio recordings.

Survivability Design Analytical Frame

B2 currently describes itself as the "world's largest controlled environment dedicated to understanding the implication, mitigation and adaptation

solutions for resilience of our planet (Biosphere 1) due to the global climate crisis" (Biosphere 2, n.d.-a, para. 1). In this broad remit, current B2 scientific researchers consider people, flora, fauna, and systems as essential to their survivability purview.

B2's revised priorities may be seen in B2's current research in two primary ways. First, research includes both observational science and applied solutions. For example, the NSF-funded, multi-institution collaboration, Landscape Evolution Observatory (LEO) project – located in the former phase 1 agricultural space – focuses on interactions between air, soil, water, plants, and microbes through the use of an "array of more than 1,800 sensors and sampling devices that are installed on, within, or above each [of three, multi-ton, multi-story] landscape[s]" (Biosphere 2, n.d.-b, para. 3). Simultaneously, B2 scientists perform agrivoltaics research – the optimization of agriculture grown within the shade of solar energy panels – in the field adjacent to the primary research buildings (Biosphere 2, n.d.-c; Barron-Gafford et al., 2019). Second, B2's climate impact research in both the rainforest and ocean environments sit within the legacy of phase 2's constructively destructive experimentation, but in ways which shift from the previous burn-it-all-down-for-science method towards investigation of assisted evolutionary tactics that could increase ecosystem resilience. For example, within phase 2, researchers implemented predicted climate conditions in ways which significantly damaged the coral reef (Langdon et al., 2003; Cohn, 2002). In phase 3, a global cohort of researchers are collaborating on complex, coupled research informed by multiple field sites to determine what assistive measures may increase coral resilience within both general and specific conditions (Biosphere 2, n.d.-d; Bugaj, 2020). The recent rainforest research also takes the phase 2 CO2 and drought research in the rainforest biome (Cohn, 2002; Reider, 2009; Poynter, 2006) steps further. By studying controlled drought and ecosystem recovery (Werner et al., 2021;

Eisenhauer & Weigelt, 2021; Stokstad, 2019), a global cohort of phase 3 researchers learn more about both impacts and forest infrastructures in ways in which ecosystem resilience might not only be understood but also potentially bolstered in the face of future conditions.

I understand phase 3 notions of survivability design as the most considered and robust – identifying the most SETS aspects as essential for persistence – in B2's institutional history. This may, at least in part, be the result of increased broad academic and public support for SETS complex systems thinking, evolving notions of what it might take to survive within future climate conditions, and increased scientific acceptance of what insights can be achieved with B2's unique facility. Phase 3 research cares more broadly about SETS, but also – as another evolution from the one-or-the-other attitudes of phases 1 and 2 – investigates both Earth and outer space contexts. Alongside the extensive Earth science experimentation, phase 3 B2 scientists perform space-focused agricultural research and even the original phase 1 test modules – used for "mission" preparation – are being repurposed for a new generation of space-related experimentation (Price, 2021; Aguirre, 2022). B2, as a phase 3 institution, concerns itself with the resilience of multiple lifeforms, on Earth and in space, now and for the future.

Credibility and Expertise Analytical Frame

Whether due to their prolonged commitment to the facility and/or different institutional imaginations about the usefulness of B2's uniqueness, current B2 leadership has accomplished goals set out during phase 2 institutional repositioning. B2 scientific research is funded by a combination of other sources and legitimate governmental agencies, including the NSF and the European Research Council (Biosphere 2, n.d.-b, n.d.-e). B2 scientists publish in peer-reviewed scientific

publications, including *Nature* and *Science*. The work performed at B2 is interdisciplinary both in the co-existence of different types of scientific investigation and in massive research projects – such as LEO and the coral resilience work – designed for interdisciplinary, as well as multi-institutional investigation. In addition, B2 participates in multi-institutional educational programs and collaborates in educational initiatives with multiple University of Arizona departments at undergraduate, graduate, and post-doctoral levels. B2 hosts postdoctoral researchers within its research initiatives, and it performs educational outreach with primary and secondary schools in Arizona and northern Mexico. In continuation of previous phase efforts, B2 also operates as a site of edutourism. In phase 3, B2 education and outreach specialists aim to engage visitors with narratives about the history and research of the site as well as larger notions of complex systems Earth science worldviews and the importance of resilience for both human and ecological persistence.

Possibly in part because B2 scientists have gained traditional credibility signifiers such as federal research funding and dozens of publications in peer-reviewed scientific journals, current B2 leadership now supports artistic partnerships such as resident artist programs and use of the facilities for creative endeavors. In 2018-2019, I attended both a film screening – organized by a Tucson cinema society – and a Tucson Museum of Contemporary Art staging of performance artists on B2 grounds. The involvement of artists is now seen as a creative extension of B2's mission that may increase communication and outreach with additional public audiences. In this era, art entanglements are now viewed as beneficial, rather than a credibility liability.

Contextual Imaginations Analytical Frame

In a 2021 interview, B2 Director Dr. Joaquin Ruiz described B2 as an "icon of possibilities" (Bugaj, 2021). Within the conversation, he notes his linguistic phrase play on the name of the B2 originators' theater company, Theater of All Possibilities. Ruiz harkens back to the institution's unusual foundations, as he references the multi-decade resonance of this description throughout the interview. A primary public B2 imaginary sites the facility as a place of both histories and mechanisms through which to imagine potential futures.

At phase 3's stage in B2's history, the potential of environmental catastrophe due to climate change is no longer controversial. Contestation about pending climate realities can be proven as more political gambit than based in scientific evidence—or lack thereof. Phase 3 scientists continue their work within the long legacies of climate science performed since the mid-20th century. As B2 scientists study the impacts of CO2, they build upon research reaching back to the 1950s (Oreskes, 2021; Sepkoski, 2020) and bolstered by scientists since, such as those who were a part of B2's influential phase 2 research on CO2 environmental impacts (Langdon et al., 2003; Cohn, 2002; Poynter, 2006; Kolbert, 2006). The scientists' abilities to model local and global Earth systems are now common practice, rather than just emerging as context for the phase 2 research (Edwards, 2010). In addition, B2 research is no longer positioned at the dawn of the concept of the Anthropocene; the conceptual framing is widely accepted and employed as an acknowledgement that the human/social part of SETS cannot be extracted from technological and environmental systems and implications (Sepkoski, 2020). Also, nuclear fears, as well as their entangled ecological catastrophic counterparts of nuclear winter and other forms of devastation, still loom. Within the last year within which I write this, 2022, the world has again seen credible threat of nuclear war. However, in

acknowledging how the science sits in these legacies, I am not excluding the key difference within which phase 3 scientists contend. Phase 3 scientists still engage with the dystopian nuclear apocalyptic imaginary of the B2 founders, but they also live within a rapidly increasing climate emergency. Importantly, there is a shift from B2's phase 2 work to predict futures into one that explains the present, yet with crucial linkages to simulating outcomes. B2's phase 3 work is notably speculative in the ways in which the facility's eco-technical cyborgian configurations allow scientists to experiment within predicted conditions. Whether or not those conditions will occur are no longer in question within the broader society that embeds B2.

However, per historian of science Sepkoski (2020), a considerable phase 3 contextual attitudinal shift may be found within societal perceptions about human agency in the face of anthropogenic impacts. As of the late 2010s, he notes, responses to the Anthropocene often fall into a binary of cultural perspectives. The Anthropocene-related oncoming SETS catastrophe is either seen as an opportunity to stimulate meaningful, necessary change or a death sentence.

Through this lens, B2 can be read as an instrument through which to complexify and expand those binary attitudes in ways which imagine greater human agency to perform short- and long-term interventions. One of the most transformative things I have learned from my time spent at B2 is to acknowledge both urgent conditions and longer timeframes. I credit this, in the greatest part, to my exposures to and informal conversations with Dr. Ruiz himself. Talking with geological chemist Ruiz is to converse with someone who cares deeply about both the environmental and unequal climate justice conditions of now and the future, while also bringing the perspectives of a geologist—someone who's spent decades comprehending historical time differently than most of us would ever imagine. As per geologist Bjornerud (2018), "Geology is not concerned with the nature of time per se

but rather with its unmatched powers of transformation" (p. 22). And this faith in change is a perspective I have heard in communications with Ruiz and transposed into B2's work in phase 3. Bringing longer timeframes – and the possibilities for transformation – into B2's work, the ways in which we comprehend B2, and the ways in which B2's work can inform resilience thinking is not only useful but potentially essential to the ways in which B2 can impact our collective imaginaries about our futures. Complicating historian Sepkoski's emphasis on binary reactions, Bjornerud (2018) writes:

> Those who believe that the End of Days is just around the corner have no reason to be concerned about matters like climate change, groundwater depletion, or loss of biodiversity. If there is no future, conservation of any kind is, paradoxically, wasteful (p. 11).

One of B2's strengths, leveraged in this phase, is its ability to model predicted near and future climate conditions. And, as I have mentioned early in this section, a B2 phase 3 research specific strength is to model these conditions to both comprehend and consider means through which to mitigate destruction. Whereas phase 2 research modeled apocalyptic imaginaries, phase 3 research engages in more complex ways with ideas that the End of Days may not be a binary to fulfill.

Bjornerud also argues that the comprehension of the Anthropocene is increasingly a modified one from that understood when defined by Crutzen in 2002. She generally describes geology as a palimpsest – a repeated re-inscription of history into the environmental record, over and over again. But she says that geologists increasingly understand that the record itself has become more erratic. Human impact persists, but the rates and scales at which those impacts appear are changing. She writes (2018):

> The new rules of the Anthropocene are even making it difficult for Earth scientists to use the quantitative models they have developed to study

> geologic systems. Such models are based on the concept of stationarity—the idea that natural systems vary within a well-defined range with unchanging upper and lower bounds, an assumption that has yielded reasonable predictions in the past. A sobering report by an international group of leading hydrologists recently stated that 'stationarity is dead and should no longer serve as a central, default assumption in water-resource risk assessment and planning' (Milly et al., 2008). In other words, the main prediction about weather and the water cycle is that they will become increasingly unpredictable (p.133).

