The Need to Invest in Social Science Infrastructure to Address Emerging Crises

Chapter Eight

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CHAPTER EIGHT

The Need to Invest in Social Science Infrastructure to Address Emerging Crises

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Emerging crises, such as civil unrest, natural disasters, economic crashes, and major terrorist attacks, can cause societal disruption by upsetting norms and breaking down traditional governance and social services. These issues have substantial and lasting impacts on societies, economies, and nations. Such emerging crises, which create undergoverned spaces (UGS), raise safety, security, social, and economic challenges. They also raise time-sensitive research questions about how we as a society respond to crisis, how vulnerabilities are disparately distributed among different groups, and how we can extract lessons learned from crises and improve long-term planning for such crises. More generally, enabling policy for emerging crises—or those yet to emerge—and promoting security and resilience for the United States and its communities requires nimble and adaptive scientific capacity. Such capacity would provide a means to react, recover, or correct course after a surprise, which will inevitably happen. However, such capacity cannot be built on the fly; rather, it must be established and maintained in advance as existing social science infrastructure.

Take the example of the coronavirus disease 2019 (COVID-19) pandemic. COVID-19 emerged and spread rapidly, creating a global shock to a variety of interlocked social, political, economic, and health systems. These interdependencies mean that the impacts of major events are often nonlinear and multilevel.[1] The pandemic has motivated a flurry of rapidly conceived, proposed, funded, and fielded studies on elements of these systems. Notable studies include research on the epidemiology of the virus and disease, biomedical countermeasures, economic impacts, and our collective behavioral and social lives. This work promises significant scientific advances, a variety of pharmaceutical and nonpharmaceutical interventions, and sweeping policy changes, similar to those made in response to the last major pandemic (the 2009–2010 H1N1 influenza).

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[1] Susan L. Cutter, Bryan J. Boruff, and W. Lynn Shirley, "Social Vulnerability to Environmental Hazards," *Social Science Quarterly*, Vol. 84, No. 2, 2003; Fran H. Norris, Susan P. Stevens, Betty Pfefferbaum, Karen F. Wyche, and Rose L. Pfefferbaum, "Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness," *American Journal of Community Psychology*, Vol. 41, Nos. 1–2, March 2008.

The pandemic also demonstrates the limitations of responsiveness. All too often, scientists, funders, and policymakers can only react to a crisis, marshaling funds and capabilities as quickly as possible. This is partially unavoidable, given that such events are by their very nature unexpected. However, if the disaster research field tells us anything, it is that *something* will happen with regularity, even if we do not know what that specific crisis will be—readiness is necessary, not just response.

Operational readiness for crises is often discussed, but it is less common to discuss scientific readiness for crises.[2] Operationally, we plan for the unexpected. However, without investments in scientific readiness in the form of standing infrastructure that is poised to adapt,[3] responses are slower, costlier, and less coordinated.

COVID-19 is hardly the only example or application for such infrastructure. Disasters and crises of many sorts are on the rise, and, like COVID-19, such crises represent unexpected, systemic shocks that lead to a feverous if reactive scientific response. Table 8.1 summarizes a 2020 United Nations report comparing worldwide disaster declarations during 2000–2019 with such declarations during 1980–1999.[4] It shows substantial increases in number of events, people affected (but not deaths), and economic losses.

The past 80 years have seen outbreaks of over 300 previously unknown diseases, with other disease outbreaks becoming worse and more widespread.[5] In addition, recent unrest against systemic racism in the United States and abroad, sparked by instances of police brutality; the 2008 financial crisis; and major terrorist attacks (such as those on September 11,

TABLE 8.1

Worldwide Disaster Impacts in 1980–1999 Versus 2000–2019

Period	Reported Disasters	Total Deaths	Total Affected	U.S. Economic Losses
1980–1999	4,212	1.19 million	3.25 billion	1.63 trillion
2000–2019	7,348	1.23 million	4.03 billion	2.97 trillion

SOURCE: Adapted from United Nations, 2020, p. 6.

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[2] The term *scientific readiness* is used in engineering to denote the readiness for a given mission, a quite different idea. Here, I use *readiness* in the same sense as used by first responders and in public health to denote capacity and capability to respond to emerging (and as-yet unknown) events. Similar, if more narrowly focused, concepts are offered in Avi Loeb and Dario Gil, "Let's Create the Science Readiness Reserves to Advise on Catastrophes," *IBM Research Blog*, May 12, 2020; and Elisabeth Jeffries, "Governments Detail Gaps in Their Scientific Readiness for a Pandemic," *Nature Index*, June 9, 2020.

[3] David D. Woods, "The Strategic Agility Gap: How Organizations Are Slow and Stale to Adapt in Turbulent Worlds," in Benoît Journé, Hervé Laroche, Corinne Bieder, and Claude Gilbert, eds., *Human and Organisational Factors: Practices and Strategies for a Changing World*, Cham, Switzerland: Springer International Publishing, 2020; David D. Woods, "The Theory of Graceful Extensibility: Basic Rules That Govern Adaptive Systems," *Environment Systems and Decisions*, Vol. 38, No. 4, December 1, 2018.

[4] United Nations, *The Human Cost of Disasters: An Overview of the Last 20 Years, 2000–2019*, New York, October 12, 2020.

[5] Kate E. Jones, Nikkita G. Patel, Marc A. Levy, Adam Storeygard, Deborah Balk, John L. Gittleman, and Peter Daszak, "Global Trends in Emerging Infectious Diseases," *Nature*, Vol. 451, No. 7181, February 2008;

2001) have had substantial and lasting impacts on societies, economies, and nations. Recent rapid technological changes (e.g., the surge in video conferencing precipitated by telecommuting), political shifts (e.g., increased polarization around the world), and even scientific events (e.g., the replicability crisis) can also act as unexpected systemic shocks. More generally, these shocks fit within a larger set of instances in which governance is disrupted or degraded.[6] These events, disastrous or otherwise, illustrate the ongoing need to understand the dynamic nature of public behavior and social systems at the core of UGS along with their influences on global and domestic security and resilience.

This lack of scientific readiness is not uniform; readiness levels vary depending on the features of the crisis, the societal context, and research silos. For example, the exact timing and size of major tropical storms are unknown, but the tropical storm season is relatively well anticipated every year, whereas major terrorist attacks typically are conducted by an intelligent adversary who must be unpredictable to succeed. Societal context will include the availability of on-the-ground partners and capabilities needed for data generation, model formation, validation, and other common scientific tasks. To the extent that conditions do not allow this (whether through lack of basic capacity or through degradation of normal capacity), readiness will suffer.

Academically, scientific readiness is bolstered within the physical and computational sciences through investment in major infrastructure, such as observatories, sensing networks, laboratories, vessels, analytic resources, knowledge bases, and scientific networks. However, crises and other events the scale of COVID-19 are rarely restricted to physical systems. This can be seen in the public response to changing COVID-19 guidelines (e.g., regarding social distancing), political battles contrasting public health and civil liberties, changes in fertility and mortality, job loss, decreased consumer spending (among those with more discretion to do so), and dramatic reduction in geographic mobility. Human and disease dynamics influence each other, again highlighting the importance of complex interdependencies.

