

# From Disruption to Resilience: Adaptive Strategies in Big Science Organizations During a Global Pandemic

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Kerk F. Kee<sup>1</sup> , Mahedi Hasan<sup>1</sup>,  
Oluwabusayo Okunloye<sup>1</sup>, Cassandra Hayes<sup>2</sup>, and  
Ewa Deelman<sup>3</sup>

## Abstract

This qualitative study grounded in phronetic iterative analysis examines how big science organizations adapted to the COVID-19 pandemic while sustaining their scientific missions. Using the communication theory of resilience (CTR) as a guiding framework, infused with the literature on high-reliability organizations (HRO), the analysis draws from 56 semi-structured interviews across three phases (2020–2023) to identify 10 adaptive strategies linked to four of CTR's five core processes. The fifth—affirming identity anchors—did not surface as an explicit strategy but operated implicitly, suggesting that when organizational identity aligns with crisis demands, explicit identity work may be unnecessary. Flexibility emerged as a central meta-process that shaped

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<sup>1</sup>College of Media and Communication, Texas Tech University, Lubbock, TX, USA

<sup>2</sup>Bob Schieffer College of Communication, Texas Christian University, Fort Worth, TX, USA

<sup>3</sup>Information Sciences Institute, University of Southern California, Marina del Rey, CA, USA

## Corresponding Author:

Kerk F. Kee, College of Media and Communication, Texas Tech University, 2500 Broadway, Lubbock, TX 79409, USA.

Email: [kerk.kee@ttu.edu](mailto:kerk.kee@ttu.edu)

how strategies were implemented in context. Key strategies included adjusting work expectations, focusing on outcomes over time/place, and leveraging peer networks. This study contributes to CTR and HRO scholarship by emphasizing the contextual, communicative, and identity-sensitive nature of adaptive resilience during systemic disruption.

### **Keywords**

resilience, pandemic, research infrastructures, big science organizations, high-reliability organizations, adaptive strategies

The COVID-19 pandemic introduced an unprecedented global crisis that reshaped operational landscapes across sectors, impacting organizations' functioning in fundamental ways. On March 11, 2020, the World Health Organization formally declared COVID-19 a global pandemic, leading all 50 U.S. states and the District of Columbia to declare states of emergency. Early responses included sweeping stay-at-home orders, with California leading on March 19, 2020, as organizations scrambled to adjust to the changing conditions. These drastic shifts triggered widespread disruptions that persisted for months and years, necessitating a reexamination of organizational structures, policies, and strategies.

The pandemic's scale and unpredictability intensified interest in organizational resilience as institutions grappled with challenges to continuity, operational stability, and workforce adaptability (Lee & Kim, 2022; Sahay & Dwyer, 2021; Stephens et al., 2020; Vomacka & Buzzanell, 2024). Even organizations accustomed to functioning reliably in hazardous environments, such as the healthcare industry, had to struggle with pressures such as rapid development and mobilization of a new vaccine for the virus (Houtsma et al., 2023). Due to the pandemic's widespread disruption, the contextual factors unique to specific organizations and individuals became visible. These factors shaped their ability to adapt and remain resilient during crises, with implications that echoed long after the pandemic's initial impact.

For many organizations, the COVID-19 pandemic reemphasized the long-standing idea that organizing may be a process of continual crisis and adaptation. Perrow (1984) first brought up the "normal accidents" of organizational functioning, especially for certain high-risk organizations. Following the pandemic, scholars and organizational leaders noted the need to adopt policies and procedures to remain resilient in the face of inevitable disruptions (Kirwan, 2021). Organizational resilience, defined as the capacity to withstand, adapt, and/or recover from significant disruptions (Buzzanell, 2010),

has gained prominence in recent research as scholars seek to understand how institutions navigate complex crises. However, little work has examined how organizations dedicated to scientific missions, with members who have unique identities such as scientists, impact resilience.

This study adopts the communication theory of resilience (CTR; Buzzanell, 2010) as a framework to explore the adaptation strategies employed by science organizations in response to the pandemic. CTR emphasizes communicative practices as central to resilience-building (Buzzanell, 2010). By examining science organizations through the lens of CTR, this study seeks to understand how these organizations cultivated resilience and adapted to COVID-19's disruptive impact while striving to maintain their operations. We adopted a qualitative, phronetic iterative approach (Tracy, 2024) characterized by context-sensitive theorizing and ongoing dialogue between data and theory.

## **Resilience and Adaptation in Big Science Organizations**

We define science organizations as groups or institutions that are primarily dedicated to advancing scientific research and knowledge and supporting scientists and the scientific enterprise in a particular field (e.g., astrophysics, oceanography), and secondarily engaging in educational programs, public outreach, and policy advocacy (Varner, 2014). Science organizations have additional challenges to remain reliable and resilient despite often seeking out dangerous or unknown environments to carry out their work. While we refer to science organizations as a broad category, we recognize significant variation in their structure, size, research focus, and stakeholder arrangements.

### *Research Infrastructures as Big Science Organizations*

Our research aimed at exploring how professionals (i.e., project administrators, senior scientists) within a specific type of science organization funded by the U.S. National Science Foundation (NSF)—“research infrastructures” (RIs)—adapted their work during the pandemic. Broadly speaking, RIs include two forms of science organizations generally known as major facilities (MFs) and mid-scale research infrastructures (MSRIs). MFs are science facilities with large-scale instruments funded at \$100 million or more each. There are about 30 such facilities, such as the U.S. Academic Research Fleet, the Green Bank Observatory, the National Center for Atmospheric Research (see a complete list at <https://new.nsf.gov/focus-areas/infrastructure>). They are essential for addressing complex and transformative scientific questions.

Complementing the MFs, MSRIs fill a critical funding gap for research infrastructure projects costing between \$4 million and \$100 million each, enabling high-impact, cost-effective investigations. There are about 36 such facilities, such as the National Extreme Ultrafast Science Facility, SAGE: A Software-Defined Sensor Network, and Next Generation Radar Designs (see <https://new.nsf.gov/bfa/rio/midscale-research-infrastructure-list>). RIs (including both MFs and MSRIs) exemplify the concept of “big science,” which is characterized by significant financial investments, interdisciplinary collaborations, and the ability to tackle grand scientific challenges, guided by strong science missions.

We focus on science organizations for several reasons. First, RIs offer a valuable context for advancing communication research on resilience. These science organizations are structurally complex, with multiple stakeholders, and require distributed coordination. Studying RIs allows us to extend CTR from centralized organizations into multi-stakeholder environments (involving NSF, host universities, national labs, researcher communities, scientific regulatory bodies, international, federal, and local governments).

Second, the COVID-19 pandemic posed unique challenges to science organizations because the crisis was rooted in science. RIs had to interpret evolving public health guidance while sustaining their own scientific missions. This created tensions between protecting personnel and maintaining scientific productivity, offering a distinctive lens on how science-based institutions navigate crisis when their core values are directly implicated.

Third, RIs play a vital role in producing public knowledge. Their resilience is both operational and epistemic, affecting not only internal functioning but also long-term societal impacts. Studying resilience in RIs helps leaders support staff, protect scientific continuity, and prepare for future disruptions—answering recent calls to examine the human dimensions of risk-based scientific work. Scholars such as Ford et al. (2025, p. 3) have advocated for an increased interest in organizing practices that span organizational boundaries and “the human aspects of risk-based work” within research on resilience, especially regarding high-reliability organizations such as the big science organizations in this study.

### *Research Infrastructures as High-Reliability Organizations*

RIs fulfill fundamental work within complex conditions. For example, oceanographic research vessels under the U.S. Academic Research Fleet often operate in dangerous and remote locations where they face significant environmental and weather-related hazards such as high seas, severe storms, extreme cold, and shifting ice conditions. Another example is the Green Bank

Observatory, which involves risks of electromagnetic exposure, particularly during the operation or testing of auxiliary radio transmitters with harmful levels of radiofrequency radiation. More importantly, many RIs presented hazardous situations where employees were required to work onsite despite the risks of COVID-19 infection during the pandemic. Therefore, the RIs examined in this article can be categorized as high-reliability organizations (HROs).

