Toward a Resiliency and Vulnerability Observatory Network: *RAVON*[1]

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[1] The authors comprise the steering committee of the workshop discussed in this report. Peacock served as the committee chair; hence the authors are listed in reverse alphabetical order. The RAVON (rā'- vŏn) name was proposed by Carl Shapiro (USGS) and Robert E. O'Connor (NSF) who initiated and were the program officers supporting the workshop. This report (and the workshop reported on herein) was supported by a grant from the National Science Foundation (SES-0831115). Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the National Science Foundation nor the United States Geological Survey.
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Toward a Resiliency and Vulnerability Observatory Network: *RAVON*

I. Introduction

Recent decades have seen an exponential growth in the physical impacts and losses due to natural disasters stemming from climatological events such as flooding and hurricanes and geological events such as earthquakes in the United States and throughout the world. Even after adjusting losses for inflation, the notion of billion dollar disasters is becoming the rule rather than the exception. In the future these mega-catastrophes may no longer be viewed as low probability events particularly if we consider both their direct and indirect losses. Indeed, given the ever increasing interdependence in the world economy what might have once been seen as local problems with confined impacts, increasingly will be seen as global problems having world-wide consequences.

The consensus of the scientific community is that natural disasters are not in fact wholly “natural” events. Disasters are outcome of the interaction between biophysical systems, human systems, and their built environment. Furthermore, they are in large measure a function of human action or, all too often, inaction. This position was the central conclusion of the *second assessment* of natural hazards and disaster research in the United States as summarized in the aptly entitled volume *Disasters by Design* (Mileti 1999). Despite increasing knowledge on natural hazard agents and their potential impacts, disasters losses increase in part because of where and how we “design” our communities. This message was echoed by White, Kates and Burton (2001) who suggested that losses continued to grow because of a failure to either employ or to effectively employ knowledge on where and how our communities should develop.

Many of our nation’s communities continue to develop and expand into high hazard areas, contributing to increased hazard exposure and often resulting in the destruction of environmental resources such as wetlands that can reduce losses. There is still far too much reliance on short term technological fixes such as levees, sea walls, and beach re-nourishment programs that can also have detrimental environmental consequences and promote increased development. When major disasters occur, recovery requires massive infusions of external public and private resources, is highly uneven, and is likely to reproduce many preexisting vulnerabilities. In short, many of our communities are becoming ever more *vulnerable* to natural hazards while simultaneously becoming less disaster *resilient*.

II. The Workshop’s call for RAVON

Despite advancements in hazards and disaster research in large measure because of the investments by programs like the National Earthquake Hazard Reduction Program (NEHRP), there is a growing sense in the scientific community that current programs and approaches are inadequate for tackling the most fundamental and critical knowledge gaps in resiliency and vulnerability science. The ability to systematically expand the knowledge base is increasingly constrained by four major obstacles. First, current funding mechanisms almost exclusively support one-shot case studies of limited duration which preclude the ability to monitor change in resiliency and vulnerability thereby hindering the development of models that explain change over time. Second, the preponderance of independent studies too often fail to replicate measurement protocols of common concepts which limit comparability across data collection efforts. Third, most studies only offer partial views of place failing to capture the full complexity of coupled socio-ecological systems. Fourth, many independent data collection programs in the public and private sectors are poorly coordinated constraining data sharing among researchers and use by practitioners.

In June of 2008, with the support of the National Science Foundation and the United States Geological Survey, a workshop drew together leading researchers from the natural hazards and disaster research community to explore and explicitly address the creation of a new National Science Foundation observatory focused on resiliency and vulnerability. This observatory would address current obstacles by: 1) supporting development of long term longitudinal data sets; 2) investing in the development of data collection protocols to ensure comparable measurement in multiple socio-political environmental settings and across multiple hazards; 3) building on and complementing existing data collection efforts and activities in the public and private sectors; and 4) enhancing the sharing of data throughout research and practice communities.