From both scientific and cultural perspectives, B2's phase 3 inhabits a time of increased uncertainty in both the short- and long-term. As per Bjornerud (2018), "When we peer into the geologic future, a paradox emerges: to some extent, we can see what lies in the far distance more clearly than what is in the foreground" (p.172). And, as she noted in the quote I include above, even longer time-frame views include increased ambiguity. However, as per Perrow (1984), complex systems may be not entirely predictable, but they are not incomprehensible in the ways in which they may be navigated. And, as per Scarry (2011), just because one is a node in much larger systems, that does not mean that acts of agency cannot occur.

Within both the O'Keeffe and CTP chapters, I have discussed the complex systems notion that shifts in node boundaries and hierarchies may transform overall system outputs (Simon, 1962; Holland, 2014). In those chapters, I have also identified ways in which national projects ascribe some members of the populace as allowable sacrifices within nuclear and pandemic threat conditions. Scarry's (2011) comparative analysis of national defense projects provides a reminder that being left out of residence in the bunker infrastructure does not mean that one cannot build their own fallout shelter—in fact, she argues, doing so is considered good citizenship within U.S. governmental notions of collective responsibility.

Agency means different things to different people, and this variation can be seen in the ongoing context of what McCray (2013) identifies as a "visioneering" imaginary. In the face of looming multifaceted global catastrophes, phase 3-era

"visioneers" (McCray, 2013) – charismatic, male technodeterminists – are building themselves luxury bunkers in New Zealand. As per Bjornerud (2018), "Many of these people are Silicon Valley billionaires whose high-tech companies would seem to be predicated on optimism for the future. Instead, their plan seems to be to sell that illusion to the masses while quietly preparing themselves for apocalypse" (p. 170). Plenty of people, it anecdotally appears to possibly be an exponential increase within the last decade, focus on themselves and their own survival. One of the instigators of current sociocultural doomsdays has also joined B2's small cadre of ongoing controversial imaginaries.

B2's ongoing controversial imaginaries are, in one case, legacy narratives about the scientific validity of the phase 1 missions and, in another case, an old player re-found anew. As mentioned earlier in this chapter, the mission era continues to incite curiosity and be reframed for new audiences. In addition, a phase 1 participant in the dissolution of the relationship between Bass and Allen, as well as the establishment of the phase 2 partnerships, is none other than Steve Bannon—a major player in the 2016 U.S. presidential election and ongoing rise of far-right wing politics. Bannon, at the time of his B2 involvement, was an investment banker who specialized in company turnover. Bass hired Bannon to make the phase 1 iteration more economically efficient and to establish the transition to the phase 2 institutional partnerships. In most B2 history accounts, Bannon appeared as the guy who called in the U.S. Marshals to drive Allen and his collaborators from the B2 site. In Reider's (2009) insider narrative of the phase 2 transition, Bannon additionally shepherded the institutional relationships that put B2 on the path to scientific credibility. After 2016, many articles about B2 mentioned Bannon as almost a cultural "gotcha" that signals "look how crazy this place is. Even Steve Bannon was involved." However, most articles I have read do not appear to actually understand his role and context.

Bannon has become the new salacious B2 narrative—loosely based in fact, addressed in an egregiously shallow manner, and something used by media to overshadow everything else the various phases of B2 instantiations and scientists have accomplished.

Perhaps ironically, scientific researchers have simultaneously begun to arrive at B2 with less historical baggage informing their views. Within our January 2022 conversation, I asked Deputy Director John Adams whether or not increasing external academy accreditation of their decades-long strength in complex adaptive systems (CAS) science impacted their ability to attract researchers and funding. His answer surprised me. He explained that though the differences in external perception about the importance of CAS science likely did play a part, he did not perceive that as the strongest driver of change. According to Adams, a shift in researchers' own perceptions of B2 instigated new relationships. A new generation of scientific researchers, he claims, have shown a greater interest in interdisciplinary research and complex collaboration, and they approach B2 with less baggage in their perceptions of the institution and what scientific methods they're capable of performing using the B2 facility. The origin story does not cause them to pause; they're just excited about what B2 allows them to do now.

B2 SETS: OPERATIONAL AND CONCEPTUAL SYSTEMS, SHIFTS IN SURVIVABILITY

Scientists, administrators, and publics have understood B2 in different but overlapping ways between the three phases. B2 is simultaneously a physical facility, an institution, and a concept that ignites imaginations. As I have mentioned throughout this chapter, B2's deeply entangled SETS have always been its greatest strengths. I understand B2's SETS as physical architectural, technological, ecological, and informational systems, as well as less tangible interwoven concepts which

provide insights into relationships between humans, ecologies, and technologies. Within this section, I employ multiple scholarly perspectives on B2 to acknowledge B2 SETS as both operational and conceptual systems.

B2 purports to be and allows for the study of nature, but one of its most poignant aspects is its reflection of the nature / machine relationships that currently underlie most Earth environments. B2 environments are controlled and cyborgian. The underlying "technosphere" – where machinery is housed – and connected "lungs" – geodesic domes that contain massive metal and rubber contraptions to balance the building air pressure when the system is sealed – allow the ecosystems within the primary B2 building to thrive.

B2 is also a landscape machine that's inextricably entangled with its human constructors and caretakers. In his book *Ecocritique: Contesting the Politics of Nature, Economy, and Culture*, political scientist Luke (1997) argues that B2 is an exercise in "reinterpreting Nature itself as a cybernetic mechanecology" (p.110). He writes, "Although fragments of Nature are shackled into Biosphere 2 as slave servomechanisms, its basic ecology is essentially cybermechanistic, simulating the increasingly denatured Nature of Earth inside an ecological formation in which humans, computers, mechanisms, and biomasses become one interdependent, coevolutionary energy generation and conversion circuit" (ibid, p.109).

These relationships are not abstractions. Instead, they are evocative representations of our world. Luke (1997) writes, "Biosphere 2's architectural complex closely emulates the cyborg planet being constructed now by transnational capitalism in Biosphere 1" (p.108). As science journalist, historian, and science fiction author Annalee Newitz (2014) explains, humans terraform; this is fundamental to how we interact with our surrounding ecologies and technologies. "We're an invasive species, and we've turned wild prairies into farms, deserts into

cities, and oceans into shipping lanes studded with oil wells" (p.216). Humans insist that the environments within which we live operate as human-centric life support systems. Biosphere 2 was constructed as a model version of this conceit.

STS scholar Sabine Höhler (2010) additionally contextualizes B2's creation within a global movement to create "biosphere reserves," as articulated at the 1968 "Biosphere Conferences" in the UNESCO Headquarters in Paris. As per Höhler (2010):

> Biosphere reserves were set up as ecological laboratories to study and explore the wealth of nature, not only for protection and preservation, but also for human benefit and future utilization… This new form of human environmental stewardship marked a transition from a nature-centered view of conservation to a human-centered view on the environment (p. 43).

"Ecotechnics [principals upon which Biosphere 2 was built] conceptualized ecological relations as physical and biochemical causal relations and transformed them into cybernetic servomechanisms," writes Höhler (2010, p.49). "An elaborate infrastructure of electrical, mechanical, chemical, thermal, and hydraulic transmissions formed the fundament of a new hybrid version of nature" (Höhler, ibid).

B2's identity as an ecological-technical hybrid, as described by Höhler, has been fundamental to B2 operations since its origins. She posits that the simulation-like construction of B2 is an opportunity. She writes, "Biosphere 2 as an example of a technologically controlled *endosphere* advanced an understanding of the environment as a 'life support system' that emphasized not completeness but systems integrity, and was based on principles of functionality and replaceability" (Höhler, 2010, p. 39). Höhler describes B2 as a CAS. She identifies B2's ability to evolve and repair SETS components without jeopardizing the entirety of the system. B2's SETS, and – in her text – particularly the technical systems housed in the B2

technosphere, contain flexibility and adaptive capacity (Turner et al., 2003). As I have discussed in the first three chapters of this dissertation, flexibility and adaptive capacity both increase SETS's abilities to persist despite disturbance.

Resilience, the ability to persist, is built into B2's design of their SETS, but I argue throughout this chapter that B2's institutional worldviews on robustness, the operationalization of resilience through definition of who and what needs to persist in order for the overall CAS to function, have changed significantly from phase 1 to phase 3. Throughout this dissertation, I have identified the concept of robustness as one through which survivability priorities, what I refer to as survivability purviews, may be identified. Within each earlier phase section, I addressed robustness when I identified what I understand to be each phase's determination of who and what are most essential to maintain overall system functioning. From phase 1 through present day phase 3, these robustness identifications have significantly expanded. In the rest of this chapter, I reiterate each phase's survivability priorities, describe the prioritization shift, and identify what might be learned from B2 about increasing collective survivability, deeming – more humans and environments – as being necessary to protect and worthy of protection in the face of social-ecological-technical uncertainty.

Phase 1 B2 prioritized humans as the most important life to sustain throughout the mission experimentation. Within this phase, ecological systems were understood as both sustenance and warning indicators of potential SETS dangers to human lives. Ecological and technical systems were deemed valuable and necessary, but they were acceptable sacrifices as long as B2's SETS continued to support Biospherian, human, persistence. In phase 2, the social parts of multiple configurations of SETS were extracted from daily concerns, in that B2 no longer needed to support daily, proximate, entirely dependent upon the entangled systems,

human life. Instead, ecological systems became the focus of phase 2 research in ways that served larger, global notions of human life support. By studying the CO2 impacts on the ocean and rainforest biomes, phase 2 researchers pursued comprehension of ecological systems in ways which potentially increased human survival at a global – rather than Biospherian – scale. The environments were again deemed acceptable sacrifices, but to define phase 2 survivability robustness is a slightly less straightforward task than in phase 1. In phase 2, researchers examined biomes' own robustness when they identified what CO2 quantities and overall conditions cause corals and rainforest flora to tip into ecosystem degradation.