HROs operate within situations in which complexity and risk are the norms. Following the 1979 partial nuclear meltdown that occurred at the Three Mile Island Nuclear Generating Station near Harrisburg, Pennsylvania, sociologist Charles Perrow (1984) theorized that some accidents are inevitable and normal within complex systems. HRO literature arose to refute Perrow's claims, providing analysis of organizations that manage to remain functioning and safe despite hazardous circumstances (Cantu et al., 2020). Christianson et al. (2011) provided the examples of aircraft carriers, electrical grid operators, nuclear power plants, air traffic control systems, and commercial aviation as other HROs, "organizations in which accidents rarely occur despite the error-prone nature of the work" (p. 2). Finding that resilience looks different within different organizations, Ishak and Williams (2018) mentioned emergency medical units and firefighting crews as examples of HROs, as they operate by necessity in crisis situations. HROs manage to remain resilient even when actively seeking out crisis situations in which they must function.

HROs differ widely in their enactment of resilience, and in how they continue to function in highly hazardous environments. Despite organizational differences, Weick and Sutcliffe (2001) outlined five hallmarks of HROs: (a) preoccupation with failure, (b) reluctance to simplify interpretations, (c) sensitivity to operations among environments rife with problems and disorder, (d) a commitment to remain functioning and adapting following setbacks, and (e) deference to expertise. Chewing et al. (2024) expanded theories on HROs to include high *resilience* organizing and organizations, concepts that include a wider range of organizational contexts and outcomes beyond reliability. This expansion explains how "reliability seeking" science organizations such as the National Aeronautics and Space Administration (NASA) conform to some, but not all, hallmarks of HRO at times (Boin & Schulman, 2008).

Science organizations, such as the RIs we focused on within this study, touch on the hallmarks of HROs, especially due to their seeking out solutions to problems never solved before, expertise and depth of knowledge, diversity in geographical location and often hazardous environments, and dedication to their scientific missions. These organizations especially exemplify that resilience is highly dependent upon communication and context, such as how

organizational members define reliability (Busby & Iszatt-White, 2014) and the implementation of technologies during crises (Chewning et al., 2013). While work has examined science organizations as HROs before, especially in healthcare and medicine (Christianson et al., 2011; Sculli et al., 2022), the unique professional identity and communicative relationships of scientists within science organizations dedicated to research remain understudied (Schäfer & Fähnrich, 2020). To focus on this angle of science organizations, we apply the CTR.

### *Communication Theory of Resilience and Science Organizations*

The communication theory of resilience (CTR; Buzzanell, 2010) provides a generative framework for understanding how individuals and collectives adapt to disruption through communicative practices. Rather than treating resilience as an individual trait or organizational outcome, CTR conceptualizes it as a dynamic, interactional process by which people “talk, resist, and imagine new normalcies into being” (Buzzanell, 2010, p. 1). This theory has been widely applied to contexts such as health communication (Houston & Buzzanell, 2020; Lillie et al., 2018), education (Wilson & Scacco, 2023), employment loss (Kuang et al., 2023), and disaster recovery (Doerfel et al., 2008), offering insight into how resilience is constructed across personal, organizational, and societal levels.

CTR identifies five interrelated communicative processes that contribute to resilience: crafting normalcy, affirming identity anchors, maintaining and using communication networks, putting alternative logics to work, and downplaying negative feelings while foregrounding positive emotions. These processes are not sequential or prescriptive; instead, they reflect patterned responses to disruption that are shaped by relationships and meaning-making efforts (Buzzanell, 2010, 2019).

Together, these processes show how people maintain stability during times of change. For instance, crafting normalcy involves restoring or reimagining routines to signal stability (Chernichky-Karcher et al., 2019), while affirming identity anchors centers communication around core values or roles that provide cohesion in times of uncertainty (Villagran et al., 2013; Wilson & Scacco, 2023). In some studies, identity anchors are examined primarily at the level of individual roles and narratives (e.g., how people draw on identities as parents, workers, or caregivers to make sense of disruption), whereas other work highlights more collective or organizational anchors, such as shared values, mission commitments, or professional identities that are invoked to sustain cohesion. Dutta’s (2019) analysis of women in STEM careers, for example, illustrates how identity and narrative processes support resilience

within gendered institutional structures, pointing to the ways both individual and institutional logics shape identity anchoring. This distinction between individual and organizational identity anchors is important for our study, as our findings suggest that explicit organizational identity work did not surface, even as individual identity work was evident in participants' accounts.

Maintaining and using communication networks emphasizes the importance of both strong and weak ties for resource mobilization and emotional support (Barbour et al., 2020; Doerfel et al., 2008), whereas putting alternative logics to work entails reframing disruption in empowering ways—through humor, hope, or redefined goals (Barney et al., 2024; Lillie et al., 2018). Finally, foregrounding positive emotions while downplaying negative ones reflects a forward-looking posture that enables action without denial (Anderson & Jones-Bodie, 2022).

CTR has provided valuable insights into various disruptions, including job loss, grief, and public health crises. We also found Dutta's (2019) work on women in STEM careers in Singapore, which highlights how identity and narrative processes support resilience in gendered institutional structures. However, broader application to big science organizations has been limited. These organizations involve complex infrastructures, strong science mission commitments, and coordination across multiple institutions and stakeholders. This gap presents an opportunity to extend CTR into contexts where resilience is shaped not only by interpersonal relationships but also by the structural and professional logics of science.

Traditional resilience models, primarily focused on individual-level or family-level dynamics and/or developed for hierarchical organizations with centralized decision making, fall short in capturing the resilience dynamics within science organizations. RIs present unique resilience challenges due to their multi-stakeholder governance structure and their science mission-driven, rather than profit-driven, objectives. Unlike most organizations that strive for structure, routine, and certainty, RIs inherently operate in dynamic situations as part of their core scientific work (Vaughan, 1999). In other words, RIs must constantly engage in adaptations, especially during the pandemic, making them a unique site for studying resilience.

### *Adaptive Strategies as Key to Organizational Resilience*

By adaptive strategies, we mean the purposeful behavioral or communicative adjustments that help individuals or organizations sustain operations during periods of disruption (Denhardt & Denhardt, 2010; Somers, 2009). We define adaptive strategies as intentional, patterned responses that enable RIs to sustain operations, reconfigure practices, and preserve their mission during

systemic disruption. These strategies are shaped by internal capacity, external constraints, and professional norms. Rather than ad hoc reactions, they reflect deliberate organizational adaptation and communicative problem-solving.

Our use of the term “adaptive strategies” is informed by scholarship on both resilience and adaptive leadership. Adaptive leadership, as articulated by Heifetz et al. (2009), emphasizes mobilizing collective capacity, tolerating ambiguity, and iteratively responding to emerging challenges. These principles were reflected in many of the strategies enacted by RIs during the pandemic. These actions were not merely reactive; they represented deliberate organizational adaptations to complex, evolving conditions. Additionally, our framing draws on the concept of adaptive capacity (Walker et al., 2002), which highlights an institution’s ability to adjust behavior, restructure operations, and generate systemic flexibility under stress. By integrating these perspectives with CTR, we understand these strategies as situated actions through which resilience is collaboratively enacted.

Given the literature reviewed, we analyze CTR’s five processes to understand resilience dynamics throughout the pandemic’s phases. Specifically, we asked the research question: “How did big science organizations pivot and adapt in response to the COVID-19 pandemic to cultivate organizational resilience while sustaining their science missions?”

## **Methods**

This study is grounded in interpretivist epistemology, which understands knowledge as contextually situated and socially constructed through communicative practices (Tracy, 2024). Rather than seeking objective, generalizable truths, we aimed to develop credible, trustworthy, and resonant interpretations (Tracy, 2010) of how RI professionals made sense of and responded to pandemic disruptions within their specific organizational contexts. Consistent with our interpretivist epistemology and phronetic iterative approach (Tracy, 2012, 2024), we designed this study with three key features: our multi-phase structure (capturing evolving strategies as the pandemic unfolded), our iterative coding process (moving between data and theory throughout analysis), and our member-checking phase (enabling collaborative refinement of interpretations with participants).

