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A Framework for Convergence Research in the Hazards and Disaster Field: The Natural Hazards Engineering Research Infrastructure CONVERGE Facility

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The goal of this article is twofold: to clarify the tenets of convergence research and to motivate such research in the hazards and disaster field. Here, convergence research is defined as an approach to knowledge production and action that involves diverse teams working together in novel ways – transcending disciplinary and organizational boundaries – to address vexing social, economic, environmental, and technical challenges in an effort to reduce disaster losses and promote collective well-being. The increasing frequency and intensity of disasters coupled with the growth of the field suggests an urgent need for a more coherent approach to help guide what we study, who we study, how we conduct studies, and who is involved in the research process itself. This article is written through the lens of the activities of the National Science Foundation-supported CONVERGE facility, which was established in 2018 as the first social science-led component of the Natural Hazards Engineering Research Infrastructure (NHERI). Convergence principles and the Science of Team Science undergird the work of CONVERGE, which brings together networks of researchers from geotechnical engineering, the social sciences, structural engineering, nearshore systems, operations and systems engineering, sustainable material management, and interdisciplinary science and engineering. CONVERGE supports and advances research that is conceptually integrative, and this article describes a convergence framework that includes the following elements: (1) identifying researchers; (2) educating and training researchers; (3) setting a convergence research agenda that is problem-focused and solutions-based; (4) connecting researchers and coordinating functionally and demographically diverse research teams; and (5) supporting and funding convergence research, data collection, data sharing, and solutions implementation.

Keywords: convergence research, natural hazards, disasters, interdisciplinary, transdisciplinary, training, Science of Team Science, research coordination networks

INTRODUCTION

This article offers a definition and framework for bringing *convergence research* to the field of hazards and disasters. Drawing on insights from several foundational publications and extending them to our field, we define convergence research as:

> *An approach to knowledge production and action that involves diverse teams working together in novel ways—transcending disciplinary and organizational boundaries—to address vexing social, economic, environmental, and technical challenges in an effort to reduce disaster losses and promote collective well-being.*

Understanding and managing the convergence of people, supplies, and information has long been of interest to disaster researchers and practitioners (Prince, 1920; Fritz and Mathewson, 1957; Quarantelli and Dynes, 1977). Our focus here, however, is not solely on convergence as a post-disaster phenomenon. Rather, our goal is twofold: (1) to clarify the tenets of convergence research and (2) to motivate such research in the hazards and disaster field.

The hazards and disaster field – which has a well-established history of encouraging inclusive forms of multidisciplinary research (Kendra and Nigg, 2014) as well as of supporting distinctly problem-focused approaches to science and engineering (White and Haas, 1975; Mileti, 1999; Pulwarty et al., 2009) – is poised intellectually and institutionally to advance convergence research. In fact, from the inception of the field, studies have concentrated on issues of great practical and societal concern (White and Haas, 1975; Quarantelli, 1987). This has led to insights – ranging from risk communication to recovery – that have had a meaningful influence on emergency management practice and, in some cases, local, state, and federal policy (Mileti, 1999; Tierney et al., 2001; Birkland, 2006; Olson et al., 2020).

Yet knowing more has not helped to contain disaster-related losses such as property damage, direct and indirect economic costs, population displacement, and other socially and financially harmful disruptions. Burton (2018) offers various explanations for this "knowing more-losing more" paradox, including the settlement and growth of populations in risky areas, the expansion of the global economy, the onset of climate change, inadequate knowledge mobilization frameworks, and, especially, unchecked disaster risk creation in capitalist markets. In addition, social and economic inequality have left more people in harm's way with fewer resources available to prepare for, respond to, and recover from disaster (Fothergill and Peek, 2004; Verchick, 2010). Hazards-related damages and biased disaster policies may further widen wealth inequalities – especially along lines of race, education, and homeownership – rendering already marginalized population groups more vulnerable to future crises (Howell and Elliott, 2018).

Rising risks and losses demand a new approach to extreme events research that focuses on the interconnections between technical, ecological, social, cultural, political, and economic systems. Such an approach must involve researchers from a wide range of disciplines and historically underrepresented groups, such as women and racial and ethnic minorities. This will help ensure that diverse perspectives and paradigms are brought to bear to respond to pressing challenges through elevating research outcomes designed to promote collective well-being. In this context, collective well-being is defined as a community's measured and perceived social and physical health across the domains of vitality, opportunity, connectedness, contribution, and inspiration (Roy et al., 2018).

Convergence, with its focus on *deep integration across disciplines* and *research driven by a specific and compelling problem,* offers a possibility for moving forward as a field (National Science Foundation [NSF], 2019). Convergence requires interdisciplinary or even transdisciplinary approaches. But it also goes beyond these approaches through offering a framework where members of the hazards and disaster research community come together to characterize the mounting threats communities face and, importantly, identify specific actions that will reduce the historical and socio-technical problems, inequalities, and injustices that turn natural hazards into disasters. It is this focus on problem identification and especially solutions implementation that distinguishes convergence research from interdisciplinarity and transdisciplinarity, even though they are each closely interrelated.

For the sake of conceptual and theoretical clarity, we proceed with a brief review of the literature on convergence in disasters. We then offer an overview of the recent turn toward convergence research in other disciplines including those in the life sciences, physical sciences, and engineering. The remainder of the paper is dedicated to describing a novel framework for convergence research through the lens of the activities of the National Science Foundation-supported CONVERGE facility. Convergence research and the Science of Team Science undergird the work of CONVERGE, which is led by a social scientist and brings together networks of researchers from geotechnical engineering, the social sciences, structural engineering, nearshore systems, operations and systems engineering, sustainable material management, and interdisciplinary science and engineering. CONVERGE is the specific component of the Natural Hazards Engineering Research Infrastructure (NHERI) that is dedicated to advancing convergence research. As such, we describe CONVERGE and offer illustrative examples of how its associated activities and research coordination networks are supporting convergent approaches that are ethical, collaborative, holistic, and scientifically rigorous.

BACKGROUND

Convergence behavior has long been of interest to hazards and disaster researchers. As this section demonstrates, however, the more recent process-oriented and research-based definition of convergence differs from the ways that convergence has historically been conceptualized and studied in disaster research. Both uses of convergence, however, evoke an image of people or things coming together for a common purpose. They also both draw from the same Latin root, *convergere: con-* = together + *vergere* = to incline. In other words, to be inclined toward each other.

Convergence Behavior in Disasters

Fritz and Mathewson (1957), both pioneers in the social scientific study of disasters, published the first comprehensive report on the topic of convergence behavior in disasters. They defined convergence as the "mass movement of people, messages, and supplies toward the disaster struck area" (p. 1). They distinguished between "external convergence," which involves "movement toward the disaster-struck area from the outside," and "internal convergence," or the "movement toward specific points within a given disaster-related area or zone" (p. 3). They were especially concerned with characterizing and understanding how to control three major types of informal, unofficial, and unauthorized convergence, which they defined as: (1) personal convergence: the actual physical movement of persons on foot, by car, or by other mode of transportation, (2) informational convergence: the movement or transmission of messages, and (3) materiel convergence: the physical movement of supplies and equipment (p. 4).

Although the field was still in its nascent stages, Fritz and Mathewson (1957) asserted that convergence is so common that it should be considered a "virtually universal phenomenon following disasters" (p. 1). Decades of subsequent disaster research has proven these words prescient, as researchers have documented convergence behavior in the aftermath of floods (Neal, 1994; Arnette and Zobe, 2015; Montano, 2015), earthquakes (Subba and Bui, 2010, 2017; Holguín-Veras et al., 2012), hurricanes (Holguín-Veras et al., 2007; Wachtendorf et al., 2013; Schumann and Nelan, 2018), terrorist attacks (Sutton, 2002; Steffen and Fothergill, 2006; Kendra and Wachtendorf, 2016), humanitarian emergencies (Black, 2003), and numerous other disasters across the United States and globally (Tierney et al., 2001; Holguín-Veras et al., 2014). Researchers have also extended Fritz and Mathewson's (1957) classic typology, offering additional categories of convergence behavior in the context of various hazard types (Kendra and Wachtendorf, 2003; Subba and Bui, 2010, 2017).