In phase 1 the technological systems remained the iceberg below the surface, as the mechanisms that maintained conditions for the B2 human support system. Biospherians also cared for the biomes by hand, as described in multiple Biospherian memoirs (Nelson, 2018; Alling et al., 2020; Poynter, 2006). However, the B2 technosphere and the humans who monitored its data from the secondary control buildings were B2's 24-hour nannies who watched over and maintained the environments when the human caretakers were otherwise occupied or at rest. As first mission Biospherian Roy Walford said, "Biosphere 2 is like the Garden of Eden on top of an aircraft carrier" (Weideman, 2018, para. 3; Nelson, 2018, p. 71). The technical systems have been B2's invisible soldiers beneath the flight deck, keeping the boat afloat.

B2 was designed as SETS similar to those with which I began my discussion of survivability. In chapter 1, I traced the concept of survivability to complex military mechanisms designed to persist in the face of potentially deadly disturbances. B2 founders designed the facility to carry both humans and environments as its cargo, and they integrated SETS in ways no less essential than on an aircraft carrier, military airplane, or nuclear submarine. B2's technological systems have also always

been designed as a means by which to negotiate choices about SETS survivability.

Though phase 2 also prioritized human persistence by focusing research on ecological devastation in ways which could support increased global human survival, it was the first of the three phases to activate the greater role B2's technological systems could play in supporting B2 research that can inform and expand collective survivability. In phase 1, the technological systems were primarily utilized for monitoring and maintaining the biomes, as well as keeping overall conditions to those which supported human life. In phase 2, humans were removed from daily sustenance concerns, and the research activated B2's technological systems to deliberately modify environmental conditions. As with phase 1, these phase 2 conditions were monitored by on-site data and operations specialists, but the phase 2 machines operated less as facility nannies and more as built-in time machines which placed B2's biomes into predicted temporal and spatial conditions. Phase 2 scientists transformed technical systems' greatest function within B2 SETS in ways which hinted at opportunities now used by phase 3 scientists within pursuits that extend past comprehension of destruction towards increased collective survivability.

Phase 3 research again focuses on environmental conditions, but recent and current projects demonstrate a considered shift in survivability prioritization. There appears to be a greater value placed on not only increasing comprehension but also enabling constructive interventions. Research that includes or leads to constructive interventions includes acknowledgement of threat contexts, adds information about potential mitigation or resilience strategies, and works towards applied solutions that increase survivability. B2's current coral research, currently in relatively early stages of funding acquisition and SETS modifications, is an evocative story about this shift.

SETS SURVIVABILITY PRIORITY SHIFT EXAMPLE: THE CORAL REEF

B2's coral research exemplifies how B2 scientists' survivability purview shifted from protecting eight Biospherians to sacrificing B2 environments towards larger potential human survival to then experimentation on and with ecosystems in order to both comprehend the survivability of environmental systems and increase whom and what is protected when environments, and their SETS, are faced with extreme disturbances. Within this section I provide a top-level description of B2's coral reef research, informed by my field research, to illustrate B2's expansion of their survivability purview and to identify research opportunities provided by B2 as a CAS comprised of SETS.

The coral reef was a spectacular inclusion within the B2 facility build and has been a superstar evocation of B2's scientific utility since Columbia's phase 2 research. While operating the facility as a controlled but not closed system, Columbia scientists increased climate change-related chemistry within the biome to such an extreme that they permanently damaged the reef. This resulted in seminal published science which significantly contributed to comprehension of global impacts due to increasing climate catastrophe (Langdon et al., 2003; Cohn, 2002; Kolbert, 2006).

When I first met the B2 leadership team in 2016, the reef remained visibly damaged. The first anecdotal stories I heard were that the reef was deliberately left that way. The conditions were an evolution of the environment and part of the facility's history. Ocean research, at the time, was focused on other aspects of the biome. Just before I transitioned from B2 collaborator to PhD student in 2018, I heard rumors that B2 leadership were pursuing coral restoration. Global reports of coral damage were increasingly, exponentially bleak, and the urgency contributed to a rethink of the roles that B2's ocean biome could play in supporting coral survival.

Multiple non-B2 marine biology labs focus on restoration, but – as I learned through informal conversations with B2 scientists – restoration is tricky for at least two reasons. First, the scale of what can be accomplished in a controlled lab is limited, and tight regulations exist on open-water experimentation due to risks of causing potentially unexpected and irreversible damage to ocean ecosystems. Second, performing restoration in current conditions restores coral for the present. Coral that can survive present conditions may not yet be sufficiently resilient to survive future climates. B2's ocean environment, the largest controlled environment of its type in the world, provides three opportunities to both think and act on coral resilience differently.

First, B2's controlled environments allow researchers to perform lab work at field scale. This characteristic provides means by which scientists may perform larger system exploration, and it also allows researchers to take increased risks. One of B2's phase 3 essential ocean collaborators was the late Dr. Ruth Gates, a leader in coral resilience research who led the Gates Coral Lab and the Hawai'i Institute of Marine Biology until her death in 2018. In my January 2022 conversation with B2 Deputy Director John Adams, he confirmed an anecdote I informally heard from another B2 researcher in 2018. Gates instructed the B2 team to use the ocean environment to take the risks that they could not perform in open waters. This, she said, was the greatest asset—not only for B2, but for ocean research. Of course, B2 researchers would not want to create catastrophic failure within their ocean environment. However, aligning with sociotechnical imaginaries of B2's utility, the implications of unexpected consequences within B2 are perceived as manageable.

Second, B2's ability to fine-tune and closely monitor environmental conditions allows for increased size and complexity in research design, while it also provides for the possibility to perform complex, coupled experimentation. The current ocean

research design leverages this strength within multiple ways. First, the group of more than 40 researcher collaborators – led by geoscientist, marine biologist, and B2 Director of Marine Research, Dr. Diane Thompson – are tied to dozens of institutions and at least four field sites, located in Hawaii, Florida, Brazil, and Australia. In current plans for this emerging phase 3 coral research, scientists will simultaneously perform research on scales from system-wide monitoring to developing the equivalent of a probiotic for coral health. The experimental reef within the B2 environment will be grown from materials sourced from the field sites, and the insights gained from the experimentation will not be monolithic.

When I first heard about the coral research it was described to be me as research towards building a "super coral," a term often used in the work of Gates and her collaborator Dr. Madeleine van Oppen of the Australian Institute of Marine Science (Kolbert, 2021). Super coral, as a term, describes the development of a species of reef that is resilient enough to survive all future conditions. Over years of discussions, I heard the explanation of the research evolve. From "super coral" I then heard the term "Franken-reef," which brings to mind both a seminal text on responsible innovation and a patchwork configuration born from the various field sites and scientists. As one researcher explained to me, this future-resilient coral would not look like anything I have seen because anything I've seen would not survive future climate conditions. That notion persists, but B2 ocean scientists decreased their use of the word "Franken-reef", because they saw it as not the most useful description (Bugaj, 2020), and my comprehension again evolved. I learned that the desired result of the research would not be an uber-coral that could survive all conditions, but instead – reflecting the intermingled configurations of the research itself – the B2 resulting coral would provide complex, coupled solutions from which each researcher and field site could gain their own insights and interventions. A

complex configuration of researchers would bring together multifaceted materials from field sites to create a second complex configuration of digital and embodied information that could provide multifaceted solutions for different global conditions. This kind of complex, scientific experimentation could not be supported without the environmental scale, lab controls, integrated machinery, and persistent oversight of the B2 site and scientists.

Third, phase 2 ocean and rainforest research confirmed B2's abilities to evoke imaginations of the future and to create tangible future, predicted conditions within the environments. This remains a unique opportunity for phase 3 work. Within the coral research, conditions will be pushed forward to future predictions. This is one more thing that B2 can accomplish that cannot occur in open water resilience or restoration work. Future climate condition research has occurred at smaller scales within both Gates's and van Oppen's labs (Kolbert, 2021), but B2 will allow that work to be expanded to include a larger coral ecosystem while maintaining tight lab controls. Experimentation will occur in ways in which solutions could emerge to increase coral resilience in far-future conditions, rather than those tactics from open-water research which bolster assurance in resilience for present day. This future-leaning remit, too, is a part of the risk-related instruction Gates gave the B2 team. In her portrait of Gates and van Oppen, science journalist Kolbert (2021) quotes Gates as saying, "Really what I am is a futurist" (p.94).

Throughout my time learning about the coral research, I sometimes described the research as geo-engineering. In our January 2022 conversation, I directly asked B2's Deputy Director Adams if I understood the project properly. He confirmed and expanded upon my abstract-length summary of the research plan, but he also explained to me that geo-engineering is the wrong description. Geo-engineering brings together visions of terraforming, whereas – as per Adams – what B2 is

working on is called assisted evolution. "Assisted evolution" is a term I first heard during an interview with Adams, as a modified conception of researchers' work in the ocean and rainforest environments, and I again encountered the concept in science journalist Elizabeth Kolbert's (2021) portrait of Gates and van Oppen. Assisted evolution describes SETS interventions on biological forms in ways that nudge the non-human living creatures towards increased resilience. For example, coral remain coral but assisted evolutionary research may put coral within conditions where they may develop greater resilience to disturbance and/or the coral may be altered through breeding, supplementation, or modification performed by scientists (Kolbert, 2021). While describing the research that the Gates Coral Lab and Australian Institute of Marine Science led that pushes future conditions to create increased coral robustness at tank scale, Kolbert quotes Gates as saying, "Our project is acknowledging that a future is coming where nature is no longer fully natural" (p.94).