## **Recruitment**

Our study focused on capturing the lived experiences of RI professionals during the pandemic across three phases of data collection between December 2020 and August 2023. During the pandemic’s early chaos, it was uncertain

who would respond to recruitment efforts, which led us to use a three-pronged approach to maximize insights across a wide range of RIs (i.e., 30 MFs and 36 MSRIs based on NSF). First, we used purposive sampling (Baxter & Babbie, 2003), targeting participants based on their roles within RI organizations. Many of these participants have publicly available online profiles on RIs' homepages.

Our case selection was guided by the following criteria: targeted participants work at a science organization with (1) formal recognition as an RI by the NSF; (2) dependence on physical or technical infrastructure that was affected by COVID-19; (3) operational activity during the disruption period; and (4) feasibility of organizational access for interviews by our research team. We sought conceptual variation in size, disciplinary scope, geographic distribution, and governance complexity whenever possible.

Second, we drew on a known pool of RI professionals based on our last author's existing contacts, leveraging her personal relationships for recruitment. We initially came to this research topic due to one of our research team members' relationships with RIs. However, we quickly recognized the theoretical opportunity to conduct a study on adaptive strategies as situated actions through which resilience is collaboratively enacted. Third, based on the participants from our first two approaches, we used snowball recruitment augmented by the maximum variation method (Baxter & Babbie, 2003), asking participants to recommend colleagues from different demographic and/or professional backgrounds. These recruitment pathways required reflexive attention to how our positions within RI networks shaped the study. Existing relationships likely facilitated access and rapport in prestigious scientific environments, but they may also have influenced what participants chose to emphasize or withhold. To address this, we emphasized confidentiality and voluntary participation, and triangulated perspectives across roles and sites. We also used team discussions and member reflections to surface and question our assumptions about participants' accounts. In line with interpretivist commitments to positionality, we understand our embeddedness in RI communities as both a strength for insight and a source of ongoing interpretive responsibility.

### *Interview Phases*

A total of 56 interviews were conducted with 41 participants, with 15 individuals participating in two of the three phases described below. This overlapping structure allowed us to conduct reflections with returning participants, while also incorporating new perspectives to expand and enrich our understanding of adaptive strategies. Approximately 32 of the 56 participants

(about 57%) were project personnel (e.g., engineers, system architects), while 24 participants (about 43%) held top-level management roles (e.g., directors, principal investigators).

All authors were involved in the interview process across different phases of the study. While not every author conducted interviews in every phase, each participated in at least one phase through leading an interview and/or supporting notetaking and asking follow-up questions as a co-interviewer. This collaborative model allowed us to ensure consistency in approach while integrating a range of perspectives throughout data collection. Interviews were conducted via Zoom and followed an open-ended, semi-structured protocol. Informed consent was obtained for each participant, and IRB approval guided the study's ethical compliance.

- Phase 1 (December 2020–May 2021): We conducted 13 interviews focused on the immediate disruptions caused by the pandemic and initial adaptation strategies. Participants included 11 from MFs and two from MSRIs; seven were project personnel and six held management roles. There were nine men and four women, representing Massachusetts (4), Oregon (2), and one each from Alaska, North Dakota, Wisconsin, Colorado, Hawaii, Washington, and Virginia.
- Phase 2 (April 2022–June 2023): We conducted 17 interviews, with new questions focused on the post-pandemic landscape, asking participants to assess how their organizations' strategies evolved and which adaptations became long-term (Kuang et al., 2023). This sample included 13 participants from MFs, one from an MSRI, and three from related organizations (e.g., science consortia, affiliated research centers). There were 10 project personnel and seven held management roles, including 13 men and four women who came from Oregon (3), Florida (3), California (3), Massachusetts (2), Washington (2), and one each from New Jersey, Missouri, Michigan, and Virginia. Theoretical saturation was determined after the 30th interview, in line with Tracy et al. (2024), as no new thematic insights emerged despite continued data collection. In other words, saturation was reached when additional data no longer produced new conceptual insights or meaningfully altered existing themes.
- Phase 3 (July–August 2023): We conducted 26 member-check interviews with a mix of returning (15) and new participants (11). Among the 15 returning participants, six were from Phase 1, and nine were from Phase 2. Of the 26 total participants, 19 were from MFs, two from MSRIs, and five from related organizations. This phase included 15 project personnel and 11 top-level managers; 20 men, five women, and one nonbinary individual. Participants represented Massachusetts (4), California (3),

Washington (3), Oregon (3), Florida (2), Michigan (2), and one each from Illinois, Rhode Island, Virginia, North Carolina, New York, Alaska, Wisconsin, Hawaii, and Missouri.

Phase 3 member-checking interviews were conducted to refine (Birt et al., 2016; Tracy, 2010) the 10 strategies we had identified in Phases 1 and 2. Following Tracy's (2010) conceptualization of member-checking as "member reflections," we treated this phase as collaborative interpretation. We shared our preliminary findings with participants and invited them to assess whether these strategies resonated with their experiences, to elaborate on contextual nuances we might have missed, and to reflect on which strategies appeared most meaningful in their specific organizational contexts.

This two-pronged process allowed for participants' critiques, corrections, and verifications of the thematic structure to increase "qualitative credibility," following the spirit of Tracy's (2010, p. 844) "big-tent" criteria. Moreover, this approach reflects an effort to bridge communication scholarship with practitioner communities, as we use member-checking to share our qualitative findings with our participants with the hope of improving their adaptive organizing. We did this to counter the criticism of "extractive research" (Gaudry, 2011), the practice of taking data from communities without giving back meaningful insights or interventions.

Across all phases, participants ranged from advanced-early to late-career professionals, with online professional biographies indicating bachelor's degree attainment between 1977 and 2009, and many hold graduate degrees. While we did not systematically collect age or ethnicity data because we wanted to minimize potential adverse reactions that could lead to difficulty in recruitment and interviewing efforts during the stressful pandemic, the sample reflected diverse institutional roles across multiple geographic regions. Interviews ranged from 27 to 90 minutes in length (average  $\approx$ 55 minutes), resulting in 50 hours, 25 minutes, and 46 seconds of recorded data.

## Analysis

Data were transcribed using Otter.ai and verified by the second and third authors. As mentioned before, our analytical process followed Tracy's (2012, 2024) phronetic iterative approach. Coding and interpretation occurred concurrently with data collection and were shaped by ongoing comparison and reflection throughout the three interview phases.

In Phase 1, we conducted open, manual coding of transcripts, developing initial codes through brainstorming, based on Owen's (1984, p. 275) criteria of

recurrence, repetition, and forcefulness. Themes were generated by identifying repeated ideas, language, and actions in participants' descriptions of their early pandemic responses. Codes such as "family comes first," "Zoom fatigue," "loss of field access," and "rotating schedules" emerged inductively, forming early thematic clusters like flexibility, work-life balance, and logistical adaptations. These were discussed in our weekly meetings to enhance reflexivity and shared interpretation.

In Phase 2, we conducted another round of open coding (Charmaz, 2014) to refine and consolidate emergent themes, and then axial coding (Charmaz, 2014) to identify relationships across themes. We explored how Phase 1 themes were sustained over time, which strategies evolved, and which were abandoned. For instance, "loss of field access" was refined to "fieldwork exceptions." Subsequently, axial coding led us to develop "adjust expectations" to link "fieldwork exceptions" from Phase 2 with "rotating schedules" from Phase 1, and that eventually was refined into a more specific theme: "provide flexibility for quality and quantity of work, not location." This theme was fine-tuned into "shift the focus to quality/quantity of work, and not when/where employees do the work" in Phase 3.

As previously mentioned, theoretical saturation emerged during Phase 2 analysis. By the later stages of Phase 2, we observed that new data fit within existing thematic categories without generating additional conceptual dimensions. For instance, while participants continued to describe flexible work arrangements, these descriptions reinforced rather than extended our understanding of Strategy 2 (shifting focus to quality/quantity of work). This pattern of thematic redundancy across multiple interviews signaled saturation (Charmaz, 2014). Phase 3 member-checking interviews confirmed this saturation, as participants reinforced these established categories through elaboration rather than expansion, confirming that the analytic framework had stabilized.