Convergence Research

In the early twenty-first century, new approaches to research began to take root. Researchers with backgrounds in engineering, biology, and chemistry started more regularly joining forces to harness technological and scientific advances and accelerate their implementation (Bainbridge and Roco, 2016). The key to this type of progress is *convergence,* a research concept that was introduced and elaborated in a series of foundational publications (Roco, 2002; Roco and Montemagno, 2006; Roco and Bainbridge, 2013). In that literature, convergence has been defined most generally as "an approach to problem solving that cuts across disciplinary boundaries. It integrates knowledge, tools, and ways of thinking from life and health sciences, physical, mathematical, and computational sciences, engineering disciplines, and beyond to form a comprehensive synthetic framework for tackling scientific and societal challenges that exist at the interfaces of multiple fields" (National Research Council [NRC], 2014, p. 1).

In 2016, the National Science Foundation (NSF) named "Growing Convergence Research" as one of its *10 Big Ideas* for prioritizing future investments in science and engineering. In an associated program solicitation, the NSF (2019) identifies convergence research as having the following two primary characteristics (see **Figure 1**).

Examples of the first characteristic – research driven by a specific and compelling problem – abound in a broad array of sectors. In the realm of infectious disease, for instance, the threat of Zika accelerated convergence approaches that brought together immunologists, engineers, chemists, and biologists who developed techniques that can alter the genetic structure of mosquitos. This has introduced the possibility of eliminating the vectors for Zika as well as dengue and perhaps even malaria (Sharp et al., 2016b, p. 31). Researchers with backgrounds in structural engineering, biology, and chemistry are generating new organic materials that would allow buildings to self-heal their own cracks after disaster strikes (Heveran et al., 2020). In biomedical fields, researchers are working on improved disease detection, new drug delivery mechanisms, and new capabilities to modify genetic disorders (MIT Washington Office, 2011, p. 4). Physicians now partner with engineers and computer scientists to use 3D printing technologies to develop customized joint implants for a broader range of body types as well as other medical devices such as hearing aids and dental implants (National Research Council [NRC], 2014, p. 33–34). Rapid advancements in the biomedical sciences have hastened calls for additional convergence investment in the areas of energy,

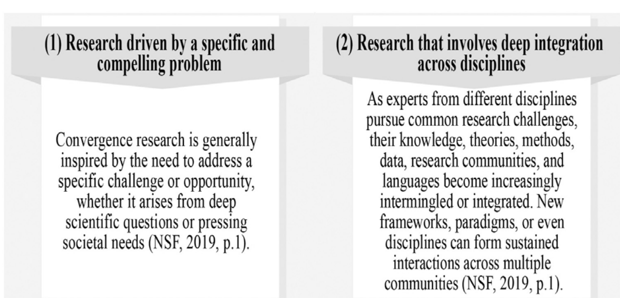

FIGURE 1 | Primary characteristics of convergence research.

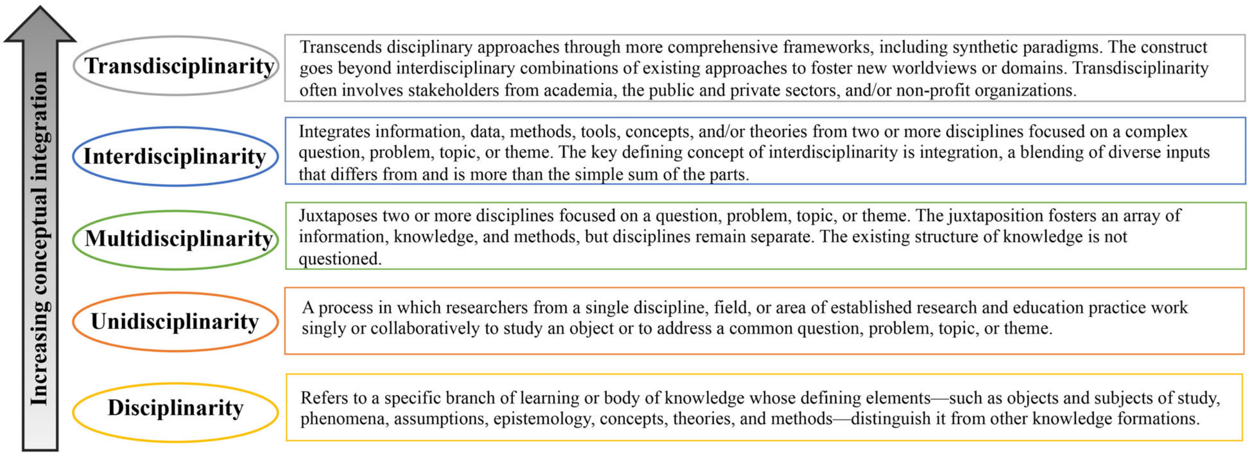

FIGURE 2 | Conceptual degrees of disciplinary integration.

food, climate, and water (National Research Council [NRC], 2009), geosciences (McNutt, 2017), health care (Sharp et al., 2016a), psychiatry (Eyre et al., 2016), and, now, hazards and disaster research.

The demand for the second characteristic – deep integration across disciplines – highlights the need for novel approaches to knowledge creation that are relevant to increasingly complex problems. This means that "convergence goes beyond collaboration" and requires the integration of historically distinct areas of inquiry into a "unified whole that creates new pathways and opportunities" (Sharp et al., 2016a, p. 1522). A report from the National Research Council [NRC] (2014, p. 45–46) offers a synthetic typology to represent such increasing degrees of conceptual integration across disciplinary boundaries (see **Figure 2**).

Promoters of convergence acknowledge that the principle of researchers acquiring a depth of knowledge *within* established disciplines remains vital to scientific progress (Sharp and Langer, 2011). But convergence also entails comprehensive integration *across* disciplines. Interdisciplinarity and especially transdisciplinarity, therefore, are most often upheld as the desired states for convergence efforts to thrive (Eyre et al., 2016). Bainbridge and Roco (2006b, p. x) point out that the goal of such integration is not to "create and enforce some kind of new 'orthodoxy' in science and engineering," but, rather, "to nurture all the legitimate connections between fields."

Convergence Gaps and Barriers

Sharp and Langer (2011, p. 527) identified convergence as the "third revolution" in the biomedical sciences (molecular biology and genomics represent the other two major revolutions). Convergence has clearly transformed the ways that researchers are leveraging computational and technological innovations and merging insights from historically distinct disciplines in the life sciences, physical sciences, and engineering (MIT Washington Office, 2011; Sharp et al., 2016b). The National Research Council [NRC] (2014, p. 14) acknowledges, though, that the "social sciences and humanities are undertapped resources for convergence efforts."

The fact that the social sciences and humanities have received limited attention in the rapidly growing convergence literature represents an important gap (although for exceptions, see: Bainbridge and Roco, 2006a; Roco et al., 2013). Many of the grand challenges that have been identified as of pressing concern – ranging from health care access to environmental degradation – are, at their core, moral, ethical, social, and political problems that require the expertise of those skilled in the study of culture, history, policy, finance, and human behavior. This means that disciplines such as anthropology, philosophy, history, economics, political science, sociology, geography, and psychology could play a central role in advancing the convergence revolution. This will not only broaden the horizons of scientific inquiry and discovery; it could also help to mitigate the unintended consequences of issuing *technical fixes* for what are *fundamentally human problems.*

The convergence revolution has ushered in a fresh vision for how scientific and technological progress can be accelerated through transdisciplinary teams coming together to solve grand challenges for the expressed benefit of society. Bainbridge and Roco even claim that the "future welfare of humanity depends upon mastering... emerging technologies and devoting them to positive applications" (2006b, p. ix). But as Olson et al. (2020, p. 7) convincingly argue, the principal disaster risk reduction (DRR) challenge "is no longer purely the scientific understanding of hazards... nor is it so much the planning, architecture, engineering, or even the social science knowledge required to reduce or at least better manage risk." From their perspective, the principal DRR challenge "now falls primarily in the policy and implementation realms and... in building increased public support for decision-makers and political leaders to champion stronger and more consistently applied DRR policies and programs."