Unfortunately, scientific infrastructure is far more limited for addressing these social, economic, and behavioral scientific questions. However, if we take lessons from the physical and computational sciences, we can start to anticipate what sorts of infrastructure would be the most valuable investments for capturing the often-ephemeral data surrounding crises. These infrastructure priorities include *sensing capacity*, particularly that which provides early warning of unusual but potentially significant events. Such systems provide the triggers for mobilizing assets, whether research or operational, and they also can provide valuable data for predicting trouble spots and tracing trajectories over time. Priority infrastructure

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Kaiser Family Foundation, “The U.S. Government & Global Emerging Infectious Disease Preparedness and Response,” fact sheet, December 2014; David M. Morens, Gregory K. Folkers, and Anthony S. Fauci, “The Challenge of Emerging and Re-Emerging Infectious Diseases,” *Nature*, Vol. 430, No. 6996, July 2004.

[6] For examples, see Table 2.1 in Chapter Two (Aaron B. Frank, “Undergoverned Spaces: Problems and Prospects for a Working Definition,” in Aaron B. Frank and Elizabeth M. Bartels, eds., *Adaptive Engagement for Undergoverned Spaces: Concepts, Challenges, and Prospects for New Approaches,* Santa Monica, Calif.: RAND Corporation, RR-A1275-1, 2022).

also could include capacity for *experimental testing*, either real or simulated, which allows for comparing interventions, stress testing, and what-if exploration.

This chapter provides an argument for investing in social science infrastructure as a way of increasing scientific readiness.[7] I start by discussing what is meant by social science infrastructure, then turn to the general challenges of conducting research on emerging events for the research community and for science policymakers and funders. I then lay out visions for promising uses of social science infrastructures, followed by a discussion of the value added of implementing those uses. I conclude by discussing the possible benefits of implementing any infrastructure project and the challenges that need to be overcome to achieve those benefits.

What Is Social Science Infrastructure?

The scientific community has long called for enhanced social science infrastructure.[8] The National Research Board defines *research infrastructure* as "any combination of facilities, equipment, instrumentation, computational hardware and software, and the human capital needed for associated support." The board also states that research infrastructure has different meanings in different disciplines and "can include individual instruments, suites of instruments, multiuser facilities, cyberinfrastructure, or infrastructure for data storage and preservation."[9]

The National Research Council notes that this view of research infrastructure takes on two main themes—multidisciplinary centers and scientific instrumentation (e.g., observing and computational systems, laboratory and analysis systems, communication and network systems, databases and informational systems).[10] However, it goes on to note the importance of social infrastructure to promote collaboration (e.g., through scientific communities), communicative infrastructure to promote information dissemination (e.g., journals or preprint archives), and even key methodological developments. Ideally, social science research infrastructure should provide a community resource that enables multiple scales of research on high-priority topics of national interest.

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[7] I will often use the term *social science* as shorthand to refer to scientific inquiry into a range of social, behavioral, political, and economic sciences.

[8] National Research Council, *Investing in Research Infrastructure in the Behavioral and Social Sciences*, Washington, D.C.: National Academies Press, 1998; R. Duncan Luce, Neil J. Smelser, and Dean R. Gerstein, eds., *Leading Edges in Social and Behavioral Science*, New York: Russell Sage Foundation, 1990.

[9] National Science Foundation, *Bridging the Gap: Building a Sustained Approach to Mid-Scale Research Infrastructure and Cyberinfrastructure at NSF*, Washington, D.C., October 1, 2018.

[10] National Research Council, 1998.

The Challenge of Conducting Research on Emerging Events

For the Research Community

Emerging events provide unique opportunities for conducting research, but they also create unique challenges. Researchers will typically need to stand up new endeavors quickly—rapidly recognizing the research opportunity, designing an approach to address that opportunity, possibly building a team, and applying for funding.

The release of funding opportunities is often the gunshot that starts the research sprint. For example, my collaborators and I responded to a COVID-19 Rapid Response Research (RAPID) grant opportunity cutting across the divisions and programs at the National Science Foundation (NSF). Such grant programs are designed to capture ephemeral data and address time-sensitive problems and are critical for disaster research in the social sciences. Proposals and budgets are small and quickly reviewed to get researchers into the field as soon as possible.

Importantly, however, such calls for research *follow* the emergence of an event, and it takes time to write a proposal for a grant, be reviewed, and pivot to the field. Because of this process, our first data were collected in late March 2020, weeks after the pandemic reached the United States. Such delays or longer are typical. There was little opportunity for capturing earlier dynamics, and gathering pre-event data was nearly impossible, although such data are critical for understanding short- and long-term impacts of the pandemic.[11] As stated by Elisa Jayne Bienenstock in Chapter Nine,[12] without understanding the mundane—in this case, the pre-event status quo, collected through baseline assessments, such as existing disparities, expectations, and behaviors—it is nearly impossible to fully recognize and understand disruptions.

Beyond these data limitations, a critical feature of most funding is that it typically goes to independent teams, each of which is standing up its own research machinery. This provides

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[11] Man-pui Sally Chan, Kenneth Winneg, Lauren Hawkins, Mohsen Farhadloo, Kathleen Hall Jamieson, and Dolores Albarracín, "Legacy and Social Media Respectively Influence Risk Perceptions and Protective Behaviors During Emerging Health Threats: A Multi-Wave Analysis of Communications on Zika Virus Cases," *Social Science & Medicine*, Vol. 212, September 1, 2018; Baruch Fischhoff, Gabrielle Wong-Parodi, Dana Rose Garfin, E. Alison Holman, and Roxane Cohen Silver, "Public Understanding of Ebola Risks: Mastering an Unfamiliar Threat," *Risk Analysis*, Vol. 38, No. 1, 2018; Courtney A. Gidengil, Andrew M. Parker, and B. Zikmund-Fisher, "Trends in Risk Perceptions and Vaccination Intentions: A Longitudinal Study of the First Year of the H1N1 Pandemic," *American Journal of Public Health*, Vol. 102, No. 4, April 2012; Rupa Jose, E. Alison Holman, and Roxane Cohen Silver, "The Importance of the Neighborhood in the 2014 Ebola Outbreak in the United States: Distress, Worry, and Functioning," *Health Psychology: Official Journal of the Division of Health Psychology, American Psychological Association*, Vol. 36, No. 12, December 2017; Imelda K. Moise, Joseph Kangmennaang, Tricia Caroline S. G. Hutchings, Ira M. Sheskin, and Douglas O. Fuller, "Perceptions of Zika Virus Risk During 2016 Outbreak, Miami-Dade County, Florida, USA," *Emerging Infectious Diseases Journal*, Vol. 24, No. 7, July 2018.