In Phase 3, we showed participants our findings and invited their constructive feedback. In line with Tracy's (2010) framing of member-checks as member reflections, we treated Phase 3 as an opportunity for participants to collaboratively assess, critique, and elaborate on our interpretation. This process helped us clarify thematic boundaries and incorporate new context-specific nuances.

Coding proceeded through both primary and secondary cycles. The first cycle involved descriptive, in vivo, and process coding (Saldana, 2015) to preserve participant voice. The second cycle used thematic (Nowell et al., 2017) and pattern coding (Miles et al., 1994) to group conceptually similar ideas and strengthen category coherence. Primary cycle coding was descriptive and thematic (e.g., "loss of field access," "rotating schedules"), while

secondary cycle coding involved conceptually organizing codes into broader categories (e.g., “fieldwork exceptions,” “adjust expectations”).

Our interpretivist foundations shaped how we established analytical rigor. We employed consensus-based validation, recognizing that qualitative coding involves interpretive judgment rather than mechanical categorization (Tracy, 2010). Through weekly team meetings, we engaged in deliberative dialogue about emerging codes, debated interpretive decisions, and iteratively refined categories. When disagreements arose, we treated them as generative—signals that codes needed refinement or that phenomena were genuinely complex—rather than as failures to achieve objective agreement. This approach made room for interpretive reasoning and contextual sensitivity essential to qualitative analysis.

We began this study with Weick’s (1995) sensemaking theory, followed by Stephens’s (2007) ICT succession theory as our initial conceptual frameworks. These were particularly useful in guiding early data collection questions around uncertainty, ambiguity, and the rapid transition to remote work with different technologies. However, during later stages of coding and writing, these frameworks became less explanatory for our full data set (Tracy, 2012). Instead, Buzzanell’s (2010) CTR became our primary lens for organizing and interpreting the 10 adaptation strategies. We also engaged HRO (Chewning et al., 2013) to examine how adaptations unfolded in high-stakes, science-driven environments like RIs. CTR and HRO ultimately supported our analysis of adaptive practices during the pandemic.

## Findings

This section reports the 10 main strategies that emerged from the analysis of how RIs pivoted and adapted during the pandemic while maintaining their science missions. Based on patterns of emphasis in our member-checking interviews, we organized these strategies into three types that reflect how participants characterized their necessity: necessary strategies (1–3) that participants described as essential for maintaining operations and workforce retention; helpful strategies (4–7) that participants characterized as beneficial adaptations that improved effectiveness and morale, but more flexibly applied; and optional strategies (8–10) that participants discussed as context-dependent and variably effective. Below we report the strategy types along with qualitative excerpts that illustrate the themes. Table 1 summarizes the 10 strategies.

**Table 1.** Ten Adaptive Strategies in Big Science Organizations During the COVID-19 Pandemic

| Strategies   | Definitions   |
|--|---|
| <b>Necessary strategies</b>  |   |
| (1) adjust work expectations to accommodate employees' personal/family needs.                            | Modifying workplace expectations to accommodate employees' personal and family responsibilities, allowing for attention to family and understanding of individual challenges during crises.   |
| (2) shift the focus to quality/quantity of work, and not when/where employees do the work.               | Prioritizing results and output over traditional attendance or location-based metrics, enabling employees to work at times and locations that suit their productivity and circumstances.  |
| (3) reach out to peers in other facilities/organizations for ideas, strategies, and best practices.      | Proactively exchanging knowledge and strategies with professionals across organizations to share experiences, learn effective methods, and adopt best practices for resilience and adaptability.  |
| <b>Helpful strategies</b>  |   |
| (4) embrace a "do what you can, when you can" mindset.   | Encouraging flexibility in managing workloads, allowing employees to accomplish tasks within their personal capacity limits and prioritize as needed in challenging circumstances.  |
| (5) have a master scheduler/project management platform to track tasks and assignments.                  | Using a centralized system to organize and track project tasks and schedules, ensuring clarity, accountability, and coordination, particularly for remote teams.  |
| (6) accept delays, adapt to changes, and manage uncertainty and feelings of overwhelm.                   | Building resilience by acknowledging that delays and uncertainties are common, helping employees adapt to shifting plans and manage feelings of stress and uncertainty.   |
| (7) schedule virtual meetings (strictly) to foster team cohesion, even when interruptions occur at home. | Establish a precise and well-maintained timetable for virtual meetings, creating a structured team environment. This helps prevent employees from missing meetings due to home-related interruptions or disorder, ensuring effective participation. |

*(continued)*

**Table 1.** (continued)

| Strategies  | Definitions   |
|---|---|
| <b>Optional strategies</b>  |   |
| (8) use digital nonverbal Cces to make online meetings engaging, turning cameras on/off when appropriate. | Make online meetings more engaging by actively incorporating nonverbal cues. Utilize gestures, facial expressions, and visual signals to effectively communicate and keep participants interested in virtual discussions.   |
| (9) form a committee/task force to collect input and explore solutions across organizational levels.      | Establish a committee or task force to gather input and explore solutions throughout different levels of the organization. This entails forming a group with representatives from various levels to collectively address issues and generate ideas for enhancement. |
| (10) set up social platforms for informal interactions among employees.                                   | Create informal social platforms for employees to interact. Set up online spaces where workers can engage in casual conversations, promoting a sense of community and connection beyond formal interactions.  |

*Adjust Work Expectations to Accommodate Employees’ Personal/ Family Needs (Necessary Strategy)*

The COVID-19 pandemic necessitated a significant shift in organizational priorities as employees’ family needs—particularly those concerning young children and older adults—became paramount. RIs quickly adapted, prioritizing employee well-being alongside productivity. This shift highlighted the realization that supporting employees’ personal needs was essential for both sustained productivity and workforce retention. Therefore, the first theme is considered a necessary adaptive strategy. Adjusting work expectations enabled resilience in RIs by prioritizing employee retention and well-being over traditional productivity metrics, ensuring that organizations could continue functioning by keeping their essential workforce committed during the crisis.

During the pandemic, many employees prioritized family obligations, requiring RIs to realign from a focus on getting work done to a balanced consideration of employee well-being. A male project manager from an MF in Massachusetts noted, “We had a lot of team members who had older family

[members], or [young] kids ... And we had to work around ... meetings, to protect those members” (Interview 32). This observation explains the urgency of addressing employees’ personal and family needs, portraying this adaptation as necessity rather than optional. This quote illustrates the HRO principle of sensitivity to operations, where the needs of frontline personnel (in this case, employees balancing caregiving responsibilities) drive operational decision making. Rather than impose top-down expectations, leaders deferred to employees’ lived realities to preserve continuity.

While many RIs embraced these changes, implementing flexibility remained a careful balance. A female director from a science research consortium based in Michigan described, “We’ve changed work expectations by providing a lot more flexibility, but I still expect people to get their work done” (Interview 55), reflecting the balance RIs sought between getting work done and accommodating employees’ personal needs. Participants acknowledged that the organizational logic shifted: flexibility during the pandemic became vital because without it, employees might not stay with the RI, pointing out that without employees, an RI cannot function.

In summary, the strategy of adjusting work expectations to accommodate personal and family needs emerged as the first adaptation. This approach highlights the essential roles of flexibility, empathy, and support in facilitating resilience. Leaders recognized empathy as an organizational imperative, making flexibility a central tenet of work expectations. This strategy illustrates how RIs adopted the CTR process of “putting alternative logics to work” through prioritizing employees’ personal and family needs throughout the pandemic, where prioritizing members’ personal and family needs in order to retain the workforce became the dominant logic over productivity. This aligns with HRO principles of deference to expertise and sensitivity to operations, where local actors closest to the task (employees) inform decision making to maintain functioning amid disruption.

### *Shift the Focus to Quality/Quantity of Work, and Not When/Where Employees Do the Work (Necessary Strategy)*

During the pandemic, RIs shifted work expectations to prioritize personal and family needs. This led them to adopt flexibility as a key adaptation strategy, focusing on work quality and quantity rather than a fixed 9-to-5 weekday schedule or specific location. As RIs reprioritized, focusing on output emerged as a parallel strategy. Participants highlighted how increased flexibility in when, where, and how work was done became essential. Therefore, the second

theme is considered another necessary adaptive strategy. Shifting focus to work quality and quantity generated resilience in RIs by enabling creative solutions like rotating schedules and flexible arrangements. These adaptations helped maintain operations while accommodating diverse employee constraints and, in some cases, even improving productivity.