Even when there is political will, identifying solutions to the many problems facing humanity is difficult and could even be potentially harmful. As social scientists who study the intended and unintended consequences of technical interventions have observed, a seemingly brilliant solution for one issue can create an entirely new challenge. For instance, curbing climate emissions through taxation can provide an incentive for behavioral change, but it may further disadvantage poor people, rural citizens, and other marginalized populations. These are not just hypotheticals. Consider the Yellow Vest movement in France, where working-class protesters took to the streets to rally against government-backed emissions reduction standards that caused fuel prices to skyrocket (Kinniburgh, 2019). A recent conflict in Portland, Oregon, also illustrates this point. There, efforts to save lives through the retrofit of unreinforced masonry churches, businesses, and homes for earthquakes simultaneously threatened to disenfranchise and displace African Americans and other communities of color with long histories of dispossession (Njus, 2019).

The aforementioned examples illustrate how fraught "problem-driven" and "solutions-based" approaches to science and engineering can be. This is especially true when there is a lack of diversity within the teams devising the approaches (Hong and Page, 2004; Homan et al., 2007; Horowitz and Horowitz, 2007). This suggests that as the convergence revolution progresses, it must continue to encourage and incentivize diversity in many forms, including *functional diversity* in problem-solving approaches and *identity diversity* in the demographic, cultural, and geographic backgrounds of researchers (National Research Council [NRC], 2014, p. 64). Focusing on inclusion along these varying dimensions can help ensure that existing social injustices and inequalities are not further exacerbated and instead can be addressed in the process of searching for solutions to problems.

In addition to these broader challenges to convergence, there are also structural barriers that threaten to diminish the potential for transformational transdisciplinary research. A report focused on convergence in the biomedical sciences identified two major underlying problems associated with the advancement of convergence research: "(1) a shortage of workers with capabilities in convergence scientific, medical, bioengineering fields, and (2) inadequate [corporate and government] funding for early stage research" (Sharp et al., 2016b, p. 56). The authors cite related challenges associated with siloed agency structures and missions, institutional structures that do not reward cross-disciplinary work, narrow and restrictive grant review processes, and shortcomings in STEM-related education – from grades K-12 through the university-level.

An earlier National Research Council report on convergence identified many similar challenges in advancing convergence research, and advocated for the following correctives: (1) establishing effective organizational cultures, institutional structures, and governance systems; (2) addressing faculty development and promotion needs; (3) creating effective and holistic education and training programs; (4) forming diverse stakeholder partnerships; and (5) obtaining sustainable funding (National Research Council [NRC], 2014, p. 60–62). In each instance, the authors offer specific recommendations and strategies for how institutional resources can be applied to help overcome longstanding challenges, while also acknowledging that the various barriers to convergence echo those described by interdisciplinary and transdisciplinary team members more generally.

Convergence and the Science of Team Science

Early as well as more recent convergence publications focus heavily on *what* new innovations and trends in science should be pursued and the economic or societal benefits associated with them (Roco, 2002; Bainbridge and Roco, 2006a; Roco and Bainbridge, 2013). The lessons developed by researchers advancing the Science of Team Science (SciTS) can inform the *who* and *how* of convergence research while also helping to overcome some of the identified barriers.

Scholars in the SciTS examine the "processes by which scientific teams organize, communicate, and conduct research" (Börner et al., 2010, p. 1). This emergent field recognizes that teams vary not only in terms of their research goals, but also in their disciplinary composition, size, geographic scope, organizational complexity, levels of intellectual integration, and translational capacity (Stokols et al., 2008a). Ultimately, SciTS helps to understand "*how teams collaborate to achieve scientific breakthroughs that would not be attainable through either individual efforts or a sequence of additive contributions*" (Falk-Krzesinski et al., 2011, p. 146, emphasis added).

Although the term emerged in 2006, SciTS is in many ways a continuation of a body of research on teams that dates back to the well-known Hawthorne studies of the late 1920s and early 1930s (Mathieu et al., 2018). SciTS also builds on the "sociology of science," a research enterprise that began in the 1960s (Merton, 1973) and included studies that illuminated how scientists work together to publish (De Solla Price, 1965) and share knowledge across "invisible colleges" (Crane, 1972). These precursors to SciTS provided foundational insights regarding who was involved in the scientific enterprise and how they collaborated (or not) to conduct research. Since the 1980s, scholars have raised concerns that highly specialized approaches to science and scientific training are insufficient to solve increasingly complex contemporary problems (Hollingsworth, 1984). Pioneers in what would become the field of SciTS spent the next decade researching how to make multidisciplinary, interdisciplinary, and transdisciplinary research a reality so that various problems could be more readily addressed (Klein, 1991, 1996; Committee on Facilitating Interdisciplinary Research, 2004; Epstein, 2005; Hadorn et al., 2008).

Drawing heavily on this body of social and behavioral science research on group dynamics and interpersonal processes, SciTS researchers address both *micro-level team processes* associated with team member familiarity and social cohesiveness, team size, leadership traits and behaviors, goal setting, communication patterns, and task and outcome interdependence, as well as more *macro-level conditions* such as organizational support, institutional reward structures, histories of collaboration, and distributions of power and control across team and institutional boundaries (Hall et al., 2008, 2018; Stokols et al., 2008a). SciTS researchers have also studied many of the challenges that can impede the work of diverse research teams and have offered clear advice for how to overcome them (Cooke and Hilton, 2015).

Convergence researchers can learn from SciTS research how to create inclusive research teams and how team composition affects performance (Guimerà et al., 2005; Contractor, 2013; Zhu et al., 2013; Lungeanu et al., 2014). Managing diverse research teams often requires new forms of leadership, which is another area of inquiry pursued by SciTS researchers (Bammer, 2008; Gray, 2008; Adams et al., 2012). SciTS researchers have also explored how communication processes work in teams and how to develop shared languages and meanings that enable researchers to bridge disciplinary divides (Eigenbrode et al., 2007; Klein, 2014; Hardy, 2018).

While leadership and communication are vital to functioning teams, other elements related to the context in which scientific teams work can also shape project outcomes (Stokols et al., 2008b). As previously noted, institutions can either hamper or cultivate convergence research, and existing SciTS research has illuminated how multi-university research collaboration works and why certain types of universities tend to have higher success rates with this approach (Cummings and Kiesler, 2007; Jones et al., 2008).

Existing SciTS research offers a roadmap for how to measure knowledge integration within convergence research projects (Wagner et al., 2011). Insights from SciTS researchers who have developed evaluation systems for interdisciplinary and transdisciplinary research can assist convergence researchers in developing quantitative and qualitative measures that account for the goals, objectives, and benchmarks of success of teams comprised of researchers with diverse backgrounds (Defila and Di Giulio, 1999; Klein, 2008).

The SciTS has garnered much scholarly attention and momentum over the past decade, in large part because this approach helps to establish not only how and why teams work, but how they can work more effectively together to generate rigorous scholarship (Fiore, 2008). As a case in point, an analysis of more than 17 million publications in the Web of Science found that teams not only produce more research, but also generate higher impact research (Wuchty et al., 2007). Teams are more likely to combine knowledge in atypical ways that lead to scientific breakthroughs that can help address vexing problems (Fiore, 2008; Uzzi et al., 2013). The SciTS is therefore an essential partner to convergence progress.

A FRAMEWORK FOR CONVERGENCE RESEARCH IN THE HAZARDS AND DISASTER FIELD

Even with the potential challenges and barriers in mind, we believe the hazards and disaster field is poised to advance convergence research while also benefiting from the adoption of its core tenets. Researchers in the field have already employed what McNutt (2017, p. 2) refers to as "convergent-like" approaches. She observes, for example, "the remarkable reduction in earthquake fatalities in nations such as Japan, Chile, and the United States is the result of convergent-like research partnerships between geologists, seismologists, earthquake engineers, architects, social scientists, and public officials. These partnerships have resulted in improved maps of earthquake risk areas, estimates of strong ground motion, engineering designs for earthquake resistant structures, and revised building codes compliant with those designs" (McNutt, 2017, p. 2–3).

Similarly, the reductions in loss of life from weather-related hazards can be attributed to "convergent-like" collaborations between meteorologists, sociologists, psychologists, transportation engineers, urban planners, geographers, wind engineers, architects, and emergency managers. These multidisciplinary and cross-organizational partnerships have led to more timely and accurate weather forecasting, a sustained focus on socially vulnerable populations, more effective risk communication and evacuation strategies, wise land use planning in hazard-prone areas, enhanced engineering designs for wind resistant structures, and more stringent building codes and standards (see Gruntfest, 2018; Lindell et al., 2019; Laska, 2020).