[12] Elisa Jayne Bienenstock, "Operationalizing Social Science for National Security," in Aaron B. Frank and Elizabeth M. Bartels, eds., *Adaptive Engagement for Undergoverned Spaces: Concepts, Challenges, and Prospects for New Approaches,* Santa Monica, Calif.: RAND Corporation, RR-A1275-1, 2022.

an important diversity of perspective, but it also creates inefficiencies when commonly needed capabilities are multiply created. For example, we were fielding COVID-19–related surveys, but so were many other groups. In many cases, these groups reinvented similar processes.

Funding streams often reinforce this, because there typically is no easy way to leverage capabilities across multiple proposals. For example, these teams (including ours) each needed to gather large and diverse (even nationally representative) samples. Each needed to collect many of the same variables (e.g., risk perception, protective behaviors, demographics), and each needed to write and refine survey instruments. One solution for avoiding this redundancy in time, effort, and monetary costs is to have access to centralized, preexisting resources (in this case, survey capabilities). Such standing capabilities could efficiently provide core, common needs while still maintaining flexibility and adaptivity to specific needs (e.g., for customized surveys whose data could be merged with core data sets).

For Science Policymakers and Funders

As a whole, science struggles with an inherent tension. Independent inquiry promotes innovation and competition of ideas, which has the potential to accelerate research progress and increase quality. However, coordination adds efficiency, enables the pursuit of broader strategic goals, and helps organize fields of inquiry.

Funding agencies are often tasked with maintaining this balance. In the physical sciences and engineering, it is more common to fund large scientific infrastructure projects. These projects provide a public good, centralizing large, fixed costs within a single public resource that can provide a foundation for smaller, more nimble inquiries unburdened with the need to spin up common capabilities for each project. Examples of natural science infrastructure are truly massive: NSF's National Radio Astronomy Observatory; the Integrated Ocean Observing System, which is funded by the National Oceanic and Atmospheric Administration, and 16 other federal agencies; NSF's Academic Research Fleet; the U.S. Department of Energy National Laboratories; and NSF's Big Data Regional Innovation Hubs. The data and analytic capacity produced by these facilities is beyond the scope of any specific research project, the resulting capabilities can be leveraged for diverse uses, and the scientific production facilitated by these resources is truly impressive.

Obviously, these resources come at substantial cost and (given limited resources) are funded in lieu of other, typically smaller, research opportunities. Large particle colliders, such as the Large Hadron Collider run by CERN (European Organization for Nuclear Research), are an example of such resources. CERN is proposing a new, even bigger collider whose budget would dwarf the almost $4.9 billion price tag of the Large Hadron Collider.[13] Such massive international investment provides unique capabilities to the physics research community, but this funding prioritization comes at a scientific opportunity cost. This cost applies to not only questions in physics but also many of our greatest "human" problems,

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[13] CERN, "Facts and Figures About the LHC," webpage, undated.

such as our response to climate change and massive economic and health disparities.[14] The challenge to funders is sensibly trading off the value of the public good that can be accomplished through these large scientific projects versus the opportunity cost of other research that could be supported with those funds, such as social sciences research.

Another aspect of this challenge is to avoid being captured by pressures toward honoring past expenditures. Rational decisions should be made based solely on expected future costs and benefits. That said, past expenditures (so-called sunk costs) are notoriously difficult to ignore cognitively or politically,[15] and large projects tend to have substantial momentum. This makes decisions to abandon scientific infrastructure particularly agonizing, as evidenced by recent deliberations regarding the Arecibo Observatory in Puerto Rico.[16] Mechanisms need to be in place to maintain, update, and decommission large infrastructure projects, as necessary, along with clear criteria for when to do so.

Ideas for Social Science Infrastructure

I propose ideas for potential social science infrastructure that are analogous to physical science infrastructure and discuss the advantages they offer.

Human Observatories: Readiness to Understand and Track Public Response to Emerging Events

Issues

Population surveys remain a key tool in understanding public response to emerging crises and other similarly disruptive events. Surveys are often the best (or only) source of key information about the public, such as risk perception, intention to engage in protective behavior, or social learning. In the social sciences, surveys play a role similar to that of sensing networks or observatories within the physical sciences, providing observations of conditions as they occur in the world. Although “social observatories” may or may not be designed for specific events, they have the potential to detect systemic change and adapt on the fly to emerging events. For example, major industrial accidents happen with some regularity, but the United States and Caribbean nations still were not prepared for the specifics of the 2010

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[14] Sabine Hossenfelder, “The World Doesn’t Need a New Gigantic Particle Collider,” *Scientific American*, June 19, 2020.

[15] Hal R. Arkes and Catherine Blumer, “The Psychology of Sunk Cost,” *Organizational Behavior and Human Decision Processes*, Vol. 35, No. 1, February 1, 1985; Barry M. Staw and Jerry Ross, “Commitment to a Policy Decision: A Multi-Theoretical Perspective,” *Administrative Science Quarterly*, Vol. 23, No. 1, 1978.

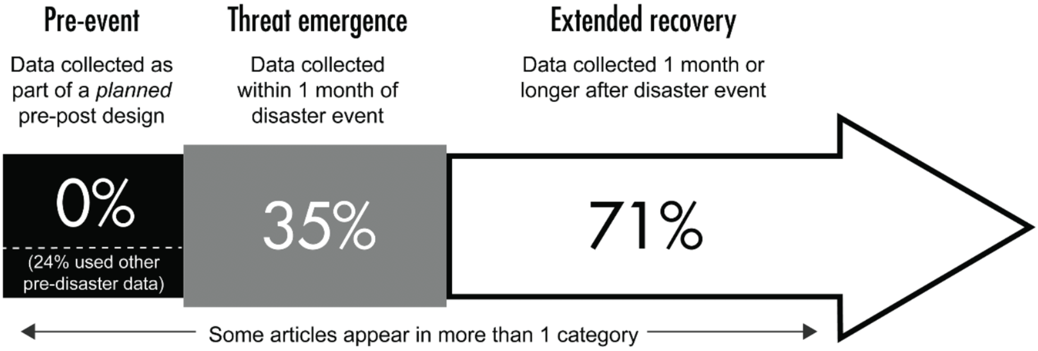
[16] Daniel Clery, “Arecibo Radio Telescope to Be Decommissioned,” *Science*, Vol. 370, No. 6520, November 27, 2020.

Deepwater Horizon oil spill. After the fact, multiple research groups highlighted the need for social and human health sensing capabilities to better learn from such events.[17]

Unfortunately, population-representative surveys that longitudinally track public responses to emerging events are rare. We reviewed 20 years (1998–2018) of peer-reviewed articles reporting on crisis-related surveys, covering diverse events (e.g., terrorist attacks, disease outbreaks, hurricanes).[18] Most surveys focused on narrow outcomes, such as mental health, rather than capturing the breadth of experiences with these events. As illustrated in Figure 8.1, only 24 percent involved pre-event data, and most of those data and samples were preexisting (i.e., collected for other purposes). None were planned pre-post designs. An older, well-known example involved the Chernobyl nuclear accident, which happened to occur during the fielding of a survey on nuclear power risk perception. This provided a natural pre-post comparison, but even here the survey had to be quickly adapted to address the crisis.[19] We cannot count on such coincidences to address such important issues.