Despite organizational desires to control work methods, such control proved unrealistic. A male computing manager from an MF based in Wisconsin shared, “We were flexible in terms of when work gets done and how work gets done” (Interview 46), emphasizing the importance of flexibility. Another male director from an MSRI in North Carolina echoed, “I tried to work as much as possible with people’s schedule rather than against it. It was impossible to force anything” (Interview 41). Both participants stressed the impracticality of imposing rigid schedules, with the latter concluding that “[providing] flexibility for workers to focus on quality and quantity of work and not where to do that work [is key] ... I made sure that they [employees] knew that the deadlines are malleable” (Interview 41). By allowing flexibility in how and when work is done, this strategy reflects the HRO emphasis on managing complexity through decentralized control and adaptability under conditions of variability.

Nevertheless, some RIs encountered limitations in being fully flexible and developed creative adaptations. The project manager from Massachusetts recounted, “We did have requirements to be [on-site] ... We do a lot of hands-on [tasks] ... But we gave them flexibility of schedule... Some worked weekends to increase separation... We had others that could purely work from home” (Interview 32). To address these constraints, some RIs implemented rotating schedules to maintain operations with flexibility. A male operations manager from an MF based in Washington explained, “We created a rotating schedule to go in [the site], so there’s only one person at a time... In terms of field safety, I think those were effective [strategies]” (Interview 56). These examples show that, even when full flexibility was not feasible, RIs developed creative solutions.

In summary, flexibility regarding when and where employees work has become a critical resilience strategy. Originally a response to disruption, flexibility has emerged as a long-term approach crucial for employee retention, signaling how employees can assert power. Though achieving complete flexibility across all roles presents challenges, RIs recognize its benefits. This flexibility demonstrates an organizational effort in enacting the CTR process of “putting alternative logics to work” during the pandemic, where being flexible with the timing and location of members’ work in order to retain and recruit the workforce became the dominant logic over traditional 9-to-5 work arrangements.

### *Reach out to Peers in Other Facilities/Organizations for Ideas, Strategies, and Best Practices (Necessary Strategy)*

The pandemic introduced an unprecedented crisis, leaving RIs without prior experience or guidance on effective responses. To adapt, many turned to peers across facilities and organizations to gather ideas, strategies, and best practices through a process akin to crowdsourcing. This approach was crucial for adapting to new work challenges during the crisis. Therefore, the third theme is considered another necessary adaptive strategy. Reaching out to peers created resilience in RIs by normalizing shared struggles, providing effective solutions, and building external support networks that prevented organizational isolation during the crisis.

In our data, interviews revealed participants frequently endorsed reaching out to others for guidance and feedback. A male senior scientist from an MF based in California explained this strategy within his particular scientific field: “Because there are 14 operating institutions in our community, we often engaged with others to make sure that we are all attempting to operate ships as safely as possible, given the circumstances ongoing at the time” (Interview 42). More broadly, many RIs found this outreach beneficial. A male systems engineer from an MF based in Oregon added, “[We reached out to peers] all the time ... It was especially helpful to ... find out that they’re having the same struggles” (Interview 37). It reveals that connecting with others normalized shared struggles, reducing the sense of isolation. This strategy echoes HRO emphasis on commitment to resilience—leveraging external networks and peer learning to bounce back from unexpected challenges.

However, implementing this strategy posed challenges for some RIs. The overwhelming demands of the pandemic and employees’ busy schedules limited accessibility. As the computing manager from Wisconsin explained, “It’s sometimes a little difficult, especially in a pandemic. People were so busy, and you could not reach some” (Interview 46). A senior manager of cyberinfrastructure from an MF based in Massachusetts cited his own limited time for proactive outreach, noting, “[I didn’t have] a whole lot of time for that. We learned from others as you would organize or attend other meetings. But I really didn’t necessarily reach out per se” (Interview 34). Taken together, these statements indicate that, while necessary, this strategy was sometimes implemented flexibly depending on time availability.

In conclusion, the pandemic pointed out the necessity of seeking external advice and strategies. While some fully embraced crowdsourcing, others found it challenging. Overall, most participants deemed it effective. A female assistant director of cyberinfrastructure from Missouri emphasized its importance, “If I could give that a six [out of five], I would. Crowdsourcing is

always good” (Interview 51). This approach demonstrates how RIs leveraged the CTR process of “maintaining and using communication networks” to develop resilience during the pandemic.

Taken together, these three necessary strategies show how RIs enacted CTR processes of putting alternative logics to work, maintaining and using communication networks, and crafting new forms of normalcy in order to sustain their missions under acute disruption. As such, necessity in this cluster is not merely about operational survival, but about communicatively reconfiguring work, relationships, and expectations in line with CTR’s resilience processes.

### *Embrace a “Do What You Can, When You Can” Mindset (Helpful Strategy)*

The strategy of “doing what you can, when you can” emerged as a good approach during the pandemic, embodying the resilience and adaptability necessary to manage the unprecedented challenges of COVID-19. Faced with rapidly shifting circumstances, many participants prioritized tasks that were feasible within the moment’s constraints. Rather than waiting for ideal conditions, this strategy focused on accumulating small wins along the way. Embracing this mindset facilitated resilience in RIs by maintaining productivity through task reassignments and enabling continuous progress despite constraints, rather than allowing operations to stall completely.

Certain facilities, particularly those requiring fieldwork, necessitated physical presence. The senior scientist from California explained, “For ships, people needed to go to the ship ... because we have a timeline to meet” (Interview 42). A male marine technical project coordinator from an MF based in Rhode Island noted, “The nature of what we do [is] working on a ship, you sort of have to be on-site for 90% of it” (Interview 38). To adapt, RIs applied the “do what you can, when you can” mindset by reassigning some employees to tasks outside their primary roles. A female senior scientist from an MF in Florida shared about her RI, “Some people have very physical on-site jobs and we had to change their assignments and keep them useful, employed, and make a contribution to our work” (Interview 48). This approach helped maintain productivity. The project manager from Massachusetts elaborated, “Some people just couldn’t go in the field because of family responsibilities... And we would re-task them with desk work. ... updating processes and procedures, things like that” (Interview 32). While desk assignments may not fully utilize fieldworkers’ expertise, the reassignments ensured continued employment during the pandemic.

This approach emphasized productivity within immediate constraints rather than pausing until conditions improved. The systems engineer from Oregon observed, “That’s a very good approach to keeping a project moving” (Interview 37). The choice was not between operating at full capacity or stopping completely, but instead to proceed at a manageable pace and, when necessary, reassigning employees to alternative tasks. The senior scientist from California encapsulated this mindset, “If we can’t do XYZ, what can we do?” (Interview 42). This rhetorical shift reveals how participants enacted adaptive reframing. Rather than fixate on losses or missed targets, leaders oriented teams toward feasible action. This mindset repositions disruption not as paralysis, but as a space for improvised resilience.

Overall, the “do what you can, when you can” mindset reflects an optimization approach, defined as producing the best possible outcomes within existing constraints. Even if not ideal, this strategy enabled continued productivity in a highly constrained environment. This strategy exemplifies how RIs prioritized action over frustration, enabling progress despite the pandemic’s limitations. It demonstrates the CTR process of “downplaying negative feelings while foregrounding positive emotions,” where the negative feelings are the frustrations of work disruptions, and the positive emotions came from the ability to keep work moving forward.

### ***Have a Master Scheduler/Project Management Platform to Track Tasks and Assignments (Helpful Strategy)***

The use of a master scheduler or project management platform received both strong endorsements and cautious feedback from participants. While some viewed it as essential, others relied on preexisting systems or preferred alternative methods. Having a master scheduler supported resilience in RIs by creating structure and normalcy during chaotic times, enabling complex interdependent projects to continue functioning despite remote work disruptions.