So, have hazards and disaster researchers already been engaging in convergence? To answer that question, we return to the definition that we offered previously for convergence research for the field, now with several key elements underscored:

> *An approach to <u>knowledge production and action</u> that involves <u>diverse teams</u> working together in novel ways—<u>transcending disciplinary and organizational boundaries</u>—to address <u>vexing social, economic, environmental, and technical challenges</u> in an effort to <u>reduce disaster losses and promote collective well-being</u>.*

The aforementioned examples, as well as many others that we could draw on from the field, represent research designed with a compelling challenge in mind – the reduction of loss of life and property and the lessening of societal disruption from natural hazards. An ever-growing number of studies have expanded the evidence base. And although success at actually reducing disaster impacts varies widely at more granular scales, generally speaking, loss of life globally has lessened as economic costs have increased (Wallemacq and House, 2018).

Much of the work in the hazards and disaster field also involves cross-disciplinary and cross-organizational collaborations. But most approaches in the field remain "convergent-like" rather than representative of "true convergence" because they are not advancing solutions nor are they reflective of interdisciplinarity or transdisciplinarity in action. In each of the prior examples, the disciplinary contributions are still readily apparent – it is the urban planners and geographers who lead land use planning efforts, the engineers who develop designs for earthquake- or wind-resistant structures, the psychologists and sociologists who produce the frameworks for risk communication that are then adopted by public officials and analyzed by policy studies experts. These are, of course, laudable efforts that illustrate the powerful contributions of a range of disciplines.

A convergence framework, however, is designed to move beyond additive contributions from distinct disciplines. Again, one of the goals of convergence is to cultivate researchers who have deep disciplinary expertise (depth) and are also well-versed in other disciplines (breadth). Convergence also requires cultures, systems, and institutions that facilitate diverse teams of researchers coming together to learn and conduct integrative studies that are solutions oriented (Nash, 2008; Read et al., 2016). The level of integration that is necessary to achieve interdisciplinarity and transdisciplinarity in research is difficult and time consuming (Kendra and Nigg, 2014; Davidson, 2015), although recent scholarship signals a possibility for a turn toward convergence research. Indeed, a number of contemporary publications focused on interdisciplinarity in the hazards and disaster field detail novel methodological approaches (Reilly et al., 2018; Gharaibeh et al., 2019; Wong-Parodi and Smith, 2019; DeRouen and Smith, 2020), new theoretical frameworks (Sherman-Morris et al., 2018; Subedi et al., 2018; Sutley, 2018; Mostafavi and Ganapati, 2019; Olson et al., 2020), team-based interventions to facilitate the research process itself (Ganapati and Mostafavi, 2018; Morss et al., 2018; Tate et al., 2018; Ge et al., 2019; Gilligan, 2019; Moezzi and Peek, 2019), and advancements in policy implementation and practice (Berke et al., 2018; Sapat, 2018; Johnson, 2019).

The interdisciplinary disaster science degrees offered at the University of Delaware and University of North Texas, for example, are representative of what is possible when social scientists, engineers, policy analysts, emergency managers, and others co-create educational programs that encourage the deep collaboration that convergence calls for. Similarly, the Center for Risk-Based Community Resilience Planning, a National Institute of Standards and Technology Center of Excellence, has methodologically cross-trained well over 100 engineers and social scientists as part of their expansive interdisciplinary program of research (van de Lindt et al., 2020). Over time, if such integrative activities are supported and successful, they can take root and perhaps grow into an entirely new transdisciplinary space (see **Figure 3**). One example of where this has happened is molecular biology, which originated from cell biology and biochemistry but is now recognized as a unified discipline (National Research Council [NRC], 2014, p. 64). Disaster science may be on a similar unifying path (Peek et al., 2020).

Disasters occur at the interface of built, natural, social, and economic environments. Efforts to characterize the range of causes and consequences of extreme events therefore require approaches that draw on multiple disciplines. It is perhaps no surprise, then, that the hazards and disaster field has historically encouraged and incentivized researchers to work together across disciplinary and organizational boundaries. The National Science Foundation Humans, Disasters, and the Built Environment (HDBE) program, for example, supports "fundamental, multidisciplinary research on the interactions between humans and the built environment" in the context of "natural, technological, and other types of hazards and disasters" (National Science Foundation [NSF], 2020). In their analysis of funding for multidisciplinary research between 1982 and 2017, Behrendt et al. (2019) found a positive correlation between award funding and increasingly large multidisciplinary teams in HDBE and other disaster-oriented programs at the National Science Foundation. These multidisciplinary teams, however, only accounted for about one-fifth of funded projects during the study period.

CONVERGE

How can the field of hazards and disaster research contribute to the convergence revolution? The National Science Foundation-supported CONVERGE facility – which was established in 2018 as the first social science-led component of the Natural Hazards Engineering Research Infrastructure (NHERI) – is dedicated to answering that question by bringing a

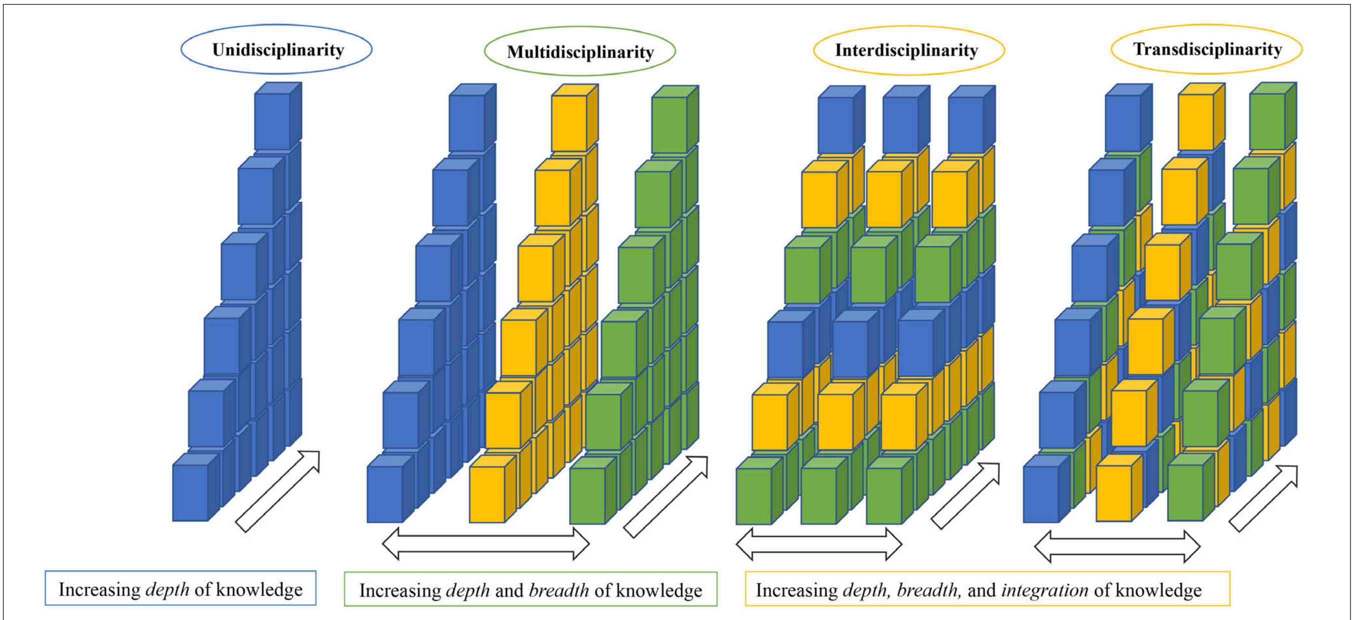

FIGURE 3 | Convergence requirements: depth, breadth, and integration of knowledge.

convergence framework to hazards and disaster research (see **Figure 4**). The following sections describe how this framework is being implemented through CONVERGE, which is headquartered at the Natural Hazards Center at the University of Colorado Boulder.

Identifying Researchers

In 2006, the National Research Council published *Facing Hazards and Disasters: Understanding Human Dimensions*. In that monograph, the Committee on Disaster Research in the Social Sciences dedicated an entire chapter to "The Present and Future Hazards and Disaster Research Workforce." The report raised numerous questions, including: How many hazards and disaster researchers are active in the field? What disciplinary backgrounds and types of methodological expertise do these researchers bring to the study of extreme events? Are these researchers prepared with requisite workforce skills and knowledge to face twenty-first century challenges?