FIGURE 8.1

Proportions of Journal Articles Published at Different Disaster Stages, 1998–2018



SOURCE: Reprinted with permission from Parker et al., 2020, p. 300, © Society for Disaster Medicine and Public Health.

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[17] Susan L. Cutter, Christopher T. Emrich, Melanie Gall, Sayward Harrison, Rachel R. McCaster, Sahar Derakhshan, and Erika Pham, *Existing Longitudinal Data and Systems for Measuring the Human Dimensions of Resilience, Health, and Well-Being in the Gulf Coast*, Washington, D.C.: Gulf Research Program, National Academies of Science, Engineering, and Medicine, June 2019; Paul Sandifer, Landon Knapp, Maureen Lichtveld, Ruth Manley, David Abramson, Rex Caffey, David Cochran, Tracy Collier, Kristie Ebi, Lawrence Engel, et al., "Framework for a Community Health Observing System for the Gulf of Mexico Region: Preparing for Future Disasters," *Frontiers in Public Health*, Vol. 8, 2020.

[18] Andrew M. Parker, Amanda F. Edelman, Katherine G. Carman, and Melissa L. Finucane, "On the Need for Prospective Disaster Survey Panels," *Disaster Medicine and Public Health Preparedness*, Vol. 14, No. 3, June 2020.

[19] Timothy L. McDaniels, "Chernobyl's Effects on the Perceived Risks of Nuclear Power: A Small Sample Test," *Risk Analysis*, Vol. 8, No. 3, 1988.

Furthermore, only 35 percent of the reviewed studies collected data within even the first month of the event, with most collecting data in the more extended recovery period. Only 17 percent leveraged contextual data from other sources, such as community characteristics from the American Community Survey. This lack of baseline data, quick-response surveys in the early stages of an event, and contextual data reveals a lack of readiness that could be addressed with pre-positioned research infrastructure. An illustrative example of the potential of this approach (but also its challenges) is provided by a recent study that quickly fielded a planned pre-post design documenting the effect of media coverage during 2018's Hurricane Irma on the mental health of those affected by the hurricane.[20] The researchers scrambled to field a survey in the days before landfall—a meaningful baseline but far from normality—and longitudinally tracked outcomes after the storm had passed. That this (very experienced) team was able to pull off such a design illustrates that such studies are possible, but their rarity shows how difficult such work is without pre-positioned resources.

Our experience with the NSF RAPID grants program, as implemented for COVID-19, also illustrates this problem. We are aware of at least four groups funded by RAPID grants, each to field surveys assessing public response to COVID-19 (in various ways, with various research goals). Each group took a different survey approach; however, the surveys were designed around available (and often redundant) resources and were often designed in redundant ways. Although the studies are all fielded by well-qualified teams and are producing valuable insights, as a whole, the collection illustrates the need for new research capabilities that, in a planned fashion, bring together social, behavioral, and economic data, at multiple scales, in diverse contexts, over periods that span disaster trajectories.

Solution

The solution to this problem likely takes the form of a large-scale panel study. Panels are standing collections of individuals, sampled through systematic and well-documented means, who regularly respond to surveys (typically for pay). Several large panels do exist in the United States for specific purposes. The Health and Retirement Study, funded by the National Institute on Aging and the Social Security Administration, and the Panel Study on Income Dynamics, funded by a variety of U.S. federal agencies, are good examples.[21] A survey panel would have the following advantages:

- Data and data-collection capabilities would be pre-positioned, which minimizes time between event onset and the beginning of event-related data collection.

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[20] Rebecca R. Thompson, E. Alison Holman, and Roxane Cohen Silver, "Media Coverage, Forecasted Posttraumatic Stress Symptoms, and Psychological Responses Before and After an Approaching Hurricane," *JAMA Network Open*, Vol. 2, No. 1, January 4, 2019.

[21] Health and Retirement Study, homepage, undated; Institute for Social Research, Survey Research Center, "Panel Study of Income Dynamics," webpage, undated-a; Institute for Social Research, Survey Research Center, "PSID Sponsors," webpage, undated-b.

- A well-designed infrastructure would adapt to events (e.g., allowing outside groups to field novel surveys to the panel; incorporating surge capacity through the ability to quickly add samples in key demographic or geographic groups).
- Because baseline data collection instruments are designed in advance to be relevant to multiple contingencies, they can explicitly track more dimensions than instruments designed post-event, providing increased opportunity for discovery.
- A stable infrastructure facilitates merging data across projects and events, allowing comparisons that are not possible in typical studies. In turn, this permits development and testing of more-sophisticated theories, such as feedback loops among socioeconomic factors.

In addition to the examples already provided, infrastructure capabilities could include data storage, data visualization, institutional review board review and survey capacity (the approval process can be a major source of delays), instrument designs, robust data collection capabilities (e.g., through apps that would be beyond the resources for smaller grants or contracts), and even interfaces with modeling and simulation capabilities. Such rigorously designed data collection platforms (i.e., designed data) can also prove critical for understanding biases in more-naturalistic data flows (i.e., "found" data, such as interactions on social media). As an example, we recently used a survey on another such panel, the RAND American Life Panel, to better understand the representativeness of beliefs expressed on Twitter regarding vaccine conspiracy theories and other beliefs.[22]

With the advent and increased prevalence of online survey panels, the feasibility of such an infrastructure within UGS is increasing. Online surveys rely on network connectivity, but surveys increasingly can be administered using low bandwidth or when bandwidth is unavailable (e.g., through software that downloads surveys onto a smartphone and automatically uploads answers when connectivity is restored). Online surveys can even be taken by individuals who have been displaced or have migrated because of conditions at home, with ancillary benefits of not exposing survey staff to unnecessary risk. In more substantially ungoverned spaces, other survey modes (phone, mail, in person) may be required, which would produce additional challenges.

This approach works best in locations (i.e., trouble spots) where there is some expectation that a degradation of governance will likely occur (e.g., the U.S. Gulf Coast during major hurricanes). In more-unforeseen events, adaptive infrastructure (e.g., for quickly recruiting and fielding surveys to geolocated Twitter users) may still allow for quick-response capabilities, but without baseline data.

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[22] Sarah A. Nowak, Christine Chen, Andrew M. Parker, Courtney A. Gidengil, and Luke J. Matthews, "Comparing Covariation Among Vaccine Hesitancy and Broader Beliefs Within Twitter and Survey Data," *PLOS One*, Vol. 15, No. 10, October 8, 2020.

Policy Testbeds: Readiness to Rapidly Understand Intervention Effectiveness

Empirical and simulation testbeds offer another set of capabilities that could be supported by social science infrastructure. These testbeds would facilitate systematic comparison of alternate interventions through either randomized control or simulation of counterfactuals. Creating such testing situations would involve a variety of techniques from different fields: randomized clinical trials, A/B testing, gaming, and testing for robustness. Such infrastructures would be akin to laboratories in the physical sciences, allowing detailed observation under tightly controlled situations.