For some, the master scheduler was vital in managing complex, interdependent projects during the pandemic. The marine technical project coordinator from Rhode Island highlighted its importance, noting, “We need our project management ... we use a couple of software tools to help us keep track of things, [and] it’s very important” (Interview 38). A female managing director from Michigan emphasized, “We have four teams ... working on projects that are interrelated with multiple dependencies. If we didn’t have a master scheduler, we would have no idea how to track everything” (Interview 33). These statements highlight the necessity of a master scheduler, as without it, tracking tasks and progress during the pandemic would have been

challenging or even unmanageable. It created a sense of normalcy and routine in a very uncertain and disorderly time.

In contrast, some RIs implemented the master scheduler with flexibility, using multiple schedules tailored to specific needs and tasks. Another male project manager from an MF based in Oregon noted, “We used a number of software programs for particular types of tasks instead of having one master program management platform” (Interview 43). Additionally, the strategy’s applicability varied with team size, as the assistant director of cyberinfrastructure from Missouri observed about her project, “You don’t necessarily need a master scheduler or project management platform ... but that could also depend on the size of the team. [For] bigger teams, that’s more important” (Interview 51). These statements suggest that task complexity and team size played a key role in shaping how RIs customized their scheduling systems. This mirrors HRO practices of structuring for reliability, where formal coordination tools help synchronize complex interdependencies and prevent errors during uncertainty.

Overall, the analysis highlights the role of a master schedule or project management platform in tracking tasks and progress for many RIs during the pandemic, though it was adapted to suit organizational needs. While the master scheduler was effective for some, others found alternative methods better suited to their contexts. This strategy shows how RIs adapted established practices through CTR’s process of “crafting normalcy” to develop resilience and continuity during disruption. The master scheduler became a symbolic and practical mechanism for continuing pre-pandemic work routines in the face of uncertainty.

### *Accept Delays, Adapt to Changes, Manage Uncertainty and Feelings of Overwhelm (Helpful Strategy)*

The strategy of “accepting delays, adapting to changes, and managing uncertainty and feelings of overwhelm” reflects the resilience and adaptability required to navigate workplace challenges intensified by the pandemic. Many participants noted that while these challenges were familiar in their work, the pandemic intensified them, emphasizing the need for patience and acceptance. Accepting delays and uncertainty generated resilience in RIs by leveraging their existing culture of working with unpredictability, allowing organizations to maintain forward momentum through patience and adaptability rather than becoming paralyzed by disruption.

For RIs, adapting to changes was inherent to their dynamic work environment. The managing director from Michigan explained, “[We] all have to deal with adjusting—like, what is your resilience to adapting to the various

things that are happening: changing work expectations, delays, emotional overwhelm, and all that” (Interview 33), emphasizing that resilience is demonstrated through adaptability. She further noted, “I mean, when you’ve got something as dramatic as a pandemic, you have to recognize that and go with it, or you’re probably just going to get stuck” (Interview 33), highlighting the importance of recognizing and accepting changes as they come.

Notably, for some RIs, these disruptions were not entirely unfamiliar. A nonbinary technical services manager from an MF working in Washington shared, “Delays, changes, and uncertainty are a big part of the role already ... It’s hard to say that changed during the pandemic, when the reality is a ship schedule, especially traveling in foreign ports, has always been uncertain” (Interview 54). This insight challenges assumptions that the pandemic introduced wholly novel stressors. Rather than respond with panic, these participants drew on a resilient baseline rooted in long-standing familiarity with unpredictability. Similarly, the senior manager of cyberinfrastructure from Massachusetts added, “We didn’t have to get used to delays or changes ... they’re built in” (Interview 34). These narratives reflect the dual reality of the pandemic’s disruptions: for some, it introduced new psychological strain; for others, it intensified preexisting norms of working through uncertainty.

Overall, this strategy emphasizes the range of perspectives on managing workplace challenges and emphasizes the importance of patience, acceptance, and adaptability. This strategy explains how RIs prioritized productive actions while minimizing negative emotions, such as uncertainty and overwhelm. It demonstrates CTR’s process of “downplaying negative feelings while foregrounding positive emotions,” in which acceptance and patience emerged as sources of constructive forward momentum.

### ***Schedule Virtual Meetings (Strictly) to Foster Team Cohesion, Even When Interruptions Occur at Home (Helpful Strategy)***

In our initial theme generation during Phases 1 and 2, we identified scheduling virtual meetings as a strategy for virtual collaboration from home. Through member-check interviews in Phase 3, we refined this to “strictly” scheduling virtual meetings to ensure everyone’s availability and participation. However, responses to this strategy were mixed; while the aim was to reduce disruptions in remote work environments, many participants preferred a more flexible approach, recognizing the unpredictability of working from home during the pandemic. Notably, this is one area where the member-checking process played a central role in fine-tuning our analysis. Scheduling virtual meetings enhanced resilience in RIs by improving collaboration efficiency and

productivity, with some organizations achieving more collaborative work than before the pandemic through advanced virtual tools.

The shift to remote work and virtual meetings was noted as a significant improvement. A male operations coordinator from an MF in Oregon described, “The advancement and utilization of virtual tools ... that’s been a game changer” (Interview 36). He explained that virtual tools transformed efficiency, “We’re already doing a lot of conference calls. But all these tools that came out of working remotely through the pandemic has just made us so much more efficient” (Interview 36). His perspective illustrates that some adaptation strategies increased productivity during the pandemic, with virtual tools enabling more collaborative work than before. He concluded, “We’re getting as much or more collaborative work done through these new tools than we ever did before” (Interview 36), highlighting that some RIs were not simply surviving the pandemic, they were thriving!

Still, the application of this strategy varied widely. The marine technical project coordinator from Rhode Island noted, “We do a ton of virtual meetings. [But] ... we’re not too strict. If you have something else going on, it’s okay. And we all kind of cover for each other” (Interview 38). A male senior scientist from an MF based in Massachusetts added, “You can’t hold people too tightly to a strict schedule if they have to take care of their mom who’s in the hospital or something” (Interview 40). These examples reflect how rigid scheduling was often softened by an awareness of the broader personal and familial demands placed on employees. In response to this feedback, we revised the strategy to “scheduling virtual meetings (strictly),” placing “strictly” in parentheses to signal that structure is important, but flexibility is often necessary. This balancing act between predictability and adaptability became central to team cohesion.

In sum, the choice to be flexible with virtual meeting schedules reflects an understanding of the need for adaptability during the pandemic. This strategy acknowledges the challenges employees faced and demonstrates that flexibility can often be more effective than strict scheduling. The strategy of scheduling virtual meetings (strictly) illustrates how RIs adapted previous practices to develop resilience and continuity amid disruption, demonstrating CTR’s process of “crafting normalcy.”

Taken together, these helpful strategies show how RIs enacted CTR processes of foregrounding positive emotions, crafting normalcy, and putting alternative logics to work by redefining what counted as “enough” progress, reassigning tasks, and structuring collaboration through project management and meeting practices. Rather than serving as generic efficiency tools, these adaptations functioned as communicative mechanisms through which resilience was actively produced in day-to-day organizing.

### *Use Digital Nonverbal Cues to Make Online Meetings Engaging, Turning On/Off Cameras When Appropriate (Optional Strategy)*

The strategy of using nonverbal cues to enhance engagement in online meetings elicited mixed responses. While some participants embraced tools like hand-raising and camera use to facilitate interactivity, others questioned their impact or found them burdensome. The systems engineer from Oregon stated, "I really do like the nonverbal cues ... raising your hands and all that stuff. I think that really is effective ... we're all [a chatty] group" (Interview 37), expressing enthusiasm for digital nonverbal cues, especially within an already socially interactive team. Using digital nonverbal cues enabled resilience in RIs by preserving essential communication dynamics and team engagement, though its effectiveness varied based on team culture and individual circumstances.

At the same time, other participants preferred not to use cameras, citing personal or environmental constraints such as family or childcare obligations. This choice was often left to individual employees. The project manager from Massachusetts noted, "We didn't require people to turn on cameras ... a lot of times they're working directly from their home, and they have other family members or kids around" (Interview 32). Similarly, a male research scientist from a supercomputing center in Illinois shared, "Staring at your own face 8 hours a day can be pretty draining for people ... [H]aving camera-on meetings and camera-off meetings and getting the right balance, that has been [key] for me" (Interview 31). These comments reflect the emotional and logistical challenges of maintaining constant camera use in remote settings.