The first step in developing a robust workforce, as the committee acknowledges, is knowing who is part of it already. No precise accounting currently exists, however, of the size or demographic composition of the members of the field (although as a start for the social sciences, see Peek et al., 2020). For this reason, the first step in advancing a research agenda rooted in convergence is to *identify* who counts themselves as a member of the research community. Understanding more about the composition of the hazards and disaster workforce matters because it must be "of adequate size, reflect the diversity of the nation, and include researchers who have both basic and applied research interests and are capable of carrying out disciplinary, multidisciplinary, and interdisciplinary research" (National Research Council [NRC], 2006, p. 319). Identification is also a prerequisite for developing comprehensive educational programs and initiating equitable collaborative efforts that involve a range of researchers – including women and members of historically underrepresented groups – from different disciplines.

Identifying researchers is no simple task, though, and that is why this effort is core to the mission of CONVERGE. The hazards and disaster field is composed, as already noted, of researchers from many different disciplines across multiple scientific and engineering domains and the humanities who are affiliated with academic, private sector, non-profit, and government organizations. While various disciplinary

FIGURE 4 | The CONVERGE framework for supporting convergence research.

and specialty organizations exist that might help to identify some members of the community – such as the Earthquake Engineering Research Institute, the American Society of Civil Engineers, or the American Association of Geographers – these organizations are fee-based and therefore their members are those who can afford to pay.

Due to these and myriad other difficulties with identifying who is a member of the hazards and disaster research community, one approach to finding researchers is to ask them to self-identify with groups or associations that are most aligned with their interests and expertise. This is the idea that has, in part, driven the creation of several NSF-supported Extreme Events Reconnaissance and Research (EER) networks. To date, such networks have been established for geotechnical engineering, social sciences, structural engineering, nearshore systems, operations and systems engineering, sustainable material management, and interdisciplinary science and engineering (see **Figure 5**). These networks are joined together under the auspices of CONVERGE, which is designed to cultivate this type of multi-team research structure working in a much larger hazards and disaster ecosystem (for additional guidance from the SciTS, see Shuffler and Carter, 2018).

Each of the NSF-supported EER networks has taken a different approach to how they identify members. GEER, for example, grew out of an *ad hoc* network of geotechnical engineering reconnaissance teams that responded to the 1989 Loma Prieta earthquake, the 1994 Northridge earthquake, and the 1995 Kobe earthquake. The NSF later awarded a grant to establish GEER to help formalize post-disaster geotechnical reconnaissance efforts (see Bray et al., 2018). SSEER, which was created to identify, support, and coordinate social science researchers, was launched with a formal "Call to Social Scientists," which included an invitation to join the network through completing a brief online membership survey (Peek, 2018). The members were then counted as part of the first census of social science hazards and disaster researchers (Peek et al., 2020) and added to the SSEER map that locates researchers geographically and summarizes their areas of expertise (Mathews et al., 2020). StEER requires that its members have formal training or experience as a structural engineer or in allied fields and that they fill out an online membership application. The point of these examples is that while each of the EER networks has developed membership requirements and generated membership rosters in different ways, they share a common goal in finding and recognizing those who identify themselves as members of a particular research community. CONVERGE, in turn, helps each of the EERs to communicate and share information regarding the size, location, diversity, and range of scientific and technical expertise across the distinct research communities.

Educating and Training Diverse Researchers

While all established disciplines are continually evolving, the hazards and disaster research field may be especially dynamic (Michaels, 2003; Power, 2018). This is because the field is composed of researchers with varying levels of integration and training. Consider, for instance, that the field is made up of *core researchers*, who are highly committed and spend the most considerable amount of time engaged in hazards- and disaster-specific studies and service activities; *periodic researchers* who do not necessarily see themselves as primary to the field but who focus on related topics from time to time throughout their professional careers; *situational researchers* who become interested in the field because their community is struck by disaster or because a specific opportunity arises to explore new phenomena; and *emerging researchers* who are students, early career scholars, or others new to the field who are still learning about its histories, theories, methods, and approaches (for elaborations on this researcher typology, see: National Research Council [NRC], 2006; Peek et al., 2020).

As the number of disaster events has increased, so too have the number of periodic, situational, and emerging researchers. Because these researchers have the potential to grow and strengthen the field – but may not be fully aware of its contributions over the decades – it is especially important to educate them and encourage them to join the long-standing community of core researchers who are often, although not always, connected to established academic hazards and disaster research centers and institutes. To this end, the 2006 National Research Council report asserts that "specific strategies must be devised (1) to put the next generation of researchers in the pipeline and (2) to recruit new researchers from the existing pool" (p. 320).

The literature on methods and approaches to extreme events research suggests that there is an ethical imperative, in addition to a scientific rationale, for educating and training new generations of researchers (Van Zijll de Jong et al., 2011; Browne and Peek, 2014; Miller et al., 2016; Packenham et al., 2017). Disasters often cause disproportionate harm among marginalized populations and can lead to long-term and shifting vulnerability among people. This recognition has led for calls to increase the number of researchers who are women and racial and ethnic minorities to ensure that the research process itself is sound and that researchers are reflective of the people they study and serve (Anderson, 1990; Peek, 2006; Louis-Charles and Dixon, 2015). Disaster researchers may also witness widespread suffering, damage, and loss, which can cause distress among researchers themselves. For these and many other reasons, not only do researchers need training and mentoring in terms of *how* to do research that is ethical and rigorous, they also need to learn *why* conducting studies in at-risk or disaster-struck communities may be especially challenging (Drabek, 1970; Stallings, 2002).

Core to the mission of CONVERGE is to accelerate the education of a diverse next generation of hazards and disaster researchers. To that end, the CONVERGE team has developed a series of training modules that cover a wide range of topics including, for example, social vulnerability and disasters, disaster mental health, cultural competence, emotionally challenging research, and Institutional Review Board (IRB) procedures for human subjects research. Designed for students, early career scholars, and others new to the field, each module features learning objectives and lesson plans; written content based on a comprehensive review of available literature; examples of past research and links

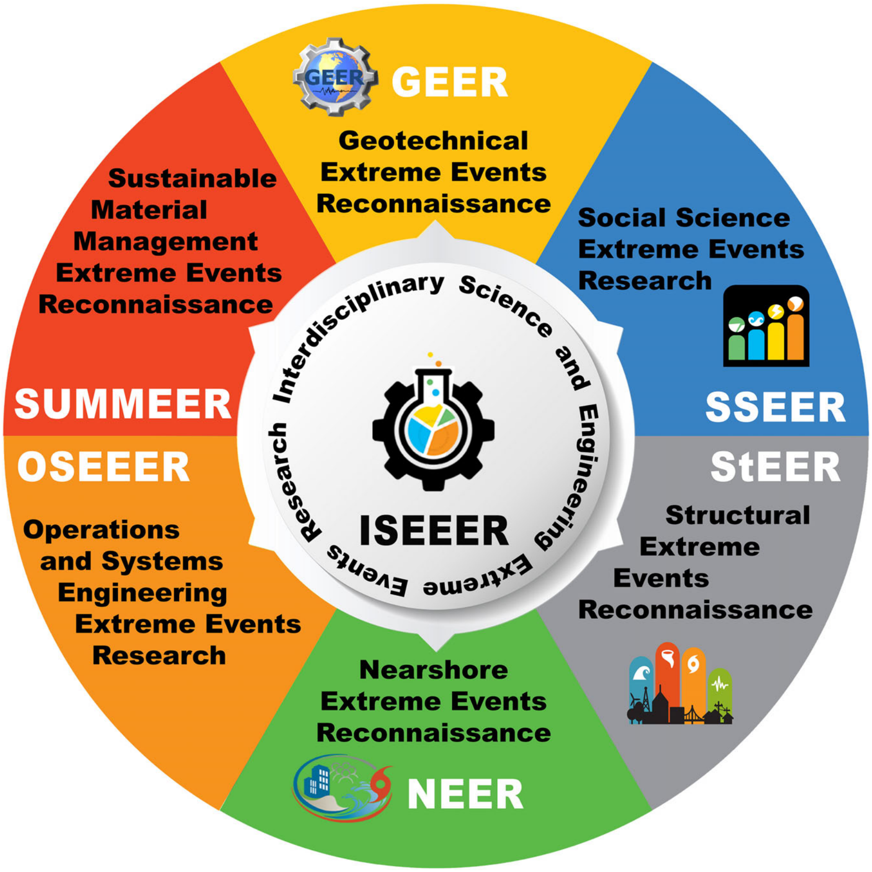

FIGURE 5 | NSF-supported extreme events reconnaissance and research networks.

to additional resources; and a final quiz and certificate of completion.