Issues

Social and behavioral experimental research suffers from many of the same problems already outlined for surveys but has continued to be a critical tool for understanding human behavior.[23] Because the focus is on tight experimental control, as a means of isolating causality, *internal validity* (the extent to which the data are known to reflect causal mechanisms) is often maximized at the cost of *external validity* (the extent to which the data are representative of real-world phenomena). For many years in psychology, for example, subject pools made up of introductory psychology students have been the norm. This provides a ready, cheap, and flexible source of data, but limiting samples to students and college communities (the so-called town-gown problem) leaves questions of how well results generalize to other populations of interest and real-world contexts. Similarly, while the recent surge in the use of Amazon Mechanical Turk, a job-sourcing service, as a means of quickly and cheaply recruiting study participants offers, on the surface, many of the desired features of social science infrastructure, it has demonstrable problems with bogus responding, largely as a result of nonprobability sampling and incentives to participate in as many tasks as possible in as short a time as possible.[24]

Solution

A dedicated freestanding resource for recruiting participants and running experiments could ameliorate these validity problems. NSF supports this on a modest scale through a grant supporting Time-Sharing Experiments for the Social Sciences (TESS).[25] TESS provides a means to field online experiments using the National Opinion Research Center's AmeriSpeak panel—a probability-sampled survey platform that accurately represents the U.S. adult population. Opportunities to field experiments on TESS are competitive, but they are free

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[23] Susan D. Hyde, "Experiments in International Relations: Lab, Survey, and Field," *Annual Review of Political Science*, Vol. 18, No. 1, 2015.

[24] Courtney Kennedy, Nick Hatley, Arnold Lau, Andrew Mercer, Scott Keeter, Joshua Ferno, and Dorene Asare-Marfo, "Assessing the Risks to Online Polls from Bogus Respondents," Washington, D.C.: Pew Research Center, February 18, 2020.

[25] TESS, homepage, undated.

to selected research teams. However, the system is not designed to scale; bandwidth is limited by funding (at the moment, $1.7 million over four years), which is far less funding than for typical physical science infrastructure programs. However, with additional investment, the existing online platform could be moved into UGS. Alternately, data collection could be established locally, as has been done successfully by Christopher Blattman and colleagues within UGS,[26] but the lack of portability of those resources suggests that such approaches are more study-specific than infrastructure.

One intriguing possibility, which could be addressed through social science infrastructure, is whether policy can be selected and managed through randomized controlled experiments (as with clinical interventions). For example, researchers could study the effects of different food aid program designs on social and political instability.

As noted, human behavioral experiments often address internal validity, but they often have questionable external validity. Games might exist as a sort of middle ground between the two types of validity by bringing interacting people together in a synthetic environment; at best, they provide more external validity than a traditional lab environment by replicating more of the real-world decision environment while still allowing a degree of control for internal validity.[27] However, many games are not designed with formal concerns about validity in mind.[28] Furthermore, many games rely on elite samples and a great deal of customization, which makes it unclear how such an approach would scale.

Expanding the TESS approach to provide behavioral experimental infrastructure would have the following advantages:

- Centralized and subsidized testbeds could reduce cost and barriers to entry for diverse research teams.
- Communal access to novel capabilities (e.g., participation modes, networked subject interactions) and methodological expertise would open new and more robust research streams.

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[26] Christopher Blattman, Julian C. Jamison, and Margaret Sheridan, “Reducing Crime and Violence: Experimental Evidence from Cognitive Behavioral Therapy in Liberia,” Washington, D.C.: National Bureau of Economic Research, working paper, May 2015; Christopher Blattman and Jeannie Annan, “Can Employment Reduce Lawlessness and Rebellion? A Field Experiment with High-Risk Men in a Fragile State,” Washington, D.C.: National Bureau of Economic Research, working paper, June 2015; Christopher Blattman, Alexandra C. Hartman, and Robert A. Blair, “How to Promote Order and Property Rights Under Weak Rule of Law? An Experiment in Changing Dispute Resolution Behavior Through Community Education,” *American Political Science Review*, Vol. 108, No. 1, February 2014.

[27] Elizabeth M. Bartels, Igor Mikolic-Torreira, Steven W. Popper, and Joel B. Predd, *Do Differing Analyses Change the Decision? Using a Game to Assess Whether Differing Analytic Approaches Improve Decisionmaking*, Santa Monica, Calif.: RAND Corporation, RR-2735-RC, 2019.

[28] Erik Lin-Greenberg, Reid Pauly, and Jacquelyn Schneider, *Wargaming for Political Science Research*, Rochester, N.Y.: Social Science Research Network, SSRN Scholarly Paper, February 17, 2021.

- In cases with a clear value proposition, standardized infrastructure could be designed to specifically support multiple, specialized subject populations (e.g., elite professionals, geographically specified) for more-realistic tests.

Issues

A related concern is the inability to observe counterfactuals within naturalistic environments. In isolation, the occurrence of an undesirable outcome after a choice (e.g., getting the flu after either getting or not getting vaccinated) argues for switching behavior, regardless of the behavior. In contrast, the occurrence of a desirable outcome (e.g., not getting the flu) provides evidence for staying the course.

In life, we rarely get to experience the counterfactual—and, unlike with the flu, we often experience a given risk just once, which prevents learning how outcomes follow probabilistically from actions. Such decision contexts include risk-related choices regarding health (e.g., choice of cancer treatment), economics (e.g., federal revisions to monetary policy), and security (e.g., responses to sensor alarms). In the real world, we are stuck in our own time line.

Modeling and simulation (M&S) provide an avenue for observing distributions of outcomes, contingent on behaviors, to help grasp this counterfactual problem while taking into account many real-world complexities. Adaptive behavior, collective group dynamics, and social interactions can be modeled at both population and individual levels. However, M&S suffers from several challenges. Just as the survey and experimental research community tends to be siloed, so is the M&S research community, resulting in redundancy and lack of integration. Unlike behavioral experiments, simulation dynamics can be hard to observe. Even well-documented code can be unapproachable to all but the most sophisticated and determined of audiences. Finally, simulations are often hampered by ad hoc synthetic worlds and assumptions that limit both internal and external validity. Big investments are needed in micro-level data sets to provide external validation of model states and dynamics and provide confidence that existing models and data can be used when needs are dictated by current events.

Solution

M&S testbeds require a suite of computing, modeling, and data resources, but these resources are rapidly growing in exciting directions.[29] However, individual researchers and teams have differing levels of access to these resources, which limits scientific progress. Social science infrastructure could account for common fixed costs and provide standard and reusable building blocks (e.g., computing, software, tools) to make M&S faster and cheaper. Leveraging these building blocks against many projects would reduce the cost per project while pro-

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[29] See Chapter Sixteen (Robert L. Axtell, "Short-Term Opportunities, Medium-Run Bottlenecks, and Long-Time Barriers to Progress in the Evolution of an Agent-Based Social Science," in Aaron B. Frank and Elizabeth M. Bartels, eds., *Adaptive Engagement for Undergoverned Spaces: Concepts, Challenges, and Prospects for New Approaches,* Santa Monica, Calif.: RAND Corporation, RR-A1275-1, 2022).

viding more-robust and better resources (akin to TESS's ability to leverage a large probability-based sample rather than convenience samples).