Despite differing views, several leaders recognized the benefits of using cameras but advocated a flexible approach. The director from Michigan explained, "We do not require people to turn on their cameras, but we have some who are extremely averse to it" (Interview 55), indicating that while cameras were not mandatory, there was encouragement for their use. She added, "However, I have definitely urged everyone to make it the norm to have their cameras on, unless it's a really large meeting and you're just listening" (Interview 55), suggesting that camera use was encouraged, with exceptions for larger meetings where active participation was not expected. This strategy is not about forcing everyone to be on camera all the time, but rather, about encouraging people to find what works best for them, and to be mindful of the signals they are sending nonverbally.

Overall, participants offered different perspectives on using digital nonverbal cues and cameras in online meetings. While some found these strategies beneficial, others faced challenges or preferred alternative methods, highlighting the importance of flexibility in virtual communication. This strategy is

an example of how RIs adapted traditional practices to maintain resilience and continuity amid disruption. It demonstrates CTR's process of "crafting normalcy," where the normalcy here refers to the communication to preserve preexisting routines of being able to read each other's nonverbal cues and each other's faces in person, but during the pandemic, the modified normalcy is digital instead.

### *Form a Committee/Task Force to Collect Input and Explore Solutions Across Organizational Levels (Optional Strategy)*

The strategy of forming committees or task forces to gather input and explore solutions across organizational levels emerged as a key adaptive response, though with mixed outcomes. While the strategy showed promise across sites, participants had mixed views—some found it effective, while others encountered limitations. For certain RIs, committees or task forces proved essential for addressing pandemic-related challenges. The project manager from Massachusetts shared: "We had one committee Task Force to discuss Marine Operations ... how we should treat pandemic safeguards, quarantine, what additional safeguards were potentially required over CDC [Centers for Disease Control and Prevention] recommendations [and all other necessary guidelines]" (Interview 32). This example illustrates the focused role of the task force in developing safety protocols. A cyberinfrastructure security officer acknowledged the benefits of committees, noting, "they do move the needle in the right direction" (Interview 45). Forming committees facilitated resilience in RIs by enabling comprehensive input for major decisions and ensuring consistent approaches across complex projects, though overuse could slow organizational response times.

However, not all participants favored frequent implementation of this approach. Some recommended reserving it for substantial issues or larger projects. The senior scientist from Massachusetts observed, "You can't do this too often, or you get paralyzed by having too many task forces. ... When you have a major problem to solve, this is the way to do it" (Interview 40), emphasizing that task forces are most useful for critical challenges. The director from North Carolina explained, "We didn't do this ... it may have to do with the size of our project; it's not so huge that we needed something like this" (Interview 41), suggesting that committees are best suited to larger, more complex projects that benefit from extensive input.

To avoid decision-making paralysis from too many task forces, some RIs empowered knowledgeable individuals to make straightforward decisions within specific areas. The senior manager of cyberinfrastructure from Massachusetts shared, "I was a one-man task force working with the PMO [Project

Management Office] to explore solutions... So, I implemented some solutions for them” (Interview 34). The research manager from California noted, “For my area, I did not form a committee or task force; I just made the decision on how we’re going forward... but for the broader organization, we did definitely form [committees]” (Interview 53). These examples indicate that smaller-scope decisions can be managed by individual experts, while committees are more appropriate for broader organizational issues. The use of task forces aligns with HRO’s principle of “reluctance to simplify,” as they create space for nuanced, multi-perspective sensemaking around rapidly shifting issues.

Taken together, these insights suggest that while committees or task forces can be effective, their success relies on careful management of decision scope, project size, and potential overuse, which could otherwise impede organizational efficiency. This strategy illustrates how RIs maintained communication networks during the pandemic, balancing collective input with operational agility, demonstrating CTR’s process of “maintaining and using communication networks.”

### *Set Up Social Platforms for Informal Interactions Among Employees (Optional Strategy)*

To support informal interaction during remote work, many RIs introduced or adapted social platforms. While the intention was clear—to strengthen interpersonal connection—participants offered different perspectives on their effectiveness. For some, platforms like Slack, Microsoft Teams, and dedicated virtual spaces served as valuable tools, enabling employees to engage in casual conversations, share personal updates, and build camaraderie in a remote setting. Setting up social platforms enabled resilience in RIs by maintaining team cohesion and informal relationships essential for scientific collaboration, though effectiveness varied widely and some participants questioned their tangible benefits.

In practice, RIs adopted or repurposed social platforms to simulate a virtual “watercooler” experience, aiming to maintain a sense of community and belonging while employees worked from home. The operations manager from Washington shared, “We did set up a lot of virtual happy hours... it was strongly pushed early on” (Interview 56). The project manager from Massachusetts noted, “We created some social channels on Slack to keep people connected ... like a pet’s channel, [where] people can post pictures of their pets” (Interview 32). Additionally, a “family channel” allowed employees to share family moments and receive comments from colleagues, enhancing a supportive, interactive environment (Interview 32). These examples illustrate

proactive measures RIs took to build interpersonal relationships among employees through online channels.

However, not all participants were convinced of the strategy's effectiveness. The systems engineer from Oregon stated, "Some of our community tried to do that, and some people take to it, and some people don't" (Interview 37). The computing manager from Wisconsin echoed: "I'm not sure what a good social platform is that simulates watercooler conversation... We made a lot more use of it, but I don't know if that is [useful]" (Interview 46). These statements indicate active engagement but also suggest doubts about the tangible benefits of these platforms.

Although RIs widely implemented social platforms to enhance informal connections, the strategy received mixed reviews during member-checking. Overall, it still explains how RIs maintained and leveraged communication networks to support resilience in a remote work environment, demonstrating CTR's process of "maintaining and using communication networks."

Taken together, these optional strategies show how RIs extended CTR processes of crafting normalcy and maintaining communication networks into the more discretionary, relational spaces of digital interaction. Rather than being peripheral add-ons, these practices reveal how everyday choices about cameras, committees, and social platforms become communicative sites where resilience is either reinforced or allowed to wither.

## Discussion and Conclusion

The analysis identified 10 adaptation strategies that can enhance organizational resilience among big science organizations we studied. They were contextual manifestations of CTR processes, suggesting that CTR may be a useful lens for explaining how these organizations adapted during the pandemic. The process of *putting alternative logics to work* is evident in strategies like "adjusting work expectations" and "shifting the focus to quality/quantity of work." The process of *foregrounding positive emotions* is reflected in emphasizing the mindsets to "do what you can, when you can" and "accept delays, adapt to changes, manage uncertainty and feelings of overwhelm." *Maintaining/using communication networks* is demonstrated in strategies such as "reaching out to peers in other facilities/organizations," "forming committees/task forces," and "setting up social platforms." Lastly, *crafting normalcy* is evident in "using a master scheduler/project management platform," "scheduling virtual meetings (strictly)," and "using nonverbal cues." [Table 2](#) summarizes these findings.

**Table 2.** Summary of 10 Resilience Strategies Mapped to the CTR Framework

| Theoretical Framework of CTR Processes                              | Ten Strategies Emerged from Grounded Analysis  |
|---|--|
| Putting alternative logics to work                                  | (1) Adjust work expectations to accommodate employees' personal/family needs.<br>(2) Shift the focus to quality/quantity of work, and not when/where employees do the work.  |
| Downplaying negative feelings while foregrounding positive emotions | (4) Embrace a "do what you can, when you can" mindset. (6) accept delays, adapt to changes, and manage uncertainty and feelings of overwhelm.  |
| Crafting normalcy   | (5) Have a master scheduler/project management platform to track tasks and assignments.<br>(7) Schedule virtual meetings (strictly) to foster team cohesion, even when interruptions occur at home.<br>(8) Use digital nonverbal cues to make online meetings engaging, turning cameras on/off when appropriate. |
| Maintaining and using communication networks                        | (3) Reach out to peers in other facilities/ organizations for ideas, strategies, and best practices.<br>(9) Form a committee/task force to collect input and explore solutions across organizational levels.<br>(10) Set up social platforms for informal interactions among employees.                          |
| Affirming identity anchors  | Operated implicitly, so no themes emerged.   |

### *Theoretical Implications*

There are several theoretical implications of the findings. First, flexibility emerged as a meta-process that makes resilience communicative rather than procedural across all 10 adaptive strategies. Flexibility operated at two levels: organizationally, RIs redefined expectations about time, place, and oversight; and strategically, each adaptation (e.g., scheduling formats, collaboration tools, or camera policies) was calibrated to local needs. Rather than viewing resilience as a fixed set of practices, our findings position resilience as the capacity to adjust practices in ways that remain aligned with organizational purpose. This extends CTR by identifying flexibility not as one process among

others, but as the organizing logic through which different resilience processes are enacted.