The CONVERGE team has also initiated a series of one- to two-page briefing sheets and check sheets which provide best practice recommendations to help inform the scientific rigor and ethical conduct of extreme events research. The briefing sheets are part of a special peer-reviewed series published in partnership with the journal *Natural Hazards Review* and involving authors from a range of disciplines. As a supplement to the briefing sheets, the CONVERGE team has developed a series of graphical check sheets meant to be used as researchers design their studies, prepare to enter the field, conduct quick response research or other longer-term field studies, and exit the field.

The training materials and guidance documents being developed by CONVERGE are available for free and online as part of a broader effort to democratize access to foundational and recent research in the field (see: https://converge.colorado.edu/resources). While we recognize that researchers will not become experts after completing a training module or reading a briefing sheet, these types of materials can help researchers to quickly background themselves with available knowledge and be prepared for further exploration. Moreover, by compiling these materials in a centralized repository, researchers who are new to the field can more quickly gain a sense of the wealth of available information. As noted by Sharp et al. (2016a), such training efforts have the important benefit of educating a generation of researchers across disciplines to become facile and conversant in a range of fields and ready to take full advantage of convergence research opportunities as they arise.

As demand for disaster-related knowledge grows, a substantial investment in academic training and mentoring programs that educate researchers within and across disciplinary silos is needed to advance convergence research. CONVERGE therefore offers additional opportunities for in-person training and mentoring through hands-on data publication workshops and annual researchers meetings held in Colorado, for example. These and other associated activities are designed to connect next generation scholars to one another and to more senior mentors in the field. CONVERGE also partners with the Bill Anderson Fund and the Minority SURGE Capacity in Disasters project – which are initiatives dedicated to increasing the number of historically underrepresented researchers and practitioners in the field – to ensure that African American, Latinx, Indigenous, and other scholars from communities of color are supported to participate in workshops and other mentoring activities.

Setting a Convergence Research Agenda That Is Problem-Focused and Solutions-Based

Once researchers are identified and educated, then additional possibilities emerge for deeper levels of disciplinary integration. This is especially true when there is a research agenda designed to help channel and focus the activities of a broader research community. CONVERGE is dedicated to developing such an agenda for cross-site, cross-disciplinary, longitudinal convergence research in the hazards and disaster field.

The increasing frequency and intensity of disasters coupled with the growth of the field suggests that the time is right for a more coherent approach to help guide what we study, who we study, how we conduct studies, and who is involved in the research process itself. While the utility of some quick response post-disaster research has been the source of recent scrutiny (Gaillard and Gomez, 2015; Gaillard and Peek, 2019), we argue that the need for refocusing efforts holds across the disaster lifecycle – including preparedness, response, recovery, and mitigation. Convergence, with its approach to promoting transdisciplinary research that is both problem-focused and solutions-based, offers a framework for moving forward given the enduring and emergent challenges confronting people and regions at risk worldwide.

This raises the following questions, though, which drive the research agenda-setting efforts of CONVERGE: *What are the problems our field is ultimately trying to address? And what solutions can be devised in response to the research that is being produced?*

Reducing disaster losses is one overarching goal that we set forth at the beginning of this article. It is also one that is widely shared across the community of hazards research and practice, but its outcome is nebulous. A convergence research agenda requires more precision, beginning with identifying which type or combination of disaster losses researchers seek to address. The issue of concern for any given team might be reducing disaster-related deaths or injuries, business closures, or educational disruptions (see **Figure 6** for more illustrative examples). The point is, the more precise the problem definition, the more focused the convergence research agenda.

Once the various types of disaster losses have been clarified, then it is important to focus our attention on the root causes of those losses. Disaster impacts emerge not simply from nature, but instead from our histories and cultures, from our technical interventions, and as a result of the ways that our societies are structured and our policies are organized (Wisner et al., 2004; Tierney, 2014; Browne, 2015). This means that the drivers of disaster losses are many, complex, and deeply interconnected. If our ultimate goal as a field, however, is to promote collective well-being in terms of advancing vitality, opportunity, connectedness, contributions, and inspiration for all people, this will require a convergence framework to address the varied drivers of disaster (see **Figure 6**, again, for more illustrative, rather than exhaustive, examples).

Identifying ways to reduce disaster losses represent one of the most vexing problems of our time. Given the number of contributors to this outcome, it will require new processes for teamwork and collaboration that can lead to novel practical interventions. This is where a convergence approach informed by the SciTS can be especially useful, as too often, our field remains in the *problem diagnosis* stage. An untold number of

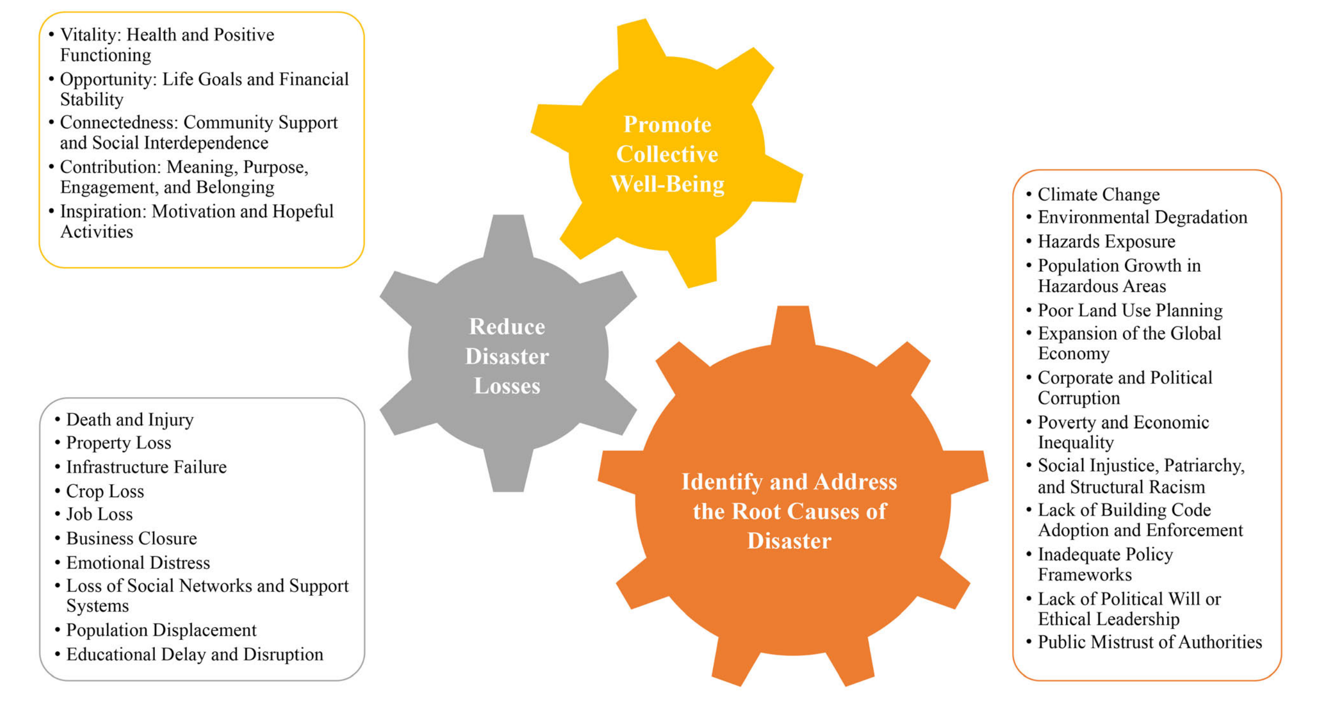

FIGURE 6 | Goals for convergence research in the hazards and disaster field.

reports, articles, and books have been published that describe vulnerabilities and failures, often leaving little space to offer a *cure* for the countless consequences of disaster. But when researchers come together with convergence as their guide, it becomes possible to develop more robust interventions. Take for example the groundbreaking work by Sutley et al. (2017a,b,c), which integrated engineering and social science perspectives. Through that collaborative process, her team first discovered that traditional engineering solutions for wood-frame structures may dramatically underestimate mitigation savings by not taking sociodemographic considerations into account. When they are included as part of more conceptually integrative research, it became apparent that mitigation approaches may save even more – in terms of averted deaths, psychological injuries, and dollars lost, especially among marginalized and potentially vulnerable populations – than had previously been considered.