This workshop represented a new link in a chain of events suggesting the need to establish such an observatory. Earlier links include: 1) the *Second Assessment* and its accompanying volumes[2] which directly assessed the state of hazard and disaster research and research needs for addressing vulnerability and resiliency (Mileti 1999); 2) the National Research Council's assessment of social science research efforts funded by the NSF as part of NEHRP and future needs (NRC 2006); 3) the National Science Board's efforts addressing hurricane science research needs and the development of a new National Hurricane Research Initiative (NSB 2007); 4) the recent *Rising to the Challenge* report that focused on the critical failures to integrate social science research into the existing national environmental observatories (Vjajjhala, Krupnick, McCormick, Grove, McDowell, Redman, Shabman, Small 2007); 5) NOAA's efforts seeking to develop a social science research agenda related to hurricane forecast and warning (Gladwin, Lazo, Morrow, Peacock and Willoughby 2007); and 6) USGS's efforts to highlight national needs related to natural hazard risk reduction and management (Shapiro, Bernknopf, and Wachter 2007).[3] In combination these events called for new approaches in addressing natural hazards and disasters that view them not as short-term episodic, acute events, but rather as reflecting long-term chronic issues demanding a comprehensive approach focusing on *natural hazard vulnerability and disaster resiliency*. These efforts also called for interdisciplinary research with a number suggesting that social sciences must play a central if not guiding role in shaping the science, for ultimately it is the actions of human and social systems that are playing primary roles in shaping vulnerability and resiliency. Taken together, these efforts also provided an important foundation and a wealth of information upon which the workshop's steering

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[2] See: *Disasters by Design* (Mileti 1999), which summarized the central findings and perspectives emerging from the *Second Assessment* of hazard research in the United States, *Paying the Price* (Kunreuther and Roth Sr. 1998), which focused on insurance and its potential role in mitigation, *Cooperating with Nature* (Burby 1998), which focused on land-use planning, *Facing the Unexpected* (Tierney, Lindell, and Perry 2001), which focused on disaster preparedness and response research, and *American Hazardscapes* (Cutter 2003), which focused on vulnerability science and spatial analysis of natural hazards.

[3] See also two other useful USGS publications: USGS 2007 and McMahon, Benjamin, Clarke, Findley, Fisher, Graft, Gundersen, Jones, Loveland, Roth, Usery, and Wood. 2005.

committee and participants drew upon in developing concepts and ideas for creating a new observatory network.[4]

The consensus of the workshop was to create a new observatory network focused on natural hazard vulnerability and resiliency. Indeed, emerging from the workshop was the call to create ***RAVON***, a ***R***esiliency ***a***nd ***V***ulnerability ***O***bservatory ***N***etwork. The vision proposed for *RAVON* is...

> *a future in which exemplary research builds the capacity of people and communities to withstand and rapidly recover from environmental extremes.*

In light of this vision, the mission for *RAVON* is...

> *...to provide the research community, policy makers, and society with the knowledge and predictive understanding necessary to reduce the vulnerability associated with natural hazards and enhance the resiliency of individuals and communities.*

To accomplish this mission and enhance the probability of reaching the observatory network's vision, workshop participants developed a framework to establish a research agenda for RAVON. In addition, the workshop identified parameters to shape RAVON's its mission and a set of key principles to guide its data collection and distribution activities. Finally, the workshop discussed the overall structure of RAVON and its governance.

This document provides an overview of the major findings and positions taken by the workshop participants. This overview is structured in the following manner. The following section (III) addresses the working definitions of resiliency and vulnerability employed by the workshop, provides a brief discussion of why an observatory network is necessary for promoting resiliency and vulnerability science, and offers cross-cutting research parameters shaping the nature of research conducted by the observatory. Section IV provides a discussion of RAVON's research agenda consisting of core research themes and focus areas and offers examples of specific research questions. This is in turn followed in Section V by a discussion of guiding principles for effectively carrying out the observatory's research and data collection activities. The concluding section discusses the structure and governance of RAVON, along with a brief statement as to how RAVON might be brought into existence. The details regarding the workshop itself appear in an appendix.

III. Working Definitions and Parameters for Research

A. Working Definitions: As noted by White, Kates and Burton (2001:86), vulnerability has emerged as a central concept in hazards research. While many definitions have been offered (Cutter 1996; Manyena 2006), ***hazard vulnerability*** is generally characterized as being a function of hazard exposure and physical characteristics. "Hazard" is generally defined in terms of the likelihood that events of different magnitude and scope will impact a particular area while

[4] This was assured because many of the authors, editors and participants of these efforts were also workshop participants or steering committee members.

"vulnerability" is generally defined in terms of the damage to the built environment that will be sustained from each of the hazard events (NRC 2006:72-3). In recent years there has been an emerging recognition that a comprehensive understanding of vulnerability requires the addition of another critical dimension, social vulnerability which is generally understood as the capacity of individuals or social systems of various scale to anticipate, cope, resist and recover from the impacts of a hazard agent (Blakie et al. 1994; Heinz Center 2000). Social vulnerability is shaped by social structures and processes that determine access to scarce resources such as income, wealth, social capital, power and housing, cultural factors that shape belief and customs, and driving forces such as urbanization and demographic change.