OPPORTUNITIES ARISE FROM MODELING BEYOND THE BINARY

B2 is a physical facility, an institution, and a concept that ignites imaginations. B2 includes SETS as deeply entangled physical and informational systems that enable B2 environments' unusual relationships to time, space, and the ability to practice the future. One way in which scientists practice the future within B2 is through treating B2 environments as models. Scientists may utilize models as venues for simulation, through which they may test hypotheses, differ threat conditions, and practice research methods. When utilizing B2's environments as models, scientists may additionally take advantage of the viscerally immersive character of B2's environments, as well as envision strategic relationships between B2's environments, global environments, the research they perform within the B2

facility and traditional ecological field work. In this section, I utilize multiple scholars' perspectives on simulation and embodiment, alongside insights of a phase 3 B2 leader, to explore how B2 environments' configurations leverage unique relationships to increase collective survivability both within B2 and global, external environments.

In phase 1, B2 founders and Biospherians crafted and lived within physical simulations to practice what they envisioned as closed-system potential habitats for Mars. In phase 2, Columbia scientists utilized B2 environments as proxies for global typologies upon which they could inflict future, predicted conditions to gain comprehension of approaching climate system trends and their implications. The phase 2 scientists' findings were the result of what I understand to be blunt force trauma; by inflicting extreme conditions on a general ecological type such as the coral reef or rainforest, the scientists' findings were generalizable in ways potentially less dependent on the ecological details of B2's particular environments. In their research, Phase 2 scientists performed physical disaster simulations, and they sacrificed the B2 ecological proxies by taking risks that they could not take in external environments.

B2 environments are unique because of their risk profiles, and they are also unique because they have grown in ways which do not replicate any specific non-B2 location. When first created in phase 1, B2 environments were named biomes, ecosystems evocative of environmental types. When we spoke in January 2022, B2 Deputy Director Adams told me that he describes them as unique environments rather than biomes because of their unusual histories, meaning the conditions and experimentation that have occurred over more than 30 years and the subsequent experimental situations within which these ecosystems have grown. Due to their variable ecosystem origins – original flora and fauna were sourced from multiple locations – and their relationships to the science performed at B2, these

environments have taken on unique characteristics. B2 environments are not replications of global environments, even as scientists may still find significant, generalizable things to be learned from studying their flora, fauna, and ecosystem dynamics at various scales.

Despite their uniqueness, phase 3 B2 environments – per my conversation with Adams – serve as models within research in three primary ways. First, as described earlier in this chapter, scientists may modify environments' climates to replicate future predicted conditions. Second, phase 3 scientists may identify strategic relationships between their B2 environment research and their broader global field work in ways that provide strategic linkages, insights, and the ability to explore research questions at different scales. Third, B2's SETS permit scientists to practice their research setups, data collection, and team configurations in environments that enable more control for refinement and less risk on the environment or the research. These configurations may then be applied to research at non-B2 sites as well as follow-up research at B2. In phase 3, scientists' acknowledgement of the environments' uniqueness, as described by Adams, support a more nuanced relationship between B2 environments and global ecologies than occurred in earlier phases. Adding to an ongoing theme of this chapter, I hypothesize that these strategic increases of B2 environmental utility in current research may be the result of shifts in scientific imaginations in both B2 as a scientific institution and how complex Earth science is performed more broadly.

This conceptualization of B2 environments as strategic research models feeds into a larger inquiry into whether or not B2 environments are simulations or nature. I'm far from the first to ask this, but I believe that my answer is different than Baudrillard, who spent a portion of his text *Illusion of the End* (1992/1994) working through this question specifically about B2.

Baudrillard (1992/1994), writing during the time of B2 phase 1, said that B2 is a simulation. According to him, being a simulation is a negative quality because the B2 project projected a future without end to either Earth ecosystems or the human race. This survival imaginary, he argued, is destructive to collective imaginations. Our world should be allowed to end, he claimed, as lifecycles always include at least some sort of terminus. Baudrillard believed that pretending that we could imagine survival, and even more so through a tourist-drawing edutainment experience, was at cross purposes to actual survival. In his view, simulating survival decreased comprehension regarding our places within larger evolutionary systems, rather than increasing humans' abilities to navigate complexity and social-ecological-technical uncertainty.

I am more in line with philosopher Pierre Lévy (1998), who generally – not B2 specific – and in opposition to Baudrillard, argues that simulations are constructive because they allow humans to practice the future by navigating variable conditions. Simulations also bolster our future-facing capabilities because participation within simulations may cause extensions and reconfigurations of our comprehensions of time and space. By engaging in fully constructed, non-physical spaces such as virtual worlds, participants may also become almost two-bodied, as they extend their haptic knowledge into speculative realms that may impact their senses of time, geographic space, affinity, identity, and even embodiment. I believe that these types of extended relationships may also occur within environments that are as physically immersive as they are full of digital information—such as those found at B2.

Comparative literature and STS scholar N. Katherine Hayles interrogates what's meant by defining a simulation and why that's useful. In her chapter, "Simulated Nature and Natural Simulations: Rethinking the Relation between the Beholder and the World" (1995), she argues that simulation and reality exist on a

spectrum, particularly as they pertain to what we understand as nature. According to Hayles, the concept of nature is always a spectrum rather than an oppositional choice. Particularly when one takes into account the SETS within which they're entangled (my reference, not hers, though she describes related sociotechnical, social-ecological, and ecological-technical systems using different terms), U.S. National Parks, she argues – as one evocative example, are as constructed as virtual reality environments. Through SETS, National Parks are conceptualized, manufactured, bounded, and maintained as simulations comprised of physical components. Binary definitions of nature and simulation are not constructive, she explains, because those notions are artificial and outdated. Additionally, all points along the simulation-to-real spectrum can be coherently understood by centering the human body as interface, as the viewpoint through which we should evaluate our interactions to nature. As Hayles (1995) describes:

> Instead of accepting a construction that opposes nature to simulation, I seek to arrive at an understanding of nature and simulation that foregrounds connections between them. Not two separate worlds, one natural and one simulated estranged from each other, but interfaces and permeable membranes through which the two flow and interpenetrate. Interactivity between the beholder and the world is key (p. 413).

Anthropologist Kath Weston (2017) takes Hayles's position one step further, and specifically in ways applicable for my exploration of B2's usefulness as a Hayles-style hybrid. Weston argues that a combination of technologically sourced information and embodied data increases the credibility of climate science information due to disjunctions that occur between scientific declarations and lived experiences. Weston grounds her claims in the concept of embodied empiricism, where she argues for the co-existence of information – and particularly environmental/climate information – gleaned through both embodied and

traditionally scientific evidentiary forms. In a similar spirit with Hayles (1995), Weston (2017) writes:

> Embodied empiricism choreographs a bio-intimacy of detection and assessment, which registers conditions through membrane, skin, and retina, then uses reason to sort out the results. In that sense it matters little whether your "environment" embodies you, or you it, or both (p. 119).

In constructive opposition to Baudrillard (1983, 1992/1994), Both Hayles (1995) and Weston (2017) support notions that an environment's character may lay on a spectrum of simulation and real, for lack of a better word, with "real" being a concept of something which we can tangibly process while using our bodies as instruments of empiricism. As Weston (2017) explains, the body has been a data collection device for generations, and therefore embodied data should not be placed in opposition to other scientific data collection and processing methods. Even, and especially, if valuing the body as instrument may increase the credibility of lay, rather than exclusively institutionally trained, scientific observers.

I suggest that B2's environments sit near the center of Hayles's (1995) simulation-related spectrum, rather than at either of its poles. This position allows B2 environments to provide for the constructive cognitive extension and imagination provided by simulation, as per Lévy (1998), and reflects the hybrid SETS nature of what nature is these days, as per Hayles. The positioning of B2 environments in this way also supports the inclusion of both technologically gathered, virtual data and embodied, physical data as per Weston (2017). It is the complexities of B2's environments as technological and ecological, constructed and organic, simulated and real, unique and generalizable, physical and informational spaces that allow for complex research that leverages deeply entangled SETS to approaches towards comprehending and addressing complex, knotty threat contexts and social-ecological-technical uncertainty. Designing research that allows for the complexity

that B2 environments embody also allows for more complex, expanded notions of who and what is deemed necessary for systems' survivals and paths towards solutions through which scientists may participate in increased protections for multiple forms of life in the face of social-ecological-technical uncertainty.

CONCLUSION

Within this chapter, I address the evolving notions of who and what are deemed essential to the survivability of B2 systems as demonstrated by three eras of scientific practice. I also examine the scientific institutional and public imaginaries that influence both experimentation and public perceptions of B2. Throughout its more than 30-year history, I identify shifts from lay person involvements with scientific institutions to increasingly scientific institutional configurations, particularly as the shifts entangle with notions of credibility and expertise across local, national, and international collaborations and transform notions of survivability. Within this section, I briefly summarize changes that happened across historical phases and what may be learned about survivability from perceiving B2 through each of three analytical frames: survivability systems design, credibility and expertise, and imaginations.

B2's phase-specific institutional values have determined who and what are essential to maintain SETS functions. Across the phases, this designation significantly expanded. Phase 1 survivability systems design prioritized eight Biospherians's well-being over B2's other forms of life. The phase 1 mission also acknowledged Earth science while it envisioned future travel to Mars, and – in this way – phase 1 B2 participants prototyped a human life-support system. Phase 2's focus fell to back to Earth. B2 scientists deliberately caused harm to B2 ecosystems in order to comprehend potential climate catastrophes at a global environmental scale. In this

phase, flora and fauna were considered in-system assets but were deemed allowable sacrifices for larger pursuits. Phase 3's institutional mission expands the survivability purview to value human and non-human life, B2 environments and global concerns, on Earth and in space. In phase 3, when harm is performed to the environments, to test punishing predicted future climate conditions, it happens through a different lens than phase 2. A B2 phase 3 research specific strength is to model these conditions to both comprehend and consider means through which to mitigate destruction. Whereas phase 2 research modeled catastrophic imaginaries, phase 3 research engages in more complex ways with ideas that the End of Days may not be a binary to fulfill.