A research agenda rooted in convergence provides a new lens for both examining longstanding problems *and* identifying courses of action to address the root causes of disaster. Convergence is an approach that can help collectively move us toward seeking out solutions for complex social and environmental problems, such as those that culminate in disaster. This is why the CONVERGE facility is invested in establishing convergent processes and supporting diverse interdisciplinary and transdisciplinary teams.

When such teams come together, they have the opportunity to more deeply explore the problem space and therefore can often devise more creative and contextually grounded solutions. For instance, through the combination and extension of engineering and urban planning, Sutley and Hamideh (2017) numerically exposed dynamic and disparate housing recovery processes by incorporating social inequities into traditional mathematical frameworks. Their research not only highlighted the unmet needs of economically marginalized households; it also pointed to sound policy interventions that promote equity through investing in more robust infrastructure in socially vulnerable neighborhoods. Furthermore, their work offers an evidence-based approach for accelerating the equitable distribution of post-disaster shelter and housing. This case is illustrative of the type of research that CONVERGE seeks to champion.

Connecting Researchers and Coordinating Research Teams

Convergence requires deep disciplinary integration. Yet, the challenge of connecting researchers across disciplinary divides and coordinating research teams is difficult and one that has long been of concern for those interested in participating in and supporting multidisciplinary, interdisciplinary, and transdisciplinary research (Wilson et al., 2015).

The nature of disaster research – which often involves the collection of perishable data and necessitates rapid team formation and deployment – does not always allow for the kind of systematic, measured approach that is required if an area of scholarly inquiry is to make substantial theoretical and conceptual advancements (Tierney, 2007; Börner et al., 2010; Power, 2018). In their report on quick response research, Kendra and Gregory (2015, p. 12) concluded that "field teams [should] coordinate their efforts, both in the earliest days after a disaster, as interest grows in the possibility of quick-response research, and after awards [are] made." Coordinating in the aftermath of the event is certainly desirable, for logistical as well as ethical reasons (Gaillard and Peek, 2019). This can be done most effectively, however, if protocols are established and a coordinating body that performs this function is created *before* disaster strikes (Wilson et al., 2015; Packenham et al., 2017). Furthermore, Tierney (2019, p. 115) argues that the "best way to deal with unacceptable levels of burdensome research is for research teams to communicate and collaborate voluntarily." She adds that "funding agencies have an important role to play in encouraging such coordination but should not mandate it."

The importance of agency-supported, researcher-driven, pre-event coordination drives one of the central tasks of CONVERGE, which is to create and cultivate the first institutionalized Leadership Corps for extreme events reconnaissance and research. The CONVERGE Leadership Corps consists of the principal investigators for the EER networks and the leaders of the four NHERI components that support reconnaissance efforts following natural hazards and other extreme events (this includes the NHERI Network Coordination Office, RAPID facility, DesignSafe cyberinfrastructure, and CONVERGE). As described previously, the EER networks are open to researchers within identified disciplines. The NHERI components, which are described in further detail below, are shared use and therefore meant to make engineering and social sciences resources accessible to the broader hazards and disaster research community.

The CONVERGE Leadership Corps serves a connecting and coordinating function while also advancing the possibility for convergence research in the hazards and disaster field. The members of the Leadership Corps – which includes principal investigators with backgrounds in engineering, social sciences, and natural sciences – meet regularly to share information and to generate opportunities for cross-disciplinary collaborations. For practical purposes, this means that the EER networks have helped to identify researchers *within* particular disciplinary and topical areas, while the Leadership Corps governance structure helps to connect researchers *across* the networks and to the NHERI components that can advance their efforts (see **Figure 7**). While the primary focus of the Leadership Corps is on the academic hazards and disaster research community, we also connect outwards with many other partners from academia, the private sector and local, state, and federal government. As has been observed elsewhere, these types of cross-disciplinary and cross-organizational organizational connections are vital to advancing convergence-oriented research in the hazards and disaster field (Pulwarty et al., 2009; Miller et al., 2016).

The investment that the NSF has made in establishing the CONVERGE Leadership Corps – including the organizational structure and the governance system – is a major step toward moving from "convergent-like" approaches to true convergence. It is now possible for researchers who are

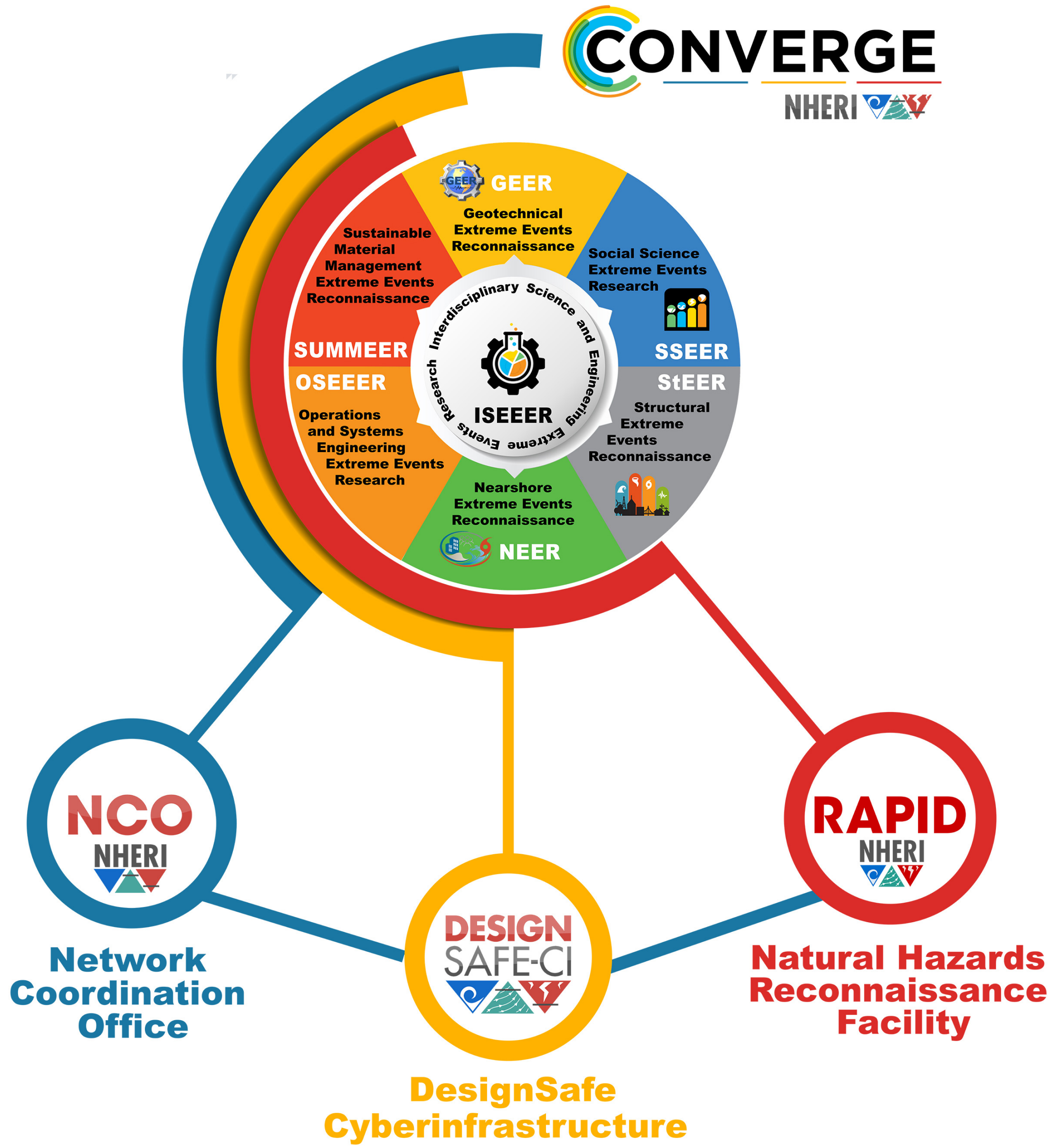

FIGURE 7 | NSF-supported CONVERGE leadership corps for extreme events research.

part of the EER networks to communicate, coordinate, and share data and information. The Leadership Corps also encourages researchers to co-design studies that are deeply integrative and explore issues across the disaster lifecycle. Researchers can access key resources through the NHERI shared-use facilities. For example, as researchers initiate projects, they can connect to NHERI and its science plan through the Network Coordination Office, located at Purdue University (Johnson et al., 2020 this issue). They can access tools, technology, and other resources through RAPID – the NHERI facility based at the University of Washington that provides NSF-subsidized equipment and support services to assist with the collection and processing of perishable data from natural hazards events (Berman et al., 2020 this issue; Wartman et al., 2020 this issue). And they can publish reports, protocols, and data through DesignSafe – the cyberinfrastructure platform for the NHERI network, which is based at the Texas Advanced Computing Center at the University of Texas at Austin (Rathje et al., 2017; Rathje et al., 2020 this issue).