Such resources are becoming more common, but they need to be expanded and become more widely available. For example, the National Dynamics and Simulation Science Laboratory at Virginia Tech generated a realistic synthetic population of a social network representing the full population of Portland, Oregon. For an agent-based model representing a population of people, this provides a much more realistic basis for modeling social interaction (e.g., compared with common simpler and stylized network structures). Such a data set could provide one resource for producing a simulation testbed that provided programming modeling tools, computing resources, and visualization and analysis capabilities to a broad variety of users.

An emphasis on broad application could also push such tools to be more flexible. Such broad applications could involve taking the model of Portland and translating it to a model of, for example, Lagos, Nigeria. Such infrastructure would also increase incentives to invest in transparency and documentation—addressing concerns, particularly among nonmodelers, about interpretability of results.

An M&S testbed would have the following advantages:

- Researchers could plan for model needs ahead of time or tap into the resources on an as-needed basis, without standing up basic building blocks each time.
- Hypotheses could be refined using formal models, with efficient consideration of alternate structures and parameters.
- Methodological stress testing could be done by simulating research designs for data collection and inferential problems, as could be done within the Defense Advanced Research Projects Agency's Ground Truth program.
- Models could be aligned with empirical approaches by first identifying promising interventions (either because they work or because they provide counterintuitive results in simulations), increasing the expected benefits of real-world experiments.

As noted by Robert L. Axtell in Chapter Sixteen,[30] the feasibility of more-sophisticated arrays of models and simulations (for example, through parallel processing) is increasing, with many exciting prospects on the horizon. This has great potential, if models of human dynamics within UGS can be brought to bear, potentially in tandem with real-world experimental studies (either in person or online).

Five Ways Social Science Infrastructure Would Add Value

Independent of the social science infrastructures chosen, infrastructure in general adds value, as I discuss next.

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[30] Axtell, 2022.

Efficiently Handling Most Common Fixed Costs Improves Access and Allows a Focus on Variable Costs

Perhaps the clearest case for investing in social science infrastructure is to centralize and establish common, core capabilities for implementing social science in quickly evolving situations. By foreseeing the need and putting in place resources for empirical data collection (e.g., instruments; data sources; tools for data integration, analysis, and visualization; mechanisms for quick institutional review board review) and M&S (e.g., data storage; computing capacity; basic, modifiable agent-based models; synthetic populations), the social science community can make the research process quicker, more efficient, and more cost-effective. Within empirical research on disruptive events, there is a critical need for *planned* pre-event baseline data that can be used as the basis for pre-post comparisons (which dramatically improves the ability to draw causal inferences) and for appropriate contextual data to account for situational factors that could moderate change. As argued earlier, research teams must typically build these capabilities *de novo*, rely on less-than-ideal comparison data (or simply do without), and create unnecessary, redundant efforts.

Such infrastructure also has the potential for training and technical support. It reduces cost of entry for less-resourced researchers and practitioners, who have been systematically excluded from many high-stakes research opportunities. Finally, resulting data and models could be made publicly available for additional users at no or limited cost.

Improving Infrastructure Promotes Research That Transcends Disciplines to Help Solve Societies' Most Vexing Problems

Such infrastructure can be the basis for broader insight on many of the most vexing problems revealed through disasters and other crises, such as maladaptive risk behavior, population displacement, social and economic disparities in crisis impacts, and the societal disruptions that result from these impacts. To have the most benefit and involve the broadest set of users and stakeholders, such infrastructure should incorporate the concepts of interdisciplinarity, multidisciplinarity, and convergence.[31] Such resources as panel studies, testbeds, data warehouses, and research networks are useful to multiple disciplines and actively bring them together. There is also a strong need to fund data and modeling together. Modeling will be far more effective if it draws on data that are designed to inform models than if it makes do with whatever data are available (and invariably designed for other purposes). Conversely, empirical data will be far more valuable if those data address a wider variety of user needs, including those of modelers.

Such infrastructure should be designed to test links across traditional disciplinary concepts—linking psychological (e.g., mental models for disaster risk), economic (e.g., incentives and constraints), and anthropological phenomena (e.g., how shared beliefs organize cul-

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[31] Phil Sharp and Susan Hockfield, "Convergence: The Future of Health," *Science*, Vol. 355, No. 6325, February 10, 2017.

tures) with physical and built environment systems (e.g., epidemiological dynamics, climate models). The results of such inquiry can motivate and test more-sophisticated theories, such as how risk materializes at different levels, with dynamic feedback in complex environments. The collaboration across disciplines also can increase measurement quality—especially in UGS where sensing might be harder—by incorporating multiple perspectives and methods.

Integrating Data at Multiple Scales and Linking Multiple Methods Adds Value

For maximum benefit, social science infrastructure should facilitate bringing together many types of data, on multiple scales and across diverse contexts, and do so in a planned fashion that creates both access and utility for many types of users. Figure 8.2 illustrates how three general types of data, typically generated by different types of researchers using different methods, can be brought together within an infrastructure both to inform each other and to build capabilities beyond the component parts.

Direct empirical data are collected for a specific research purpose from real-world sources. They offer focused measures, experimental control, and targeted samples, but they do so typically at a high cost per observation. *Indirect empirical data*, such as secondary and passively collected data, are often naturally occurring. Such data contain many available observations and wide intertemporal or geospatial coverage, but researchers have limited control over the timing and form of measurement. *Simulated data* are purposely generated through models presumed to reflect the real world or to illuminate specific real-world processes (e.g., an agent-based model could shed light on diffusion processes, even if the networks are clearly artificial). They use explicit causal structures and allow for fluid policy experimentation and observable macro dynamics, but they are at their heart synthetic and often difficult to visualize in the micro sense.

FIGURE 8.2
Value of Linking Three Types of Data

As shown in Figure 8.2, these three types of data can be leveraged against each other, bolstering validity and covering each other's weaknesses. Internal validity increases while moving up and to the right within the figure. In contrast, external validity increases while moving down and to the left. Cost per observation also varies. For example, direct empirical data collection has a relatively high marginal cost for each additional observation, whereas simulated data have a very high cost for the initial observation but a trivial cost going from the first to the *nth* observation. Low per-observation cost is generally an advantage of indirect empirical data, where large data sets are relatively economical to generate. Other methods, such as games, can have very high per-observation cost, keeping the available number of observations quite modest. In general, these relative strengths of the different types of data suggest that the value of each particular type can often be enhanced through links to other types.