This case study demonstrates that institutions may increase their survivability purview through transformation of the social, including their sociotechnical and social-ecological, relationships within their SETS without needing to entirely rebuild ecological and technical systems. The significant expansion in survivability purview that occurred between phase 1 and phase 3 was due to a shift in institutional priorities, as well as internal and contextual imaginaries. B2, as a CAS in both its facility and institutional forms, has been flexible enough to support different approaches to the social systems in ways which utilized the ecological and technical systems towards different notions of survivability. In addition, when viewing the entirety of B2's history, I understand B2 scientists' iterations of experimentation and facility use as examples of B2's complex SETS's adaptive capacity—B2 has evolved, as notions of science and contextual imaginations have disturbed, shifted, and grown around and with the institution. When systems contain adaptive capacity, systems can iterate and evolve without being rebuilt.

Throughout the phases, B2 institutional identity has been perceived through and greatly influenced by traditional scientific credibility signifiers. The ability of the

three administrations to navigate, confront, and transform their institutional relationships to both scientific institutions and public perceptions has depended partially on traditional funding sources, publications, and scientists' credentials. Phase 1 Biospherians attempted to bolster their own less credentialed expertise and more expansive, multidisciplinary backgrounds with collaborations with established scientific institutions. This attempt only partially worked, and the Biospherians continue to be a controversial narrative. Phase 2 Columbia University scientists faced a credibility crisis, as they attempted to pivot both their and public perceptions of B2 by establishing a new identity built upon their attempts at credibility transformation. They only partially succeeded, and they then fed into B2's credibility controversy upon their departure by declaring that the facility was not fit for rigorous research. Phase 3 UA scientists have mostly succeeded where phase 2 scientists failed. They receive funding from notable sources, publish in peer-reviewed scientific journals, and collaborate with educational institutions of multiple levels for their educational programming. Phase 1 credibility controversy continues, but phase 3 leadership now acknowledge the strengths of the Biospherian era while clearly communicating about the institution that B2's become. In addition, perceptions of how valid science is performed have externally shifted around the institution; scientists now arrive at B2 with less concerns about B2's past and more excitement about the ways in which B2's SETS support interdisciplinary ecological research.

Another shift that occurred between phase 2 and 3 is in how the leadership valued B2's SETS and how B2's strengths aligned with larger institutional goals. Accounts of Phase 2 research describe instances of attempting to fit traditional field work into B2's unique strengths. Phase 3 leadership have demonstrated a considerable faith in B2's utility for both comprehension of current environmental conditions and futures problem solving. Aligning with current institutional values, I

think Phase 3 scientists have most leveraged B2's unique characteristics in ways which may increase collective survivability.

As a result of this chapter's focus on survivability systems design, credibility and expertise, contextual imaginations, B2's shifting use of SETS priorities, and notions of simulation, I arrive at four additional lessons that this case study can contribute to expanded notions of survivability. Many other subtle notions may be found within the proceeding pages of this chapter, but these are takeaways that both contribute to overall dissertation findings and hint at potential additional foci for study. I imagine these four lessons as a Venn Diagram rather than a list, but I number them for clarity.

First, adding to findings from the CTP case study, I argue that one of the things we can learn about survivability from this specific case study is that the combination of adaptive capacity and a prioritization of care – in this case, the prioritization of the widest possible survivability purview – together increase collective survivability. Second, learning through hybridity – embodied as well as scientifically and technologically-driven information, on the simulation spectrum rather than at one of the end nodes – expands potential for insights and interventions, within the present and in preparation for uncertain futures. Third, leveraging unique SETS opportunities increases engagement with complex, knotty problems in ways which may also lead to multifaceted insights and interventions. B2's SETS represent poignant evocations of social-ecological-technical relationships which exist within a wide range of non-B2 environments. I suspect that leveraging B2 SETS as models that expand beyond even their current utility could constructively impact larger SETS engagement. And, fourth, practicing the future can increase resilience in the present. As with the coral research example, strengthening corals' capabilities to withstand future, predicted extreme disturbances also increases

resilience within present, uncertain conditions. I suggest that forms of future-practice alone are useful in their ability to expand future imaginaries and notions of agency, but the inclusion of constructive interventions in future-facing research may provide additional utility. Constructive interventions assess and modify SETS design towards increased survivability when researchers acknowledge threat contexts, add information about potential mitigation or resilience strategies, and work towards applied solutions that increase collective survivability.

CHAPTER 5

CONCLUSION: CONSTRUCTING SURVIVAL

"It isn't enough for us to just survive, limping along, playing business as usual while things get worse and worse… There has to be more that we can do, a better destiny that we can shape. Another place. Another way." (Butler, 1993/2012, p. 75).

"We drew, and redrew, the layout of our community" (Estes, 2019, Location No. 3866).

Within this dissertation, I have investigated conceptually interconnected stories with which to think about survivability as a field of study which explores historic, current, and future survival in the face of existential threats, social-ecological-technical uncertainty, and indeterminate futures. To interrogate survivability, this work draws from fields and concepts that probe how collaboration and change occur in complex systems. In opening up this Science and Technology Studies (STS)-driven research to consider social-ecological-technical systems (SETS), this work has revealed how human culture and social institutions interface with technology and also how ecological matters and specificities of place figure into our interactions with both technologies and society. My presentation of each case highlighted their unique configurations of expertise and agency while inviting us to imagine new paths forward, both individually and collectively, when faced with both immediate and long-term danger. By combining complex adaptive systems (CAS) framings with interrogations of knowledge systems, I look for ways in which transformations of hierarchy and epistemological boundaries may impact, and particularly increase, SETS survivability. Through marshaling themes of SETS, expertise and agency, and imaginations to extend concepts of survivability, this work drafts a conceptual scaffolding to better understand the dynamic workings of quests for survival in the 21st century.

Survivability, as an information technology (IT), military, design, and engineering concept, often uses the language of complex adaptive systems (CAS), aims to measure and instrumentalize risk and uncertainty, and attempts to essentialize and quantify concerns so that all central concepts towards increased survivability can be assessed, executed, and improved upon. Within the primary existing disciplinary frameworks, humans and environments are footnotes while technologies are the primary focus. Within this research, my use of survivability gave equal weight to concerns of and interactions between humans, environments, and technologies. My approach was relational and generative. I focused on SETS' mutable relationships within variably transformable contexts. Whereas traditional notions of survivability are structural, I instead valued both the systems views and individual parts of survivability, acknowledging both structural and anecdotal knowledge. I approached this last point through frameworks of feminist social science (Harding, 2009; Harding & Norberg, 2005; Haraway, 1988; Stoetzler & Yuval-Davis, 2002; Hinton, 2014; Hughes & Lury, 2013), which values both systems-level analysis and individual anecdotal evidence as valid data through which to comprehend research subjects. Throughout this research, my focus on survivability leveraged its qualities of assessment and design, while I expanded my employment of the concept towards a concern with increasing collective survivability.

When I refer to the phrase "increasing collective survivability," I direct my attention to two qualities of survivability. First, I refer to expanding the designation of what is deemed essential for relevant system persistence. Second, I mean making the entire system more responsive and resilient in ways which decrease the possibility of damage during operation even when faced with challenging and/or dangerous conditions. This two-part explanation can be applied to traditional contexts within which the concept of survivability is used, such as military machines

and IT systems, but it can also be used as a lens through which to think about SETS broadly and within the context of urgent conditions such as the threat of nuclear warfare, pandemics, and the increasing impacts of climate catastrophe. In particular, the concept of survivability may be harnessed to aim for constructive interventions, a phrase I define in the B2 chapter and a lens through which I comprehend all three case studies. Constructive interventions are those individual and collective research, efforts, and engagements that acknowledge threat contexts, increase information about potential mitigation or resilience strategies, and work towards applied solutions that increase survivability.

QUESTIONS

Though each case study evokes its own, often related, questions, my primary research question for this dissertation is:

> R1: How do artistic, civic, and scientific imaginations inform conceptions of agency and survivability in the face of social-ecological-technical uncertainty and multiple potential futures?

My secondary questions include:

> R2: How are expertise and credibility gained, challenged, transformed, and demonstrated by both laypeople and scientists through collaboration with scientists and scientific institutions within urgent conditions?
>
> R3: How do the protagonists acquire information, skills, and agency within their situations through their inter-personal collaborations, use of technologies, and intersections with civic and/or institutional processes? How do they teach, learn from, evolve with and care for one another? How do these acquisitions and exchanges inform their notions of survivability?

I addressed these questions in overlapping ways throughout the dissertation. I summarize my approaches to the questions for each case study later within this chapter.

SUMMARY OF CENTRAL CONCEPTS

My guiding focus within this dissertation has been on collaborations between artists, scientists, and technologists within which artistic, scientific, and civic imaginations influence their – and subsequently, our – notions of survivability. Essential to my understanding of these collaborations are questions about people as parts of systems—regarding what imaginations mean, the roles of sciences and technologies, how credibility and expertise are navigated, and how conceptions of survivability are entangled with visions of the future. I explained each primary project concept in significant detail within the dissertation introduction and expanded upon these concepts and their usage within each individual case study chapter. This section briefly re-summarizes four central concepts addressed throughout the dissertation: imaginations and imaginaries, credibility and expertise, systems as CAS and SETS, and futures thinking and uncertainty.

Imaginations and Imaginaries

Within this project, I ground conceptions of imaginations and imaginaries in the theories of Taylor (2002), Marcus (1995), and Jasanoff & Kim (2009, 2013). According to Taylor (2002), social imaginaries are constructed through the "great connected chain of mutations" of the public sphere, a market economy, and the citizen state (p. 116). All three intersect and evolve to create social conditions through which citizens imagine and invest in collective civic goals, projects, and commitments. Marcus (1995) explains imaginaries as the confluence of parts; for

Marcus, "technoscientific imaginaries" arise from interactions between individuals, scientific systems, public perceptions of the utility and risks of scientific and technological developments, governmental structures and narratives about science, scientists, and the state. As per Jasanoff and Kim (2009, 2013), sociotechnical imaginaries, particularly as they apply to national technoscientific projects, are also entangled with questions of risk, containment, innovation potential and questions of uncertainty. Within this dissertation's case studies, technoscientific imaginaries additionally intersect with cultural ideas about the importance of artistic imagination and creativity in national technoscientific projects. I provide context for this type of imaginary in histories of post-WW2 technical and cultural collaborations (Beck and Bishop, 2020).

