ORNL RESILIENCE PERSPECTIVES

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REFLECTIONS ON ENHANCING COMMUNITY AND INFRASTRUCTURE RESILIENCE

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Reflections on Themes, Findings, and Recommendations Resulting from the International Resilience Symposium, organized by the Northeastern University Center for Resilience. Studies and the National Institute of Standards and Technology, September 3-4, 2014

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REFLECTIONS ON ENHANCING COMMUNITY AND INFRASTRUCTURE RESILIENCE

I. Introduction

Organized and sponsored by Northeastern University's Center for Resilience Studies and the National Institute of Standards and Technology (NIST), with logistical assistance from the Meridian Institute, an International Resilience Symposium was held at NIST on September 3-4, 2014, to bring together a diverse group of professionals from the US and other countries to share their thoughts about (a) the development of standards for community and infrastructure/buildings resilience and (b) ways that incentives might be developed to catalyze investments in enhancing resilience. The symposium was actively and vigorously led by Steve Flynn, Director of the Northeastern center and a national leader in discussions of resilience needs and options.

The Symposium was one of a number of recent initiatives to try to improve the understanding of the powerful concept of "resilience," to try to move the concept toward operational metrics and strategies that would promote actual improvements in community and infrastructure resilience, and to broaden the community of researchers and practitioners involved in these processes.

As the discussion at the Symposium noted repeatedly, nobody is opposed to resilience; but, if so, why does progress toward realizing it seem to be so slow? If resilience is fundamentally a matter of existing and even thriving in a world pervaded by risks and surprises – which sounds both necessary and attractive – what can we do to make this a part of our national culture at all scales: from national and regional to local and even individual, family, and neighborhood attitudes and values?

II. Revisiting the "Resilience" Concept

"Resilience" has emerged in recent years as a term that captures what we seek in risk management for the human systems, built infrastructures, and environments that we value. It is more proactive than "vulnerability," which refers to threats rather than responses; or "adaptation," which tends to imply reactive coping with threats; or "emergency preparedness," which tends to imply readiness for disruptions rather than a reduction in the effects of disruptions. In fact, it includes all of these narrower concepts in a definition that looks forward not only to risk reduction but to sustained economic, social, and environmental development in the face of continuing risks from a variety of possible driving forces:

But if resilience is going to be a powerful force for action, it needs to be capable of evaluation. Is a particular community or infrastructure X more or less resilient than Y? Is it becoming more or less resilient through time? What might be the payoffs from a proposed investment in enhancing its resilience? This has led to a growing demand for

resilience "metrics" that can be used for purposes ranging from (a) defining baseline conditions within a system and monitoring changes through time to (b) making decisions about the allocation of management and financial resources to promote resilience.

Efforts to respond to this demand have found the process to be frustratingly difficult. For example, "resilience" is relative: for what? for whom? why? who decides? Developing a metric is more tractable if the focus is relatively narrow, but the reality is that resilience is deeply imbedded in interdependencies between systems and scales. Narrowness misses the point. In addition, a metric has the most meaning if it is developed through bottom-up participation by community and infrastructure stakeholders, who tend to have a range of goals and perspectives; but such bottom-up processes result in metrics that are often difficult to compare between communities and infrastructures.

In introductory remarks at the symposium, Steve Cauffman, Lead for Disaster Resilience at NIST, suggested several reasons why progress has been so slow, aside from the difficulty of measuring resilience: (a) groups and individuals exposed to risks are too poorly informed about those risks: (b) most groups and individuals are too confident that risks will be managed by current capabilities, or at least by parties other than themselves; (c) talking about risks without practical ways to address them is uncomfortable for decision-makers; (d) incentives are lacking for actions to increase resilience; and (e) organizational structures are lacking for addressing systemic and scale interdependencies. Contributing to the fuzziness of the resilience concept has been its relatively independent use across communities of research and practice that are not well-connected with each other (e.g., communities, built infrastructures, and emergency preparedness) and its overlaps with related concepts such as adaptation and sustainability – problems that the symposium was, in part, organized to address.