Several projects conducted at RAND exemplify this approach, informing agent-based simulation models (of breast cancer and mammography, influenza and vaccination, and taxation and tax evasion) using targeted national surveys along with existing secondary data sets. The goal is to use empirical data sources where they are the best (or only) sources for defining key model features. This results in models with unusually informed parameters, allowing key policy insights.[32] For example, using the agent-based model's ability to simulate counterfactuals (which are not observable in the real world) and informing it by real-world empirical data on women's social networks and experiences with breast cancer, we were able to demonstrate a 14-percent excess demand for mammograms based solely on nonlifesaving detections (specifically, early-stage detections of cancers that would be detected but not lethal in the absence of screening).[33]

Better Infrastructure Permits a Long-Term View for Addressing Gaps in Collective Resources

Investment in social science infrastructure allows research communities and funders to take a long-term strategic view, complementing existing resources and addressing known gaps. For example, such a survey panel as that described would complement existing data warehousing services (e.g., at the Inter-university Consortium for Political and Social Research)[34] and organizations of disaster and risk professionals, such as the NSF-funded Social Science Extreme Events Research (SSEER),[35] Interdisciplinary Science and Engineering Extreme Events Research, and

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[32] Sarah A. Nowak, Luke Joseph Matthews, and Andrew M. Parker, *A General Agent-Based Model of Social Learning*, Santa Monica, Calif.: RAND Corporation, RR-1768-NIH, 2017.

[33] Sarah A. Nowak and Andrew M. Parker, "Social Network Effects of Nonlifesaving Early-Stage Breast Cancer Detection on Mammography Rates," *American Journal of Public Health*, Vol. 104, No. 12, 2014.

[34] Inter-university Consortium for Political and Social Research, "Data Management & Curation," webpage, undated.

[35] Natural Hazards Center, University of Colorado Boulder, "Sign Up for SSEER," webpage, undated-b.

CONVERGE networks,[36] which coordinate researchers in rapidly collecting ephemeral data during disasters but lack the capacity for large-scale, prospective, longitudinal assessment. Within the intersection of disasters, network science, and critical infrastructure, such resources include DesignSafe-CI,[37] the National Infrastructure Simulation and Analysis Center,[38] and the Data Science Institutes across the United States. Within the epidemiologic modeling community, the Modeling of Infectious Disease Agent Study (MIDAS)[39] network coordinates a set of loosely linked National Institutes of Health grants for common strategic goals.

Flexibility Aids in Responding to the Needs of a Wide Variety of Inquiries, Stakeholders, and Events

Finally, robust stakeholder engagement should ensure robustness to diverse research questions, questioners, and motivating circumstances. The infrastructure should be capable of contributing to basic science and translational research. Infrastructure also needs to have the capacity to adapt to emerging events, taking advantage of surprises rather than itself being disrupted by them. Accordingly, stakeholders should assess ongoing and unmet stakeholder needs (such as scientific, practitioner, and policy needs) and develop best practices and opportunities to build robustness in approach.

A strong evaluation component, built in from the start, can keep this use-inspired and adaptive focus. By incorporating an action logic model for effective evaluation and adaptation, infrastructure management can specify key decisions, contextual factors, and desired outcomes and use these to design activities to address user needs.[40]

Three Challenges to Successful Social Science Infrastructure

Realizing the advantages of social science infrastructure requires overcoming the following three challenges.

Addressing a Bias Against Funding Social Science Infrastructure

Infrastructure funding has typically been focused on the physical sciences and engineering rather than the social sciences. For example, of NSF's ten awards for midscale science infra-

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[36] Natural Hazards Center, University of Colorado Boulder, "CONVERGE," webpage, undated-a.

[37] DesignSafe, homepage, undated.

[38] Cybersecurity and Infrastructure Security Agency, "National Infrastructure Simulation and Analysis Center," webpage, undated.

[39] MIDAS, homepage, undated.

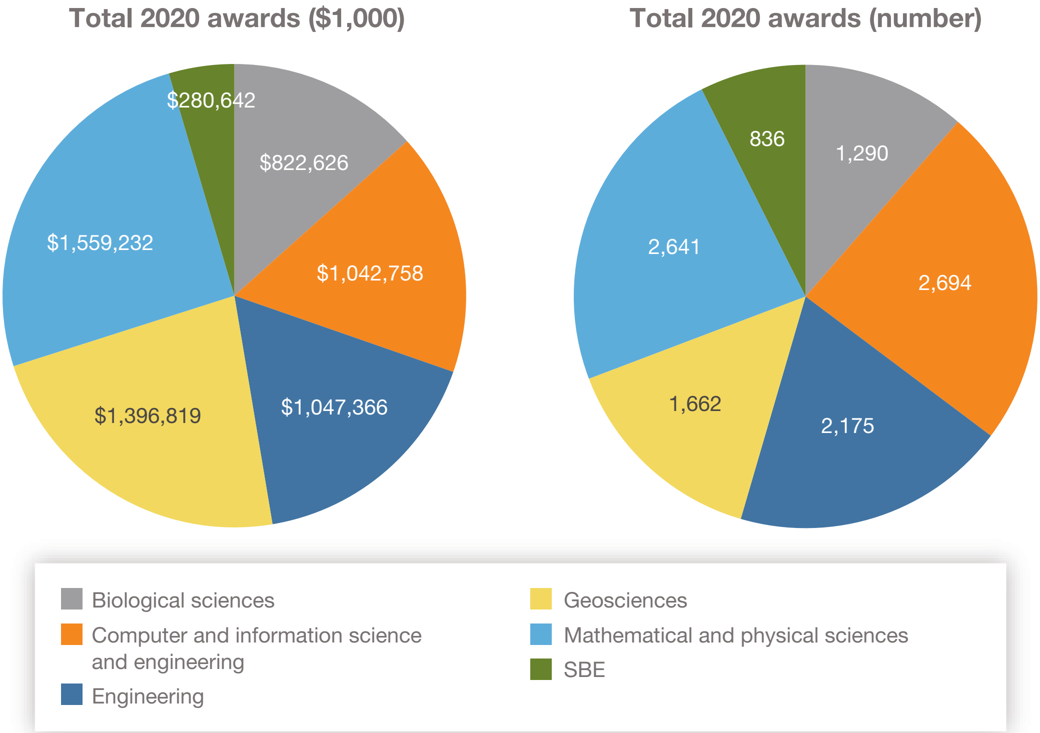
[40] Sue C. Funnell and Patricia J. Rogers, *Purposeful Program Theory: Effective Use of Theories of Change and Logic Models*, San Francisco, Calif.: Wiley, 2011.

structure in its last round of funding (which totaled just more than $116 million over five years), nine were awarded within the physical sciences and one within computer science.[41] No awards were within the social, behavioral, or economic sciences (SBE)—a lack of prioritization that also is reflected across all research support at NSF (Figure 8.3);[42] SBE accounted for about $280 million in funded grants in 2020, far less than other NSF directorates. By one estimate, the U.S. economic cost of the COVID-19 pandemic alone will be more than $16 trillion.[43]

This lack of support probably stems from a fallacy that critical multilevel problems are best solved at a physical, not a social, level. A specific example of this fallacy was the application of research funds to address the Deepwater Horizon oil spill. As part of a settlement, British Petroleum endowed the Gulf of Mexico Research Initiative with $500 million to "investigate

FIGURE 8.3

National Science Foundation 2020 Research Support by Directorate



SOURCE: National Science Foundation, undated-a.