Second, flexibility did not occur uniformly; it was shaped by a conditional matrix. According to [Charmaz \(2014\)](#), a conditional matrix helps researchers consider multiple layers of conditions that influence individual actions and interactions. In our data, two dimensions of conditions most clearly informed strategic variation. Social conditions (e.g., relational dynamics, caregiving obligations) influenced whether communication-intensive strategies (e.g., digital nonverbal cues, camera-on expectations) were experienced as supportive or burdensome. Moreover, structural conditions (e.g., team size, project complexity, decision scope) determined whether strategies such as master scheduling or forming a task force were essential or unnecessary. These findings demonstrate that resilience is not the application of universal strategies but a process of contextual calibration, adjusting intensity and form based on conditions within the conditional matrix.

Third, prior research on adaptive capacity and organizational flexibility has largely treated flexibility as either a trait (e.g., structural looseness, decentralization; [Mallak, 1998](#)) or a capacity to reconfigure operations under stress (e.g., redistributing personnel and resources; altering workflows and decision hierarchies; [Somers, 2009](#); [Walker et al., 2002](#)). Our findings extend this literature by showing that flexibility is not merely a latent organizational characteristic but a communicative process enacted in real time. Rather than existing as a preset capability, flexibility emerged through ongoing negotiation. Specifically, employees continuously evaluated conditions such as team size and personal constraints to determine how strategies should be implemented. Taken together, these three implications highlight flexibility as a central communicative capacity through which RIs enact resilience in ways that are sensitive to identity, context, and mission.

Fourth, CTR argues that affirming identity anchors is a core resilience process. However, organizationally focused identity work did not surface as an explicit strategy in our data. Across our 10 adaptive strategies, participants never explicitly referenced organizational identity, core values, or “who we are as a science organization” when describing how they sustained operations during the pandemic. At the same time, our findings point to individual identity work, particularly in the first necessary strategy, where participants foregrounded personal identities as parents and family members while figuring out how to accomplish work remotely. This absence of explicit organizational identity language is theoretically significant: the CTR process of affirming identity anchors did not emerge as a discrete, observable strategy at the collective level. Instead, we argue that it operated implicitly. Because the pandemic was itself a science-based crisis, organizational identity as scientific,

evidence-driven institutions aligned with crisis requirements. As a result, identity anchors were reinforced rather than threatened, rendering explicit organizational identity work unnecessary while other CTR processes (e.g., alternative logics, positive emotions) became more salient. This suggests a theoretical refinement to CTR: organizational identity work may only become explicit when crisis demands conflict with organizational mission; when they align, organizational identity work recedes into the background even as individual identity work continues in more implicit ways. Organizations whose missions conflict with crisis responses (e.g., hospitality businesses required to limit social interaction, religious organizations forced to close during holy periods) would experience identity tension requiring explicit communicative work to reconcile “who we are” with “what we must do.” In such cases, we would expect affirming identity anchors to emerge as a discrete, observable process.

Fifth, traditional HRO scholarship emphasizes procedures, structural redundancy, and risk awareness as the foundations of reliability. Our findings affirm this view but extend it. [Chewning et al. \(2024\)](#) note that “preoccupation with failure is critical when lives are at stake, but perhaps not as relevant when making a sandwich at a restaurant” (p. 8), illustrating that what counts as “reliability” is context-dependent. We find that reliability is also shaped by the alignment between professional identity and crisis demands. In RIs, scientific identity supported rather than hindered pandemic adaptation; as a result, some resilience strategies (e.g., adjusting expectations) became necessary, while others (e.g., explicit identity affirmation) were rendered unnecessary. This stands in contrast to cases where identity work disrupts reliability, such as the Challenger disaster, where NASA’s identity as a boundary-pushing and schedule-committed organization led decision makers to discount engineers’ risk warnings. This example demonstrates how identity can override procedural reliability when it conflicts with organizational mission or values. Reliability is therefore not only procedural; it is identity-inflected and context-dependent.

### *Practical Implications*

Our findings offer actionable insights for leaders of science organizations and other mission-driven institutions navigating prolonged disruption. The first practical implication is a prioritized implementation framework for resilience strategies based on crisis urgency and organizational capacity. Rather than treating adaptive strategies as equal options, we suggest that leaders may consider sequential implementation: necessary strategies (employee support) before helpful strategies (project management) before optional strategies

(social platforms). The necessary strategies (1–3) offered immediate actions and solutions to the pressing challenge of transitioning to remote work. The helpful strategies (4–7) expanded on existing practices and/or provided guidance for making sense of the situation. The optional strategies (8–10) can be deferred when time and resources are limited in the short-term. This framework highlights the potential importance of timing and resource allocation for crisis response effectiveness.

The second practical implication is recognizing that flexibility as a meta-process has direct implications for crisis management training and organizational design. Rather than developing extensive crisis response protocols with predetermined strategies, organizations should invest in developing meta-flexibility capabilities—the capacity to assess which strategies are appropriate for specific contexts and to adjust strategy implementation in real time. This shifts crisis preparedness from a content focus (what strategies to use) to a process focus (how to flexibly deploy strategies). Moreover, this framework suggests that post-crisis evaluations should assess not only *which* strategies were employed, but *how flexibly* they were applied. Organizations may fail not because they chose wrong strategies, but because they applied appropriate strategies too rigidly or too loosely for the specific context.

### *Limitations and Future Research*

Given that this is a qualitative study, the findings are descriptive rather than statistically generalizable. Building on our qualitative insights, future quantitative studies could test and measure the effectiveness of CTR processes across larger, more diverse organizational samples. Longitudinal studies could examine how resilience strategies evolve across different crisis phases and assess the sustained impact of these adaptations on organizational culture and performance.

Our focus on science organizations, while providing deep insights into this understudied context, limits generalizability across industries. Comparative studies across healthcare, education, technology, and other mission-driven organizations could reveal industry-specific resilience mechanisms and clarify which strategies are universal versus context-dependent. Such research would enable more tailored recommendations for organizational resilience across diverse operational structures.

### **ORCID iD**

Kerk F. Kee  <https://orcid.org/0000-0002-0543-5009>

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### Author Biographies

**Kerk F. Kee** (PhD, The University of Texas at Austin) is the Virginia & Choc Hutcheson Professor of Mass Communication at Texas Tech University. His research focuses on organizational resilience, workplace technology adoption, diffusion of innovations, and AI-human teaming, especially in science, health, environmental, and risk contexts.

**Mahedi Hasan** is a PhD candidate in the College of Media and Communication at Texas Tech University. His main research interests include adoption of cyberinfrastructure in big science organizations, and communities of practice.

**Oluwabusayo Okunloye** (PhD, Texas Tech University) is an educator and researcher based in the United States. Her work focuses on strategic communication in health and political contexts, with particular attention to how actors mobilize and frame messages in digital and social media environments, as well as organizational resilience and crisis communication

**Cassandra Hayes** (PhD, Texas Tech University) is an Assistant Professor of Journalism in the Bob Schieffer College of Communication at Texas Christian University. Her research focuses on rural voices within news, sports such as rodeo adapting to the 21st century, and technological innovations, especially within media organizations.

**Ewa Deelman** (PhD, Rensselaer Polytechnic Institute) is a Research Professor of Computer Science and Principal Scientist at University of Southern California Information Sciences Institute. Her main research area is distributed computing, including how to best support complex scientific applications on a variety of computational environments such as campus clusters, grids, and clouds. She is an AAAS, IEEE, and USC/ISI Fellow.