A particular challenge is that resilience concerns are often focused not only on multiple threats but on possible exposures to episodic low-probability/high-consequence disruptions from such growing threats as climate change. Allocating significant resources to deal with possible threats in the future whose likelihood is surrounded by uncertainty, when there are many other competing needs for such resources in the present, is often a difficult decision – which can imply a need to associate actions that improve resilience to future threats with other kinds of payoffs from those actions in the more immediate future. An additional requirement is to increase the recognition of decision-makers and stakeholders that the future is very likely to contain different and possibly more surprises for communities and infrastructures than the past – combined with a likelihood that roles of government in coping with such stresses are likely to be constrained by budget limitations and other competing priorities, while governmental leaders are virtually certain to be a focus of criticism if those surprises are unpleasant. A very daunting predicament, where good ideas might be especially welcome.

Other challenges include:

(1) The fact that resilience actions are rooted in the sustainability of social processes that shape driving forces and implementation. Resilience actions in the absence of a supportive social context are likely themselves not to be sustainable.

(2) The fact that, in some cases, threats may be so large in magnitude that resilience can only be achieved through transformational change – significant changes in the nature, scale, and/or location of systems, facilities, and activities – which is a bigger challenge for decision-making and implementation than incremental change.

On the other hand, if resilience truly reduces risks for communities and/or infrastructures, then elements of society who value risk reduction (such as insurance and financial institutions, and social organizations who care about human well-being) should be prepared to reward it. A further challenge is to get to the point where resilience metrics are persuasive enough to "mainstream" such incentives, with broad social, market, and policy support.

III. Perspectives on Community Resilience

Community resilience has been a particular concern, following the experience with Gulf Coast hurricanes in 2005 and 2007 and with Northeastern storms such as Irene in 2011 and Sandy in 2012. It was a focus of the Community and Regional Resilience Insitute (CARRI) from 2007 to 2011, including a very effective Community Leaders Working Group; and it is the current focus of the NAS/NRC Roundtable on Risk, Resilience, and Extreme Events.

The fundamental reality is that communities are highly resistant to well-intentioned efforts by academics and others to develop quantitative metrics that might be connected with resilience standards or certification, based on available data on physical conditions and/or community well-being. In virtually every case, they believe that each community is in important respects unique in its threats, its needs, its ways of confronting challenges, and its relationships with state, regional, and national institutions the public private, and voluntary sectors. They tend to be less concerned about external financial rewards for resilience improvements and more concerned about how resilience makes their own communities healthier and better.

The tradition in seeking measures of community resilience has been to look for measures of community well-being, such as the number of hospital beds per capita, and/or of physical conditions, such as available evacuation routes. It has been especially attractive to try to populate metrics with variables based on county-level census data (e.g., Cutter). Many top-down approaches have been developed, generally aimed at critical community infrastructures; and there are a few bottom-up approaches as well, such as a NOAA coastal community resilience index (scorecard-based) and the Communities Advancing Resilience Toolkit (CART) (see NAS/NRC, *Disaster Resilience*, 2012).

But one insight from the CARRI experience has been that, to community leaders, resilience is a social process, not a set of physical conditions. It is rooted in capabilities in a community to come together in a time of crisis and transcend typical barriers between public and private sector, city-wide structures and neighborhoods, rich and poor. One can imagine a set of dimensions of "social capital" that would capture this perspective, e.g., (a) social engagement, connectivity, and inclusiveness, measured for instance by the extent and diversity of participation in community activities; (b) community resourcefulness: its capacity for collective action as one community vs. competing interests; and (c) community resources for coping with threats and disruptions. The problem is that it is very difficult to find measures of these kinds of community dimensions in sets of social indicators that have developed for all or most communities. A few pioneering efforts have been made, such as RAND, 2011, and Norris, 2008; but there is no consensus on a workable approach that would not require new data development for US communities.

As indicated earlier, perhaps the most fundamental issue for metrics, standards, or certification approaches for evaluating the resilience of communities is that comparisons across communities imply that "one size fits all" for community resilience, which only makes sense for certain specific purposes. Two issues are often worth considering in developing metrics: (1) What is the metric for? Who would use it and for what? Is the proposed metric and the information to support it credible to the user (e.g., an insurer of public infrastructure in a community)? (2) Even where a single metric for the resilience of many communities is not achievable, can metrics be developed for selected determinants of community resilience as an indicator of status, progress, and needs for at least those driving forces?

IV. Perspectives on Infrastructure Resilience

Many of the participants in the symposium expected that developing standards for infrastructure resilience would be far easier than for communities – tending to reflect engineering judgments about sensitivities of built structures to risks of disruptions rather than the social complexities of communities. In fact, however, the discussion was far more nuanced than this, connecting with a wider variety of knowledge and experience.