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[41] National Science Foundation, "Mid-Scale Research Infrastructure-1," webpage, undated-b.

[42] National Science Foundation, "Budget Internet Information System," webpage, undated-a.

[43] David M. Cutler and Lawrence H. Summers, "The COVID-19 Pandemic and the $16 Trillion Virus," *JAMA*, Vol. 324, No. 15, October 20, 2020.

the effect of oil spills on the environment and public health."[44] Taking this mission at face value, it is multifold and multilevel. It addresses the physical oil spill itself, its impacts on the physical environment and organisms, and environmental mitigation strategies. However, this mission just as clearly involves assessing the social, economic, and health impacts of the spill; mitigating these impacts; building resilience among individuals, families, and communities against future threats; and determining the interdependencies among disaster impacts and nonlinear recovery paths.[45] In the end, only 4.2 percent of the funds awarded by the Gulf of Mexico Research Initiative went to SBE.[46]

Perhaps this funding bias reflects greater initiative by the physical sciences and engineering in seeking such funds; NSF proposal funding rates are not substantially lower for SBE than for other directorates. However, it might also reflect a bias for laying out substantial expenditures for tangible objects (vessels, buildings, equipment) over less tangible social science research capabilities and investments that create new patterns of practice that transform social, economic, and political systems.[47] Regardless, combating this status quo is a challenge for scientific communities and policymakers concerned with social, behavioral, and economic components of complex problems.

Capturing the Perspectives and Needs of Diverse Social Science Fields

An advantage that many physical sciences have over social sciences is the existence of unifying theories for which there is general agreement within and across fields. This makes the motivation and implementation of large-scale research infrastructure more straightforward. In contrast, social and behavioral sciences have a remarkable lack of consensus in theory, data, and interpretation—a challenge that exists both within and across social science fields. In this sense, it is harder for a given infrastructure project to serve a variety of constituencies equally well. Such projects as the long-standing Health and Retirement Study have addressed this by explicitly engaging a variety of stakeholders, such as scientists from economics, sociology, psychology, and anthropology. But typically, even these efforts are dominated by specific disciplines and funding priorities. That said, such examples speak to an opportunity here for the infrastructure itself to force discussions across disciplines and perspectives. This could

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[44] Gulf of Mexico Research Initiative, homepage, undated.

[45] Cutter, Boruff, and Shirley, 2003; Norris et al., 2008.

[46] Melissa L. Finucane, Aaron Clark-Ginsberg, Andrew M. Parker, Alejandro U. Becerra-Ornelas, Noreen Clancy, Rajeev Ramchand, Tim Slack, Vanessa Parks, Lynsay Ayer, Amanda F. Edelman, Elizabeth L. Petrun Sayers, Shanthi Nataraj, Craig A. Bond, Amy E. Lesen, Regardt J. Ferreira, Leah Drakeford, Jacqueline Fiore, Margaret M. Weden, K. Brent Venable, and A. Barrie Black, *Building Community Resilience to Large Oil Spills: Findings and Recommendations from a Synthesis of Research on the Mental Health, Economic, and Community Distress Associated with the Deepwater Horizon Oil Spill*, Santa Monica, Calif.: RAND Corporation, RR-A409-1, July 6, 2020.

[47] Hunter Heyck, *Age of System: Understanding the Development of Modern Social Science*, Baltimore, Md.: Johns Hopkins University Press, 2015.

involve discussion of scope, research design, instrumentation, analytic capabilities, and oversight mechanisms. In this sense, such infrastructure may itself be a mechanism for promoting overarching theoretical and methodological commonality. It is also an opportunity for fields to capitalize on advances and capabilities from other fields, such as psychology's emphasis on measurement (through psychometrics) and economics' emphasis on analysis causality through quasi-experimental and observational designs (through econometrics).

Promoting Effective Management, Adaptation to Emerging Trends, and Sustainability

One potential criticism of large infrastructure investment is that the substantial cost can create psychological and political escalation of commitment, which can lead to entrenchment and resistance to change. Flexibility and ability to adapt to new and emerging trends is critical for the value of long-term infrastructure, and, although standardization (e.g., of variables, of models) can facilitate comparison, regular review should attend to the risk of stagnation, especially when the focus is on the wrong things. Robust stakeholder engagement and active evaluation are both safeguards in ensuring adaptiveness and alignment with evolving needs. A robust and user-facing evaluation component is equally critical, which should use well-defined evaluation criteria.

Sustainable funding is another possible stumbling block. Importantly, some funders might be willing to fund implementation of new infrastructure but might balk at the prospect of bearing the cost to maintain that infrastructure over time. Therefore, proposers of infrastructure funding should come to the table with concrete plans for sustained funding. A broad coalition of stakeholders can create a more robust funding environment. This could involve researchers supporting infrastructure in competitive grant applications designed to use that infrastructure, universities and research societies investing in strategic collaborations, and federal agencies addressing their core missions. For example, the Federal Emergency Management Agency, Centers for Disease Control and Prevention, and National Oceanic and Atmospheric Administration could collaborate for disaster research. It could also involve strategic partnerships with other facilities (e.g., supercomputer centers, big data hubs). The U.S. Department of Defense has existing models for developing and transitioning basic research (e.g., Collaborative Technology Alliances within the Army), which could leverage such infrastructures. These infrastructures could also be aligned with the National Defense Strategy; for example, regional or domain components could be built through a Central Command country survey panel. Proposers and funds should also consider novel business models, involving academia, business, nonprofits, and government. Subscription services could provide the media with fluid access to data summaries. Specific products could be designed for local, state, and federal partners. Derivative products could be commercialized through partnerships with businesses.

Proposers and funders should both be aware that the focus inspired by a specific crisis will wane with time. We saw this following the H1N1 pandemic: Research and preparedness investments initially surged during the pandemic but declined as time progressed. As a result, readiness for COVID-19 was severely limited; maintaining this readiness for future crises will be a key challenge.

Concluding Thoughts

Research, as a whole, is typically slow and deliberative. This deliberative pace is particularly striking when researchers are trying to marshal resources and funding in response to disasters and other emerging events. Existing funding opportunities, such as rapid grant mechanisms, offer only a limited solution. Understanding the impact of such events requires suitable comparison data, such as pre-event baselines, but rapid grants are by their very nature reactive to events (rather than prospective). This lack of existing resources and nimbleness severely limits scientists' ability to learn from surprises.

The physical sciences and engineering have partly addressed these challenges through investments in observatories, sensing networks, and other standing research infrastructure, which provide them with resources to identify impacts more effectively. There is a need within SBE for similar infrastructure investments to tackle some of the most vexing scientific and societal problems that result from complex and disruptive events.

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Abbreviations

COVID-19	coronavirus disease 2019
M&S	modeling and simulation
MIDAS	Modeling of Infectious Disease Agent Study
NSF	National Science Foundation
RAPID	Rapid Response Research
SBE	social, behavioral, or economic sciences
TESS	Time-Sharing Experiments for the Social Sciences
UGS	undergoverned spaces

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