Even more recently the notion of ***disaster resilience*** has emerged as a critical concept in hazards research. Holling (1973) is generally credited with introducing the concept in ecology where it was defined as the ability of a system to absorb, change, and still persist.[5] Timmerman (1981) applied the concept to social systems in relation to natural hazards where he defined it as the capacity of a system, or part of a system, to absorb and recover from hazardous events. Many definitions draw heavily on perspectives suggested by the *Resiliency Alliance*[6] which generally holds that resilience is the ability of a system to resist or absorb an impact, organize itself to overcome or recover from the consequences of the impact, and adapt or learn from the experience (Carpenter et al. 2001; Folke et al. 2002; Resilience Alliance 2007). The workshop's working definition was consistent with the literature in that resilience is defined as the ability of social systems, be they the constituent element of a community or society, along with the bio-physical systems upon which they depend,[7] to resist or absorb the impacts (deaths, damage, losses, etc.) of natural hazards, to rapidly recover from those impacts and to reduce future vulnerabilities through adaptive strategies.[8]

The very nature of hazard vulnerability and resiliency argues for the creation of a national observatory network to meet the research needs and thereby advance these critical areas of science. To date investments have been made establishing environmental observatories focusing on the structure and dynamics of the biophysical environment and its systems related to resiliency and sustainability issues (LTER, NEON, etc.). ***What is lacking is an observatory that focuses on the nature and dynamics of the social systems and their built environments which dramatically impact the bio-physical environment and its systems.*** For example, research on the social, political, cultural, psychological and economic factors influencing the dynamics of land use change, the modification of wetlands and other environmental resources that offer protective services and functions, and the adoption of resiliency and sustainable environmental policies and planning techniques is needed to complement existing observatory-based research.

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[5] See Walker, Gunderson, Kinzig, Folke, Carpenter, and Schultz 2006; Walker, Holling, Carpenter and Kinzig 2004, and Walker, Anderies, Kinzig, and Ryan 2006 for more recent applications to coupled socio-ecological systems.
[6] http://www.resalliance.org/1.php
[7] Bates (1997) refers to social systems and the systems composing their bio-physical (built and natural systems) environment as an ecological field (see also Bates and Pelanda 1994).
[8] For examples that are generally consistent with this definition see: Mileti 1999; Berke and Campanella 2006; Buckle, Marsh, and Smale 2001; Bruneau, Chang, Eguchi, Lee, O'Rourke, Reinhorn, Schinozuka, Tierney, Wallace, and von Winterfeldt 2003; Godshalk 2003; Walter 2004; UN/ISDR 2005. It should be noted that some definitions, particularly those addressing hazards, focus more narrowly on social systems. Yet these systems are embedded and interactive with natural systems and are dependent on their physical environment. Hence, natural systems should not be ignored by hazard/disaster researchers.

The establishment of an observatory network can overcome weaknesses often encountered in traditional hazards and disaster research that have thwarted the full development of vulnerability and resiliency science. First, research on resiliency and vulnerability demands long-term sustained data collection activities to monitor and model change and the complex factors influencing these changes. Current approaches which essentially fund cross-sectional isolated case studies are not sufficient for advancing the science on the dynamics and changes in vulnerability and resiliency. Second, the episodic nature of post disaster and hazards research has generally resulted in it being carried out in a rather ad hoc manner employing different measurement, research, and sampling strategies, yielding incompatible and inconsistent findings, and limiting comparability and generalizability. For example, Lindell and Perry (2000) found up to sixteen different measures of household earthquake hazard adjustment (mitigation) in 23 studies they reviewed. Peacock Dash and Yang (2006) in turn found that household recovery was measured in multiple ways including the perception of recovery, satisfaction with current living conditions, household income, individual income, house or home size, domestic assets, or housing amenities. It is not surprising that conclusions are inconsistent at best and incomparable at worst. As a consequence, it has been difficult to develop cumulative knowledge and this has made modeling of recovery and mitigation – critical dimensions of resiliency and vulnerability – extremely difficult if not impossible. And yet, as pointed out in the recent NRC's (2006:8) *Facing Hazards and Disasters* report, "…the potential for highly structured research designs and replicable data sets across multiple disaster types and events can now be realized."