The starting point was a strong consensus on three issues, that:

(1) infrastructure resilience to particular risks and threats is related to overall infrastructure health, and we have too limited a capacity to assess infrastructure health;

(2) actions to increase infrastructure resilience should start by identifying the desired outcome – more clearly than "increased resilience." What are the performance goals? Metrics can be of a number of different types. For example, an NAS/NRC report on the appropriate use of metrics for the Climate Change Science Program (*Thinking Strategically*, 2005) listed five types:

- process metrics (measuring a course of action)
- input metrics (measuring tangible quantities inserted in a process to achieve a goal)
- output metrics (measuring products or services delivered)
- outcome metrics (measuring results)
- impact metrics (measuring longer-term consequences)

(3) the resilience of particular infrastructures in particular places is powerfully linked to interconnections between infrastructures, places, and systems: e.g., engineered vs. operational vs. policy; and between different kinds of infrastructures, such as energy, communication, and transportation; and between urban areas and the regions around them – when responsibilities for infrastructure resilience are typically very fragmented.

Avenues for progress begin with building on existing "mainstreamed" processes and practices. Examples include normal infrastructure replacement and revitalization cycles (although they are proving to be very slow for public sector infrastructures in this country) and existing codes and standards for buildings and other built infrastructures. Incorporating resilience/adaptation/sustainability in normal infrastructure planning can reduce its incremental cost and simplify decision processes; and codes and standards can often be updated by the engineering community to reflect new knowledge, as the American Society for Civil Engineering (ASCE) is currently doing for climate change adaptation. One danger that has been noted in the research literature is a "levee effect," where awareness of a risk to society and/or infrastructure managers is addressed by a specific action (e.g., building a levee to protect against river flooding), after which stakeholders stop worrying about the risk because it has been taken care of – when other factors shaping the risk continue to be threats.

But symposium participants also made the point that codes and standards do not change behavior and deliver resilience unless they are understood and supported by a broad range of stakeholders. Engineering actions are determined by people, implemented by institutions, and sustained by social consensus. If significant improvements in the resilience of US infrastructures are to be made, there is a need for far better – and far more broadly communicated – information about the current status and vulnerabilities of infrastructures, especially in the public sector and in private-sector infrastructures whose reliability affects public sector infrastructure. Specifically, this includes changes in current and future conditions and driving forces compared with familiar history, in order to generate support for practices that build resilience. There are almost certainly potentials to make better use of available data sets in this regard (as the 2014 National Climate Assessment has done) and to increase emphasis on the co-production of data and information, top-down and bottom-up, by interested parties at a variety of scales and roles in society.

At the same time, there are potentials to apply science and technology to make the job easier. For example, if metrics can be developed for at least selected aspects of resilience – if not for resilience as a whole – then sensors and control systems can be developed for monitoring infrastructure performance and responding to emerging threats. Moreover, there are many other possible opportunities for S&T innovation, such as innovative

construction approaches that might lead to structures that are more adaptable to changing conditions. Attention to such S&T potentials is not an alternative to attention to social contexts; the two components of long-term infrastructure resilience can in fact work together and reinforce each other.

V. Perspectives on Mechanisms for Improving Resilience

One of the stated objectives of the symposium was to illuminate the challenge of encouraging incentives for investment of financial resources in community and infrastructure resilience. Again, the message from the symposium was that this is more multi-dimensional than simply assessing resilience as a strategy for risk reduction and then using those assessments to catalyze financial investment. The broader issue is mechanisms for improving resilience, which can include other approaches than catalyzing financial investments alone.

Two realities cut across any discussion of such mechanisms. One is that many infrastructures and communities are already stressed by a multitude of driving forces and changes for which no immediate coping mechanism appears to exist. Resilience can be seen as just one more requirement added to a very large pile, or resilience can help to draw attention to actions that help to reduce vulnerabilities to a number of concerns. The second is that responsibilities for improving resilience to such stresses are so fragmented – in terms of knowledge development, strategy development, and action implementation – that resilience is nobody's job. Is anybody responsible for the big picture, with all of its interconnections?

In many ways, the issue is how to combine public sector and private sector mechanisms – and to use them to complement and reinforce each other. On the public sector side, the reality is that many critical infrastructures are the responsibility of local and other governments, while infrastructure replacement or revitalization is often very expensive in an era when local and state governments are expected to keep budgets balanced and, above all, avoid tax increases. Resilience may be something that we support in principle, but a local or state elected official who raises taxes to assure it is unlikely to stay in office. The challenge is finding innovative ways to overcome this very significant obstacle for progress by the public sector (see Philadelphia's "Green City, Clean Waters" program as a conspicuous example).