When addressing the three case studies all together, it is also useful to acknowledge the feminist social science concept of "situated imaginations," a consideration of the specifically positioned yet persistently shifting relationships between social imaginations and imaginaries (Stoetzler & Yuval Davis, 2002). Theories of imaginations and imaginaries, as per the definitions provided by Taylor (2002), Marcus (1995), and Jasanoff & Kim (2009, 2013), most often focus on sociotechnical relationships. Feminist social scientists Hughes & Lury (2013), suggest additional – in my case, appropriate – expansion to include ecological epistemologies within situated analyses.

Credibility and Expertise

Collaborations are one way in which my case study protagonists navigate, negotiate, and transform SETS informed by, reinforced with, and established through notions of credibility and expertise. Affirmations of expertise and perceptions of credibility enforce who may be a part of any specific system, in what ways, and

about what topics. This gatekeeping happens within individual scientific disciplines, multidisciplinary scientific contexts, and when intersections between science, other disciplines, and the lay public occur. In the first chapter, I provided explanations for typical scientific perspectives on credibility and expertise (Epstein, 1995; Epstein, 1996; Wynne, 1986; Wynne, 1992; Suryanarayanan & Kleinman, 2013; Gieryn, 1983; Knorr-Cetina, 1999; Oreskes & Conway, 2010) and Shapin's (1995) credibility economies, and I lay the groundwork for later discussion of ways in which lay communities transform perceptions of credibility and expertise (Ottinger, 2013; Weston, 2017; Kimura & Kinchy, 2019; Jalbert, 2016; Wylie, 2018; Harrell, 2020; Dickel et al., 2018; Wylie et al., 2014; Braun & Whatmore, 2010) while facing multiple threat contexts. Within the O'Keeffe case study, I discussed how O'Keeffe parlayed her own artistic credibility and expertise into access to information and respectful intellectual collaborations with scientists. The COVID Tracking Project (CTP) case study included multiple layers of negotiation and transformation of perceptions and knowledge systems of credibility and expertise, both internal and external to the organization. CTP's navigation of credibility economies crossed disciplinary borders as well as scientific and governmental institutional boundaries. Within the third case study, my examination of B2 focused on B2's ongoing negotiation to gain credibility in collaboration with - and later *as* - traditional scientific institutions. Within the B2 chapter, I also addressed evolving perceptions of B2's credibility and expertise held by broader public audiences.

Systems: CAS and SETS

B2, most amongst the three case studies, is a clear example of complex SETS. However, I undergirded my examination of all three cases with concerns regarding SETS, as well as sub-configurations such as sociotechnical systems, social-

ecological systems, and ecological-technical systems. Beyond identifying these intermingled configurations, this project is informed by ways in which complex adaptive systems are assessed and understood. This includes the prominent use of concepts such as resilience and robustness (Anderies et al., 2004; Anderies et al., 2013; Eakin and Luers, 2006; Turner et al., 2003; Meadows, 2008), adaptive capacity (Turner et al., 2003), and the impacts of transformed hierarchy and boundaries between nodes (Simon, 1962; Holland, 2014). My expansion from an STS sociotechnical lens to include SETS concerns both integrates notions of place and increases consideration of survivability of non- or more-than-human lifeforms into my case study analyses.

Futures Thinking, Anticipation and Uncertainty

Survivability is intrinsically about persisting from a present condition into a future state. Crises, disasters, and emergencies can be slow or fast, and never move in neat lines. Yet survivability is a temporalized concept that includes an implicit desired transformation.

As per Tsing (2015), "Disturbance opens the terrain for transformative encounters, making new landscape assemblages possible" (p.160). The threat contexts of each of my case studies stimulate responses that may demonstrate assemblages from which tactics towards increased long-term survivability may be learned. Through the creation of her garden, the accumulation of her library, and the construction of her nuclear fallout shelter, O'Keeffe established structural site markers that made her personal survival system more resilient to potential future damage. Via the primacy they placed on caretaking for their members, alongside their ethics of transparency around their data and work products – integrating rather than avoiding uncertainty, CTP supported the survival of both their members and

their insights in ways which may be built upon by other, future organizations. B2, as a multi-phase institution, evolved its own approaches to thinking more broadly about SETS future survival by iterating upon the lessons and challenges of each institutional instantiation. B2 was always about the future, but the most recent configuration's foci aim for increased collective survivability in comparison to the project inception's goals.

Within this project, futures thinking appears in both small and large ways. Choices made by case study protagonists transform their survival systems' designs. Protagonists' choices increase their relevant systems' survivability, as they also reflect protagonists' navigation of uncertainty and integrate their approaches to anticipation into their revised survival systems configurations. Each of these case studies, even those – such as CTP – which appear to be focused on primarily surviving the already very dangerous present, demonstrate ways in which the future may be understood as something which can be transformed, rather than just enacted or fulfilled. As per brown's (2019) approaches to complexity, knowledges and tactics to both survive the present and create better futures are things to be engaged with and iterated upon. There are no definitive, guaranteed successful future paths, brown argues, only expanded imaginations and ongoing improvements.

SUMMARY OF CASE STUDIES

Within each of my cases, I examined protagonists' collaborations within knowledge systems, their navigation of scientific disciplinary boundaries, their acknowledgement and transformation of notions of credibility and expertise, and how their engagements with these systems and concepts impact individual and collective survivability within their particular threat contexts. The three case studies exemplify a range of protagonists who are deeply entangled in SETS, knowledge systems,

multiple types of imaginations, and questions of uncertainty, risk, credibility and expertise. The cases span local, national, and international configurations, while they also respond to global concerns about nuclear annihilation, pandemics, and climate change. The protagonists of these case studies gain information and agency within their situations through different engagements with science and within different, but overlapping, U.S. social imaginations about the roles lay individuals and scientists play within larger national projects. Below, I provide brief summaries of the cases as well as the ways in which I addressed the central dissertation research questions for each.

The first case study, Georgia O'Keeffe's building of a nuclear fallout shelter at her home in New Mexico, is a previously undocumented historical study grounded in archival research. I approached O'Keeffe's construction as a doorway into the artist's autodidactic studies of science, her relationships and collaborations with science and scientists, and how those relationships may have informed her work, her worldview, and her decision to build defensive architecture. I employed O'Keeffe's story as a means of understanding how survival became a national project in mid-20th century America, forging new conceptions of survival that arise as risk becomes inextricably tied to emerging technologies, and how these may have played into O'Keeffe's perspectives on time, survival, and the future.

In addressing the dissertation's research questions, I primarily related Georgia O'Keeffe's building of a fallout shelter to the embodiment of artistic, scientific, and civic imaginations that inform her conceptions of agency and survivability in the face of sociotechnical uncertainty and multiple potential futures. Second, I asked what roles her credibility and expertise might have played in her conceptions of personal agency and survivability, particularly as they pertained to her collaborations with scientists. Third, this chapter investigated methods with

which O'Keeffe acquired information, skills, and agency through inter-personal collaborations. To address these overarching questions, I interrogated the following clarifying questions: What do artistic, scientific, and civic imaginations mean in her specific case? How could individual scientists have informed O'Keeffe's scientific imaginations? How might mid-20th century civil defense discourse have influenced her perception of her role within civic participation and survival? And, how may O'Keeffe's situated knowledges – her childhood on a farm, her art career, her residence in northern New Mexico – have influenced her conceptions of time, survivability, and the future?

The second case concentrates on the COVID Tracking Project (CTP) – a geographically-distributed, networked effort to gather and analyze pandemic data in the face of insufficient governmental sociotechnical response. Four co-founders – two journalists, a data scientist, and a content strategist – began CTP in March 2020 to acquire pandemic-related information that was not offered or easily accessed through U.S. state and federal agencies. Initially meant as a stop gap measure until federal and state data became more accessible, reliable, and comprehensible, the project evolved and expanded into a massive, mostly volunteer-powered civic technoscience initiative that persisted for the entire first year of the pandemic. Variably skilled team members taught themselves, each other, media outlets, governmental agencies, and wider publics how to comprehend evolving COVID-19 knowledge, parse multiple types of data, and utilize technological tools that they built and iterated upon to support their daily data collection efforts in the service of collective survival.

In addressing the dissertation's research questions, I interrogated what roles credibility and expertise played in how civic and scientific imaginations informed CTP members' conceptions of agency and survivability in the face of social-ecological-

technical uncertainty and multiple potential futures. Additionally, I asked what roles CTP enacted within public imaginations on these topics—including how the organization's expertise and credibility were represented and perceived. Second, I asked how both organizational and members' expertise and credibility were gained, challenged, transformed and demonstrated by both laypeople and scientists through collaboration with scientists and scientific institutions within urgent conditions. Third, I examined how CTP's members' expertise and credibility were entangled with how they individually and organizationally acquired information, skills, and agency within their situations through their inter-personal collaborations, use of technologies, and intersections with civic and/or institutional processes. In addition to these entangled variations of the central dissertation questions, I asked how a particularly striking and important aspect of internal CTP culture—the performance of care—intersected with notions of survivability both within the organization and in comprehending what we can learn from their work about survivability in the 21st century. By putting CTP's work into context both historically and in conversation with work accomplished by other organizations performing critical technical practices for civic engagement, I was also led to inquire as to whether or not CTP responded to governmental sociotechnical failure, or if it was instead responding to systems designed to fail many because the survivability of the system is focused on the persistence of some, not all.