These and many other interconnections made possible through the research coordination networks and the NHERI facilities are indicative of how researchers and research teams may begin to move across the conceptual degrees of integration – from unidisciplinarity, to multidisciplinarity, to interdisciplinarity, to, eventually, transdisciplinarity. This shift can reduce the redundancies, delays, and other challenges generated by siloed approaches. With a convergence research framework firmly in place, the focus can also shift toward identifying and working to solve grand challenges (National Research Council [NRC], 2006; Edge et al., 2020).

Supporting and Funding Convergence Research and Implementation

Many of the most significant advancements in the field would not have occurred without a sustained investment from federal agencies and established academic institutions in hazards and disaster research. Such institutional structures and sustainable funding can also help make convergence research possible (National Research Council [NRC], 2006).

With the National Science Foundation's commitment to "Growing Convergence Research," and its support of the NHERI components and EER networks, the field is now equipped with the coordinating structures and resources to support early stage convergence research. Consider, for example, that when a series of earthquakes rattled Puerto Rico in late 2019 and early 2020, field teams from GEER and StEER were able to deploy nearly simultaneously to conduct reconnaissance research in partnership with locally affected researchers on the island. GEER- and StEER-affiliated researchers shared their virtual and field observations and published their data via the DesignSafe cyberinfrastructure. SSEER leadership, drawing on those preliminary assessments, then called a virtual forum to help establish research priorities and ensure ethical coordination among the social science community.

During the global COVID-19 pandemic, CONVERGE convened hundreds of researchers from dozens of disciplines via successive virtual forums. Spurred by the interest and activity of the research community, CONVERGE then established a global research registry available in multiple languages and funded 90 distinct COVID-19 Working Groups focused on population groups of special concern, impacts and recovery, compound and cascading hazards, and emergent methodological and ethical issues. To catalyze convergence research, the funded Working Groups were required to include members from a minimum of three different disciplines and to submit a research agenda-setting paper that was published on the CONVERGE website.

These examples illustrate how an orientation toward convergence, combined with funding support, can accelerate the development of new research collaborations and innovations. A sub-award between our CONVERGE team and the RAPID facility has led to advancements in engineering, social science, and interdisciplinary capabilities in the RAPID App (RApp), which is a mobile application designed to support the secure collection of engineering damage assessment data as well as quantitative, qualitative, and mixed methods social science hazards and disaster research data.

Another major resource that is now available for the hazards research community is DesignSafe, which is the web-based cyberinfrastructure platform for the NHERI network (Rathje et al., 2020 this issue). DesignSafe provides a secure data repository and the computational tools needed to manage, analyze, and publish critical data for natural hazards research (Rathje et al., 2017). The DesignSafe cyberinfrastructure supports cloud-based research workflows, data analysis, and visualization. Since its launch in 2015, thousands of researchers – predominantly from engineering – have taken advantage of DesignSafe functionalities, publishing several terabytes of data. CONVERGE initiated a subaward with DesignSafe to develop a novel social science, engineering, and interdisciplinary data model for natural hazards research. The data model is available so that social and behavioral scientists, engineers, and members of interdisciplinary teams can publish legacy datasets and recently collected data. Hazards and disaster researchers can have a permanent Digital Object Identifier (DOI) assigned to their datasets and data collection protocols, research instruments, and IRB protocols.

Publishing data and instruments in this way enhances the possibility for richer collaboration and more cross-geographic, cross-disciplinary, and cross-hazards replication in the field. This can ultimately help convergence efforts to take root while also reducing data collection burdens on disaster-affected communities.

Rapid technological change is revolutionizing the ways that hazards and disaster researchers can coordinate, collaborate, and share data and findings. For convergence to truly thrive, however, it is also crucial that government and corporate funding be made available to prototype and test potential solutions to the problems being studied. Convergence, with its focus on addressing grand challenges facing humanity, encourages researchers to develop interventions. The hazards and disaster field, with its applied focus and ethical commitment to returning findings to affected communities, is already advancing new forms of solutions-based thinking. But to do this well, there must be a commitment to and support for working through the entire convergence cycle – from researcher identification to solutions implementation – in multiple iterations. CONVERGE is therefore dedicated to encouraging researchers and their partners to test and evaluate possibilities for reducing disaster losses and promoting collective well-being. These possibilities are nearly limitless, and they span varying geographic and time scales, ecological contexts, social institutions, and policy arenas. Given the scope and urgency of the environmental and social problems that we face, this work is desperately needed. Hazards and disaster researchers are poised to engage in these efforts and to help lead the way toward a more just and sustainable future.

CONCLUSION

This article has proposed a new definition of *convergence research* for the hazards and disaster field. We have explicated the core tenets of convergence research, identified gaps and barriers to existing approaches, and offered a framework for advancing convergence research in the field. That cyclical framework involves: (1) identifying researchers; (2) educating and training researchers; (3) setting a convergence research agenda that is problem-focused and solutions-based; (4) connecting researchers and coordinating functionally and demographically diverse research teams; and (5) supporting and funding convergence research, data collection, data sharing, and solutions testing and implementation.

The National Academies and the National Science Foundation have both championed growing convergence research across a number of fields, although the social sciences, humanities, and policy studies have been largely underrepresented. The hazards and disaster field, which has long encouraged multidisciplinary collaborations across multiple domains, is poised to contribute to the convergence revolution through recent investments in research coordination networks and shared use facilities to support natural hazards reconnaissance and research. This article has described the efforts of the NSF-supported CONVERGE facility, which is the sole component in the NHERI network that is dedicated to advancing convergence research and involves extensive collaborations across multiple disciplines. The work of CONVERGE and its partners is highlighted throughout to demonstrate current efforts to democratize educational opportunities and the research process through training and fostering interdisciplinary teamwork. These efforts are designed to ready researchers to both assess and address the many pressing social, economic, environmental, and technical challenges that lead to disaster losses. The initiatives described here draw heavily on lessons from the Science of Team Science and are rooted in an ethical commitment to diversity, equity, inclusion, and scientific rigor throughout the disaster research lifecycle.

The various research activities led by the CONVERGE facility exemplify how teams of researchers can apply the steps highlighted in the convergence research framework. To continue to move this work forward, we encourage hazards and disaster researchers to apply these steps to work together to find novel solutions to the mounting threats of extreme events. We call for additional award mechanisms and new opportunities to identify, train, fund, and support the development of interdisciplinary and transdisciplinary teams working to find solutions to complex and deeply rooted social and environmental problems. Focusing these efforts on students, early career faculty, and emerging researchers from historically underrepresented groups is especially important. This will help to grow the number of core researchers in the field, strengthening the hazards and disaster workforce and ensuring that we have the breadth and depth of knowledge to meet twenty-first century demands. As new structures and systems are developed to support interdisciplinary and transdisciplinary research, we envision that our field – with convergence as our guide – can stem the tide of growing disaster losses and promote collective well-being for all people.

DATA AVAILABILITY STATEMENT

All datasets generated from the CONVERGE facility are available at: https://converge.colorado.edu/. Further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

LP devised the research and manuscript plan, conceived the presented ideas, and wrote the manuscript. JT, RA, HW, and MM read and revised drafts of the manuscript text and figures and helped to develop and advance the CONVERGE initiatives described in the manuscript. All authors contributed to the article and approved the submitted version.

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