On the private sector side, the issues are the value proposition and business continuity. What is the bottom-line payoff from investments in this aspect of risk management, when it is only one of a number of risks? In this regard, resilience as a priority is shaped by policy environments, societal values, and co-benefits, related to normal elements of risk management – such as normal cycles of infrastructure replacement and revitalization, where new risk factors can be introduced relatively easily. Insurance costs and conditions for risk-averse financing are an important part of this process, but they are seldom the dominant part of it. Related to but not quite the same as valuing payoffs from private sector investment in resilience, i.e., in profit margins or market shares, is assuring

business continuity – reducing the risks of interruptions in sales and services due to disruptive surprises, a strong motivation indeed.

The challenge is to determine how to put the two sets of responsibilities and mechanisms into an integrated pattern of response that meets national, regional, and local needs. One step is to distinguish which responsibilities belong in which sector – for instance, federal and state agency program activities the responsibility of the public sector, while operating strategies of individual private sector firms are the responsibility of the private sector. A second step is to determine which functions a sector performs best – working in partnership, with each partner avoiding trying to do everything. For instance, the public sector is well-suited to be responsible for providing open-access data, while the private sector is well-suited for assuring economic efficiency. A third step is to take a careful look at linkages, such as contracting activities or grant programs of agencies. As is being done by some federal agencies for climate change adaptation (e.g., EPA), incorporating resilience in a proposed activity could be made a condition for a grant to a community. Another possibility could be to reward resilience by increasing regulatory flexibility for an infrastructure or community.

In either case, unless leadership is unusually effective in making new things happen, the best starting point is often to graft changes in incentives onto existing processes and practices, emphasizing three aspects of revised practices or standards: *non-stationarity* – revising current practices to reflect recent changes in driving forces; *flexibility* – providing incentives to establish frameworks for resource allocation and action that encourage and enable appropriate and creative adaptations to a wide variety of possible circumstances; and *a focus on performance rather than prescriptive compliance*, a different criterion for evaluating compliance with standards.

Several useful ideas have been suggested: (1) focus more attention on the costs of a lack of infrastructure resilience – and who suffers as a result; (2) phasing in improved codes, standards, and other practices that have community support – and then monitoring results so that fine-tuning can be considered, with future fine-tuning a part of the "social contract"; (3) seeking to identify promising innovations arising from bottom-up problem-solving, especially innovative approaches for overcoming a lack of public sector funding for infrastructure improvement (e.g., from structures such as the White House Local, State, and Tribal Leaders Task Force); and (4) developing ideas about desirable changes in policies and practice that can be proposed in a future post-disaster response.

VI. Thoughts About a Way Forward

Where do we go now? A number of contributors to the symposium, from Steve Flynn to Alice Hill, offered useful suggestions as place to start. The issues are (1) what do we need to try to do? And (2) how do we move in those directions?

a. The first issue is focusing on a limited number of objectives. Ideas worth considering seriously include:

Raise awareness of risks and interdependencies.

Obviously, this is often easier said than done, but leadership can be supported by signals from the insurance industry to make it difficult to ignore the importance of integrated risk management. In addition, the potential for social media to support informal communications should not be ignored – which might call for reaching out to a younger age cohort for assistance (!).

Encourage a sense of shared responsibility.

This is also easier said than done, but leadership can be supported by institutions whose potential roles are often overlooked. Examples include educational institutions from universities to local schools at all scales, including adult education and vocational training but also potentials for knowledge and viewpoints of students to enrich family decisions and increase societal support for resilience in the longer run. In addition, roles of environmental and social non-governmental organizations (NGOs) could contribute, related to the value of resilience for sustainability, as well as the support of faith-based organizations.

Emphasize enhancements of currently mainstreamed processes and practices.

As mentioned above, it is usually easier to tweak an existing process than to create a new one; and many aspects of strategic planning by communities and infrastructures, along with operational rules and guidelines, can be revisited by responsible leaders and stakeholders to see if changes can be introduced that would be broadly acceptable and perhaps even offer benefits beyond increased resilience alone.

Align resilience with efforts concerned with sustainability and climate change adaptation.