The third case focuses on the historic, current, and future research of Biosphere 2 (B2), a 40-acre campus located outside of Oracle, Arizona. B2 contains a distillation of our global ecologies. The primary building houses a four-story rainforest, a savanna grassland, mangrove wetlands, a desert, and the largest controlled ocean environment in the world. Completed in the early 1990s, in what I refer to as phase 1, the biomes were intricately crafted, connected to sustaining

technologies, and equipped with monitoring systems. Biospherians and collaborating scientists have employed the environments for controlled experimentation ever since. A private group originally designed B2 for closed system "missions" to explore the feasibility of establishing sustainable habitats on other planets. After the mission era, Columbia University (phase 2) utilized the biomes to undertake research for over a decade. Currently, the University of Arizona (phase 3) maintains B2 as they perform complex adaptive Earth systems science research with local and global scientists at field scale using lab controls. From the moment they began the facilities' construction, the project founders and mission Biospherians have explored survivability and practiced potential futures. The ways in which the different generations of multidisciplinary scientists have done so – as well as the scientific, institutional, and global climate contexts within which they have understood their work – have both persisted and evolved in their uniqueness, concerns, methods, and comprehension.

I framed my research about B2 with variations on the same central questions. Different from the previous two case studies, B2 – as both site and institution – is a location both for and of collective imaginations, so its intersections with artistic, civic, technological, and scientific imaginaries throughout its history have informed both researcher and public conceptions of agency and survivability in the face of social-ecological-technical uncertainty in multiple ways. I investigated how these ways varied depending on B2's historical phase, changes in perception of the site by both scientists and general publics, and the means through which scientists and credible institutions perceived and leveraged – or not – the resources that B2's construction as an ecological-technical cyborgian system provides to scientists within evolving perceptions of institutional credibility.

Second, I addressed B2's involvement with expertise and credibility as it arose in two forms. In phase 1, the Biospherian era, the project creators intersected with multifaceted credibility economies tied to traditional scientific institutions. They gained expertise, and variable levels of credibility, through their intersections and acquisitions of information. However, the unusual backgrounds and intensely questioned motivations of the project founders has haunted the evolving B2 institution for decades after their involvement. How the more traditional institutional administrators, Columbia University (phase 2) and University of Arizona (phase 3), have navigated credibility and expertise relied on their uses of traditional notions of credibility establishment within scientific knowledge economies. Their negotiations affirm the usefulness of B2 as a research site in order to affirm the credibility of the rigorous research they have performed within the facility. Within this chapter, I analyzed how this navigation has included the acquisition of financial research support from notable funding bodies in both the U.S. and the European Union, extensive publications in highly regarded peer-reviewed scientific publications, and a necessary shift in both views on complex systems science research and how the facility is perceived by scientific researchers.

Third, the B2 case study is notably different than the others in questions of information, skills, and agency acquisition in that the phase 2 and 3 scientists have overwhelmingly been credentialed researchers trained through traditional forms. However, I interrogated how the uniqueness of B2-enabled collaborations – in the ways in which ecological-technical and SETS may be leveraged as well as unique forms of research design, coupling, and collaboration – provided new means by which B2 scientists and greater publics may comprehend our present, our potential futures and persistence more broadly, and how we might practice and gain agency in the face of social-ecological-technical uncertainty.

INCREASING COLLECTIVE SURVIVABILITY

I began this research by asking how artistic, civic, and scientific imaginations inform conceptions of agency and survivability in the face of social-ecological-technical uncertainty and multiple potential futures. I discovered that imaginations are essential for conceiving of and improving survivability, but imaginations are not the sole impact factor. In order to properly comprehend how we might increase collective survivability, I discovered three components which I feel are necessary to further study beyond this research project. The three components are collaborations, adaptive capacity, and care.

These three factors inform and influence how expertise and credibility are gained, challenged, transformed, and demonstrated by both lay people and scientists through collaborations with scientists and scientific institutions within urgent conditions. Through examination of them, in sometimes overlapping ways and amongst other factors, these components also help us understand how my case study protagonists acquire information, skills, and agency within their situations through their inter-personal collaborations, use of technologies, and intersections with civic and/or institutional processes. Also, examination of these factors highlights how the protagonists teach, learn from, evolve with and care for one another. It is through these three factors that I summarize what it is that I think can be learned about survivability as a result of this dissertation.

Collaborations

First, all three of my case studies support a hypothesis that interdisciplinary collaborations, including multiple stations within system hierarchies, increase individual and collective survivability. This can be seen in the O'Keeffe case study in the ways in which O'Keeffe gained knowledge and support through her individual

relationships with scientists towards persistence of both her paintings and her own well-being. This is most clearly represented within the CTP case study in the means through which a range of members' expertise and collaborative self-education enrichened the knowledge, skills, and outputs of both individuals and CTP's organizational systems.

In the B2 case study, collaboration configurations have changed between the three phases. Phase 1 was intensely interdisciplinary in its collaboration choices, both in regard to the Biospherian mission teams and the originators' engagements with outside experts and institutions. During phase 2, as the new administration attempted to rein in and increase perception of the place as a rigid scientific institution, B2 became a more disciplinary organization. Experiments were envisioned and enacted within more narrow disciplinary boundaries, as they nonetheless continued to address complex problems. Phase 3 again expands to include interdisciplinary teams, due to both administrative attitudes and a shift in scientists' own preferences for interdisciplinary research.

The phase 1 Biospherians would not have survived in their closed environment without having been able to together cover a wide range of work, and I believe that the phase 3 research is the most successful in leveraging its collaborations for the ways in which it allows for complex, coupled experimentation that operates at high rigor towards greatest success for all, in ways inclusive of multiple disciplines and hierarchical placements within academic knowledge systems. Within the phase 3 research, the scientific collaborations which attempt to solve iterative solutions of knotty SETS challenges are models for how we are going to gain increased SETS robustness—defining survivability purviews that include wider ranges of essential components.

Collaborations support complex systems notions that CAS are collectively worth more than their parts, as well as allow for opportunities to impact node hierarchies and boundaries in ways which positively impact system outputs. Collaborations increase knowledge resources and systems resilience. They allow for increased survivability both in the ways in which collaborations impact visions of what may be deemed essential and how to protect systems components—whether people, ecologies, and/or associated technologies.

Adaptive Capacity

Second, adaptive capacity increases survivability because it encourages system evolution towards increased robustness and resilience. Because of adaptive capacity, individuals and systems may grow and learn to weather disturbance more successfully in the form of protecting more system components and deeming less people and/or parts as allowable for sacrifice.

Adaptive capacity itself may be increased and integrated into systems in multiple ways. First, collaborations increase adaptive capacity by providing systems with a wider range of expertise and skillsets upon which to draw upon for problem-solving and system evolution. In the last subsection, I addressed how collaboration directly increases survivability, but collaborative relationships also provide organizations with an intellectual and tactical nimbleness that allows for change. Second, iterative responses, as performed by both individuals and systems, allow for an agility to respond to changing conditions. Third, prioritizing iteration within responsiveness also acknowledges a level of uncertainty that I understand as constructive towards increasing collective survivability. Direct acknowledgement and allowance for a transparency of limited information in individual and system communications enable heartier responses to uncertainty. When acknowledged

rather than avoided, uncertainty becomes a factor of the situation rather than something to be feared or overcome, and thus the ability to navigate uncertainty becomes just another part of how the system operates rather than something that stymies the system's functioning.

These insights can be seen within each of my case studies. First, I think that O'Keeffe demonstrated adaptive capacity in her situation through her autodidactism and collaborations. Her own multidisciplinarity alongside her access and activation of scientific collaborators provided her with information about her place within regional and national nuclear threat conditions in ways that informed her responses towards increasing her home and studio as a site for increased survivability. Second, CTP built adaptive capacity into how they ran as an organization, as well as the means through which they communicated their data. They did this through their iterations of methods and communications as well as their transparency about uncertainty. By continuing to learn, grow, and improve within their organizational activities, internal and external communications, they continued to strengthen themselves as both individuals and systems. By emphasizing transparency about uncertainty at all levels of their activities, they positioned uncertainty as something to be navigated rather than overcome. CTP's organizational leadership and support of multi-level operations increased their organization's own survivability design robustness. As they simultaneously participated within larger systems of survivability, the inclusion of both iteration and uncertainty within their methods strengthened both CTP and the systems of which they were a part. And third, B2 exemplifies a slightly different situation because the B2 case study concerns three distinct, if also overlapping, institutional organizations located at the same site over the course of 30 years. However, an examination of B2 as a single, evolved entity allows for an identification of the presence of adaptive capacity both within individual components of each phase

as well as in an exploration of the institution as a whole. I envision B2's three-decades-long shift in survivability focus as itself an indication of B2's adaptive capacity. Through iterations of concerns, the institution now prioritizes the broadest sense of valued SETS components through the articulation of that which it aims to protect.

Care, Structures and Cultures of Support

Third, though the concept appears within the three case studies in slightly different forms, my research supports the idea that centralizing care as structures and cultures of support within system design increases individual and collective survivability. This is most apparent in the CTP case study, where I spend considerable time describing how the mutual aid-inspired design of the organization centralized the well-being of the members as much as it did the rigor of the data. However, particularly using what I learned from CTP as a lens, I see this playing out in the other case studies as well.

In the O'Keeffe case study, I consider the notion of care to be less about the fallout shelter itself and more about the ways in which O'Keeffe's Abiquiú home and studio may be perceived as a site for survivability, within which the fallout shelter is one entry point to understand her relationships to science, systems, and persistence. I see her autodidactism, her insatiable curiosity, as one form of care for herself and the home system she maintained. Her relationships to her garden both provided sustenance and activated the garden's role as an ecological part of her SETS. Both her gardening and her art conservation work focused on future practice through meticulous maintenance set in the present. Whereas a fallout shelter may be constructed to sit on standby for later emergency, both the garden and her approach to her artwork required ongoing, time-spanning attention.

In terms of B2, I perceive care through the lens of what is deemed essential within each phase's notions of survivability. In phase 1, humans were primary with ecological systems being cared for but envisioned primarily in the service of human survival. In phase 2, ecologies were experimented upon towards information useful for larger global persistence. But within the phase 2 B2 system itself, humans were not a factor – they were abstractly represented through potential impacts such as increased climate change-related chemistry – and ecologies are disposable. However, phase 3 appears to me to prioritize the broadest notion of protection. Experimentation continues to occur upon ecologies, but it is now done through the valence of assisted evolution with the intent being towards survival of ecological elements within particularly challenging conditions. In this way, the well-being of the non-human life is valuable on its own, as the ecologies are also part of human experimentation towards increased resilience for not only the ecological systems but also SETS as complex configurations.