Climate change preparedness and adaptation are increasingly recognized as essential, now that climate change impacts have been shown to be real; and sustainability is a growing concern on the part of a host of institutions and leaders concerned about interactions between society and nature. These movements have some momentum, active proponents, and supportive institutional structures; and in nearly every case their agendas have strong overlaps with resilience as an objective. Increasing the capacity to bundle these naturally aligned forces in support of effective policies and action that have multiple benefits could add to the prospects of them all.

b. The second issue is how to make progress toward achieving these objectives. Possibilities include:

<u>Mechanisms for raising awareness and encouraging a sense of responsibility</u>:

Broad-based contingency planning and exercises.

Participative contingency planning is a powerful tool for encouraging a variety of stakeholders and parties at interest to consider implications of possible futures that are not normally on their personal radar screens. Probabilities matter less than possibilities, and impacts and actions can be considered and discussed without necessarily calling for immediate action. Bodies of practice and knowledge exist for aspects of this approach from participatory scenario development to consideration of "shock" disruptions. Meanwhile, such communities as emergency preparedness and national defense frequently conduct exercises that include role playing in responding to hypothetical threats. This is a familiar mechanism for "converting the unimaginable into the imaginable" in encouraging responsibilities for resilience.

*Using focal events as opportunitie*s.

We all know that focal events such as terrorist events, extreme weather events, and pandemics "open policy windows" for actions that would be difficult to catalyze and implement in normal times. Having good ideas, fully vetted and supported, ready to go in the unfortunate event that a disruptive focal event occurs can move resilience along in ways that offer wide-ranging benefits in the longer run.

Public recognition of resilience achievements.

One of the most powerful mechanisms for encouraging resilience, and one of the easiest and least expensive to implement, is to offer widely-publicized high-level awards to individuals who show notable leadership and to community and infrastructure activities that have led to notable achievements in resilience improvement. Presidential awards announced each year?

Visualization as a key to awareness.

An item that may sound rather mundane is the underestimated power of visualization as a way to promote resilience awareness. Such possibilities as short videos showing changes in maps or communities under different threats and possible futures can support contingency planning, resilience education, and outreach through the media in publicizing risks and rewards from risk reduction; and introducing resilience as a theme in certain kinds of computer games can reach additional audiences. How about a "resilience visualization laboratory," analogous to the Decision Theater at the Arizona State University, developed with support from NSF's program on decision-making under uncertainty?

> <u>Immediately accessible mechanisms for making progress while awareness is being raised</u>:

Attention to normal processes of infrastructure revitalization and community planning, including attention to revisions in existing codes and standards.

Described above.

Developing taxonomies of determinants of resilience and focusing on those niches a few at a time.

Even if developing metrics for community or infrastructure resilience as a single variable is not generally possible at the present time, it is possible to imagine developing taxonomies or matrices of the major determinants of resilience and to start to populate the taxonomy with metrics for several of the determinants at a time, moving toward comprehensive coverage of major pieces of the resilience puzzle in the longer run.

Government as a consumer in the resilience marketplace.

Finally, government does not have to wait until it raises awareness and catalyzes investments across all of society in order to make progress. As has been done with issues from environmental protection, equipment energy efficiency, and climate change adaptation, government can start by establishing standards and practices for itself. Significant improvements can result, awareness can be raised, and markets for resilience products, services, and expertise can be created. In many cases, this can be carried out by Presidential Directive without requiring Congressional action. It can be a very real place to start.

VII. Conclusion

In some ways, the International Resilience Symposium might be considered a failure. It did not succeed in developing standards for community and/or infrastructure resilience, and it did not succeed in developing incentives for catalyzing financial investments in resilience. But its ambitious agenda led to a discourse that will be more sustainable in the longer term, because it recognizes and identifies the main challenges in moving toward a feasible agenda for resilience action. Rather than providing answers for now, it points toward some very realistic steps that can be taken now – significantly improving prospects for resilience over the next several decades.