My comprehension of B2 forms of care and my perspective on O'Keeffe's approach to survivability were significantly informed by an insight I acquired while working on the CTP case study. As I have mentioned throughout this dissertation, CTP did not respond to governmental sociotechnical failure. CTP responded to governmental sociotechnical system design. This is a fact that I did not sufficiently understand when I embarked upon this project. However, the survivability design of the U.S. public health systems, as noted by scholars such as Roberts (2011) and Gonsalves (2021), is informed by national histories of slavery and eugenics. These systems were constructed to protect some, not all. CTP, through their efforts, nonetheless attempted to increase collective survivability despite U.S. public health systems' narrow survivability purviews. Survivability purview is a term that I use to describe who is deemed essential to systems persistence and worthy of protections.

It was while working on the CTP case that my comprehension of O'Keeffe's context gained additional nuance. U.S. governmental nuclear weapons-related civil defense, as demonstrated by budgets and policies, also prioritized protections for subsets of the U.S. populace. O'Keeffe's shoring up of her own survivability systems were in concert with, rather than a correction to, nuclear citizenship responsibilities. I understood this context when I began the O'Keeffe research. However, as a result of working on the CTP research, I identified that O'Keeffe determined her individual survivability purview regardless of, if not in response to, not being included within the survivability purviews of the U.S. governmental civil defense systems.

B2 could also be viewed as another supplement rather than an overcorrection to the survivability purview of U.S. governmental policy, in this case regarding the ongoing climate catastrophe. However, B2 itself additionally provides a useful, evocative microcosm of shifting survival imaginaries of who or what is deemed worthy of inclusion within survivability purviews. Whereas O'Keeffe and CTP may be viewed as reactions, and CTP may have positively impacted governmental systems design, the B2 case study also provides evidence of the possibility of tangible, actionable institutional systems change. Over the course of the three historic phases, B2's survivability purview has expanded towards greater collective care of humans, ecological lives, and sociotechnical infrastructures.

Notably, on the other sides of the boundaries drawn upon all these survivability purview maps lie notions of allowable sacrifices built into the survivability design of all SETS. For everything included, and the overlapping zones where individuals and communities assert their own purview expansions, there remain exclusions—and these exclusions are determined and enforced by both systems and individuals. In his work on liberal democracies and biopolitics, Rose (2001) writes, "we are faced with the inescapable task of deliberating about the

worth of different human lives – with controversies over such decisions, with conflicts over who should make such decisions and who cannot, and hence with a novel kind of politics of life itself" (p. 22).

As a result of this research, I consider practices of care to be actions that take on a politics of widespread value and resist the acceptability of allowable sacrifice. Increasing survivability purviews protects more individuals, communities, and forms of life, as doing so also demands expanded SETS resilience and robustness towards greater collective survivability.

Concentrating on survivability purviews requires a broader focus on SETS and survivability resilience and robustness. Aiming particularly for increased robustness, which requires specification and operationalization of resilience concepts, expands individual and organizational agency. Agency is an ability to act within, beyond, or to transform a situation. Agency is a tipping point between what we know about the past, what we understand in the present, and what we imagine or at least may remain nimble to respond to in the future.

The notion of multiple futures is as important as the multiple threat context piece of this research's overall conceptual frame. Without being able to imagine better – or at least different – futures, possible futures are reduced to potentially unsatisfactory probable futures. Futures envisioned without agency are futures waiting to be filled in, rather than those sketched on layers of tracing paper that can be shuffled, referenced, tried out, and revised towards greater increased survivability success.

PRACTICING THE FUTURE, CONSTRUCTING SURVIVAL

Regardless of their positioning on a timeline, I have considered all three case studies to be instances where individuals and groups practice the future. In

particular, I have increasingly understood each of the case study protagonist's means of practice as constructive interventions. Their individual and collective research, efforts, and engagements acknowledge their specific threat contexts, increase information about potential mitigation or resilience strategies, and work towards applied solutions that increase survivability. The case protagonists act through tangible means—O'Keeffe built a fallout shelter as she shored up other aspects of her home and studio, the co-founders of CTP created a rapid-response data organization, and B2 scientists have performed complex Earth science system experiments to investigate and increase resilience towards more robust SETS survivability. Through various means, in different configurations within and in conversation with SETS, and while facing different threat contexts, those involved in all three cases have constructed survival—for themselves and for others. They have acted today in ways aimed to achieve greater survivability for tomorrow.

Notions of the future are positioned differently within each of the three case studies. O'Keeffe's construction of the fallout shelter appears almost entirely future-focused, but – as outlined – her actions were very much a response to contemporary concerns. As mentioned earlier in this chapter, her relationships to her garden and art preservation also portray more fluid timelines of engagement that betray a singular binary now-then future imaginary displayed by the shelter alone. CTP appears the most in-the-moment of all the case studies. Yet, all their efforts both modeled and set others up to begin future responses on more solid ground. B2 has always been about the future, and the research throughout the phases has also always taught us enormous amounts about the present.

When viewed through a survivability lens, all three of the case studies may be seen as ways in which individuals and communities assessed, engaged with, and at times redesigned the SETS within which they were embedded. O'Keeffe understood

that she needed to look out for her own safety interests when it came to both fragile food supply chains and the impacts of potential nuclear war. CTP taught themselves the intricacies of U.S. public health epidemiological data systems as they simultaneously assessed and communicated their findings about those systems. They designed their own sociotechnical systems, through the technical and personal machinations of their organization's SETS, to interact with the strengths and supplement the weaknesses in the U.S. systems in ways which transformed the usefulness of the governmental systems for the length of CTP's engagement. Within the B2 case study, the physical ecological-technical systems of the facility have been the least transformed over time. Instead, it is the social entanglements of B2 SETS – concretely as scientists and administrators and conceptually as institutional priorities, notions of scientific value, and contextual imaginations – which have repeatedly instigated assessments and redesigns of B2's SETS towards greater institutional and facility usefulness within global survival concerns.

All these case studies include elements that we may also metaphorically understand as "look-ahead" routines – tests of potential conditions – of the complex adaptive systems within which they reside (Holland, 2014; Kroer & Sandholm, 2020). The case protagonists practice the future through the ways in which they respond to social-ecological-technical uncertainty within the present, and by studying their systems' designs, components, operation, and notions of survivability, we may impact our futures as well.

It is notable that none of the future imaginations within which the case studies engage are fixed. All the responses are ones that address uncertainty rather than unassailable protections. Their actions were informed by quests for increased agency in the face of danger, lead to increased protections, and ideally make things

better, but their pursuits included no survival guarantees. These case studies are not about futureproofing their safety within their situations.

Futureproofing is a word I have encountered repeatedly within my design career because I have often worked on long-term projects that have been expected to open at the end of multi-year timeframes and then remain culturally and technologically operable and relevant for anywhere from a few years to a few decades after launch. Futureproofing is the shorthand term for how we, as design professionals, would hypothesize our best solutions – based on deep knowledge wells of past experiences – to assure the client of a product with as long-term a success as possible.

In her Essay "Calculated Risks," in the catalogue for the 2017 exhibit "Futureproof," artist and journalist Ingrid Burrington describes futureproofing as:

> creating something in such a way as to minimize or slow down its technological obsolescence. Techniques for futureproofing vary, from designing buildings that are sturdy enough to withstand nuclear fallout to creating open technical protocols that can adapt in order to accommodate new technologies. In the realm of the corporate scenario researcher and Gaynor's risk analysts, the future may not always be predictable but it can certainly be contained, plotted, modeled, and conquered. The scenario planner futureproofs by writing proofs—rhetorically breaking down the constituent parts of the future with a performative mathematical precision, turning conjecture into irrevocable truth (p.8).

My view of futureproofing is less cynical than Burrington's. However, I find her distrust of professional futures practices to be a useful signpost against which to measure my more hopeful viewpoint. We may be collectively thoughtful about our future-facing choices, even as we acknowledge and embrace our inability to truly predict or perform the future as something to be prescribed. As a consultant, even if not a scenario planner, my futureproofing communications with clients always aimed to encourage and position the team to collectively think in expansive timeframes

within sociotechnical economies that supported short-term solutions for longer-term concerns.

Constructing survival, in the sense of engendering systems and societies towards greater survivability, requires interdisciplinary, resilient, iterative, and evolving collaborative imaginations and imaginaries to both envision and enact futures which protect more, rather than just some. Constructing survival also requires a modicum of cautious hope because energy, imagination, and efforts need to be invested towards critical, essential SETS improvements. In an effort towards both analyzing and harnessing situated imaginations towards greater survivability, this project provides a matrix of concerns, considerations, and potential solutions with which expanded notions of survivability may be envisioned in the face of social-ecological-technical uncertainty.

To me, this dissertation is only the beginning. Just as these case studies are my ways of opening doors for the reader, to attempt to evoke new and different imaginations about how we may think about systems, survivability, and our places within them, they are thresholds – or maybe entry rooms – for me as well. I intend to expand upon the research within this dissertation, through both transformation of the individual case studies into extended projects as well as conceiving of means through which to additionally put the case studies in conversation in ways that evoke constructive conversations with a broad range of audiences.

In her novel *Parable of the Sower* (1993/2012), Octavia Butler's protagonist Lauren Oya Olamina attempts to convince her closest friend that they should acquire more potentially useful skills. They live in a time of immense danger and uncertainty, one that currently reads as a description of a world only steps from our own. Olamina's friend exhibits reticence to borrow Olamina's father's book on plants;

the friend is suspicious of both the book's utility and the world this knowledge may portend. Olamina pleads with her to be more open to the exploration, as she replies, "We learn to survive" (p.59).

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