Major resilience linkages

The Community and Resilience Institute (CARRI)

Established at ORNL in 2007 with support from DHS, led community efforts to enhance resilience and its research component, led by T. Wilbanks and involving several dozen leading resilience researchers across the US, produced summaries of the existing resilience knowledge base. Once established, operation was transferred to the Meridian Institute in late 2011; but ORNL is still closely linked with CARRI's activities.

http://www.resilientus.org/
http://www.resilientus.org/publications/research-reports/

NAS Roundtable on Risk, Resilience, and Extreme Events

Established in 2012 to bring together resilience researchers and practitioners to advance knowledge about resilience, including the resilience of electricity systems to disruptive events. T. Wilbanks is a member of the Roundtable, the only member from any DOE national laboratory.

http://sites.nationalacademies.org/PGA/resilientamerica/

International Symposium on Developing Standards for Disaster Resilience of Buildings, Infrastructure, and Communities, September 3-4, 2014

A major invitation-only symposium hosted by NIST and Northeastern University and attended by leading federal government officials responsible for resilience as a part of the President's Climate Change Action Plan. For a summary of findings, see the illustrative report above.

http://www.nist.gov/disaster-resilience/

Selected resilience-related papers and presentations

Selected Publications by T. Wilbanks:

"Meeting Challenges in Understanding Impacts of Extreme Weather Events on Connected Infrastructures," with S. Fernandez and M. Allen, *Environment*, 57 (July/August 2015): 4-15.

Climate Change and Energy Supply and Demand, with others. Island Press, 2014.

Climate Change and Infrastructure, Urban Systems, and Vulnerabilities, with S. Fernandez and others. Island Press, 2014.

Implications of Climate Change for Energy Systems in a Multisectoral Context," in J. Pittock et al., eds., *Climate, Energy and Water: Managing a Complex Trinity*, Cambridge University Press, 2014.

"Integrated Perspectives on Sustainable Infrastructures for Cities," with M. Merad and others, in I. Linkov, ed., *Sustainable Cities and Military Installations:* NATO Science for Peace and Security Series C: Environmental Security. Springer, 2014: 301-328.

"Transformational Adaptation When Incremental Adaptations to Climate Change Are Insufficient," with R. Kates and W. Travis, *Proceedings of the National Academies of Science* (PNAS), April 2012.

"Inducing Transformational Energy Technological Change," in W. Nordhaus and N. Nakicenovic, eds., *Technological Change and Global Warming*, special issue of *Energy Economics*, 33.4 (July 2011): 699-708.

"Considering Issues in Measuring Energy Sustainability," in T. Graedel and E. van der Voet, eds., *Linkages of Sustainability*. Strüngman Forum Report, v. 4. Cambridge, MA: MIT Press, 2010: 341-354.

"How Geographic Scale Matters in Seeking Community Resilience," CARRI Research Paper Number 7, Community and Resilience Initiative, August 2009.

"Generic Lessons Learned about Societal Responses to Emerging Technologies Perceived as Involving Risks," with others, ORNL/TM-2009/114.

Selected presentations by T. Wilbanks:

"Integrating Extreme Events into Scenarios for Climate Risk Management," EMF Climate Change Impacts and Integrated Assessment Workshop, Snowmass, CO, July 2014.

"Extreme Events and Abrupt Climate Change: The View of Users of the Science," NAS/NRC Board on Environmental Change and Society, June 2014.

"Enhancing Resilience to Climate-related Surprises in Coastal Cities," Climate Change Symposium on Sustaining Coastal Cities, MIT, Cambridge, MA, June 2014.

"Enhancing Resilience to Surprises in Coastal Hazard Management," Keynote address, annual meeting of the DHS Coastal Hazards Center of Excellence, Chapel Hill, NC, January 2014.

"Projecting Extreme Weather Events for Infrastructure Protection," Climate Data and Mapping for Infrastructure Resilience, HIFLD Working Group, November 2013.

"Climate Change and the Resilience of Interconnected Infrastructures," Conference on Climate Change and America's Infrastructure, Arizona State University, Phoenix, AZ, January 2013.

"Adaptation, Resilience, and Sustainability as Objectives for Energy Systems," with R. Kates, NAS Roundtable on Science and Technology for Sustainability, Washington, DC, December 2012.

"Impacts of Climate Change on Infrastructures That Can Affect the Oil and Gas Industry," workshop on Addressing Adaptation in the Oil and Gas Industry, London, October 2012.

Other publications:

"Application of Hybrid Geo-Spatially Granular Fragility Curves to Improve Power Outage Predictions." M. Allen, S. Fernandez, O. Omitaomu, and K. Walker, *Journal of Geography and Natural Disasters,* 4: 127ff.

"Locally adaptive, spatially explicit projection of US population for 2030 and 2050," Jacob J. McKee1, Amy N. Rose, Edward A. Bright, Timmy Huynh, and Budhendra L. Bhaduri, *Proceedings of the National Academy of Sciences (PNAS)*, 112 (2015): 1344–1349.