The establishment of a national observatory network will facilitate resiliency and vulnerability science in at least three ways. First, an observatory network will engage in long term systematic data collection activities in multiple locations monitoring vulnerability and resiliency. The development of the longitudinal systematically collected data bases will allow for the analysis and modeling of resiliency and vulnerability through time. Secondly, by strategically locating network nodes in regions subject to disasters, the network should be pre-positioned to undertake a variety of post-event studies on a longitudinal basis which is critical for a fuller understanding of resiliency. Third, a central task of the observatory network will be the development of common measurement protocols, instruments and data collection strategies that will promote comparative research across locations. These protocols, instruments and strategies will also be made easily available to the research community for adoption in other locations both nationally and internationally. Many of these and additional issues will be discussed below, however it is important to first outline several parameters that should guide RAVON's general activities in carrying out its mission.

B. Cross-Cutting Research Parameters: The following four general parameters should act as guidelines for RAVON's research agenda. These are not meant as directives that must be strictly adhered to, but rather as goals establishing general benchmarks which should be striven for when undertaking its research agenda. Furthermore, there should be periodic assessments of RAVON research activities to determine to what extent they are consistent with these parameters.

1. ***Focus on Natural Disasters:*** First, the observatory will focus on vulnerability and resiliency as it relates to natural hazards and disasters, but not deliberate or willful acts of terrorism. All forms of "natural" hazards such as hurricanes, earthquakes, floods,

wildfires, etc. will be considered, as well as technological hazards. The Department of Homeland Security (DHS) is already undertaking extensive investment in its university based centers conducting research on deliberate or willful acts of terrorism. However natural hazards and disasters themselves constitute a major threat to the U.S. population and the fabric of its communities, neighborhoods, and economy; hence, there is a need for concerted research efforts to address and reduce vulnerabilities and enhance resiliency. This of course does not mean that research and findings generated by a natural hazards vulnerability and resiliency observatory would not have relevance for many aspects of terror related hazards. Indeed, there will undoubtedly be important opportunities for collaborative efforts between DHS centers and RAVON addressing topics where researchers find shared issues and concerns. These efforts between centers and observatories should be fostered.

2. ***Enhance Interdisciplinary Research:*** Analysis of hazard vulnerability and resiliency demands interdisciplinary research on the interactions between human social systems, their built environments and biophysical systems. RAVON must seek to promote interdisciplinary research among those participating in its mission driven research and between it and other NSF environmental observatories. Currently environmental observatories have been slow to promote interdisciplinary research including the social sciences (Vjajjhala et al. 2007) despite the *Grand Challenges in Environmental Science* report which identified eight themes all of which require, to varying degrees, social science participation (NRC 2001). A more recent NRC report advocated the establishment of a national social science hazards and disaster research center that would play a key role in facilitating interdisciplinary research because such a center "would enable social scientists to negotiate interdisciplinary, collaborative research agendas ... on coequal footing" (NRC 2006:215). RAVON can serve in this capacity among the environmental observatories.

3. ***Promoting Comparative Research:*** The third parameter that should shape RAVON's missions is also borrowed from the NRC's (2006:6) summary recommendation that "comparative research should be conducted to refine and measure core components of societal vulnerability and resilience to hazards of all types." An observatory for hazard vulnerability and resiliency offers the potential for generating fruitful research and theory through comparative research across a variety of dimensions (NRC 2006; Peacock 2003a). The obvious dimension is cross-hazards comparative research because extant research has predominantly focused on earthquake hazards (NRC 2006). However, there are many other dimensions that can be exploited. For example, insurance markets are regulated by states, providing opportunities to comparatively assess different regulatory regimes for enhancing or thwarting its potential role in promoting cost-effective mitigation measures and more appropriate development of hazard-prone areas (Wharton Risk Center 2008). Similarly, political entities such as counties, which are often the focus of federal policies, vary considerably in their legal abilities and mandates to promote land use planning and building code regulations across states.

4. ***Emphasize social vulnerability issues:*** The fourth and final parameter that should shape the framework concerns the distributional aspects of vulnerability and resiliency.

Specifically issues of social vulnerability or more generally, equity, should permeate all aspects of the observatory's research agenda. Socially vulnerable populations have more difficulty implementing mitigation strategies, are likely to be disproportionately impacted in disasters, and have more difficulty and problems in recovery than other groups. Social vulnerability is evident across units of analysis such as individuals (e.g., children, elderly, female), households (e.g., minority, low income), businesses (e.g., small, owner operated), communities (e.g., rural), and even societies (e.g., emerging economies). Similar arguments apply to resiliency.

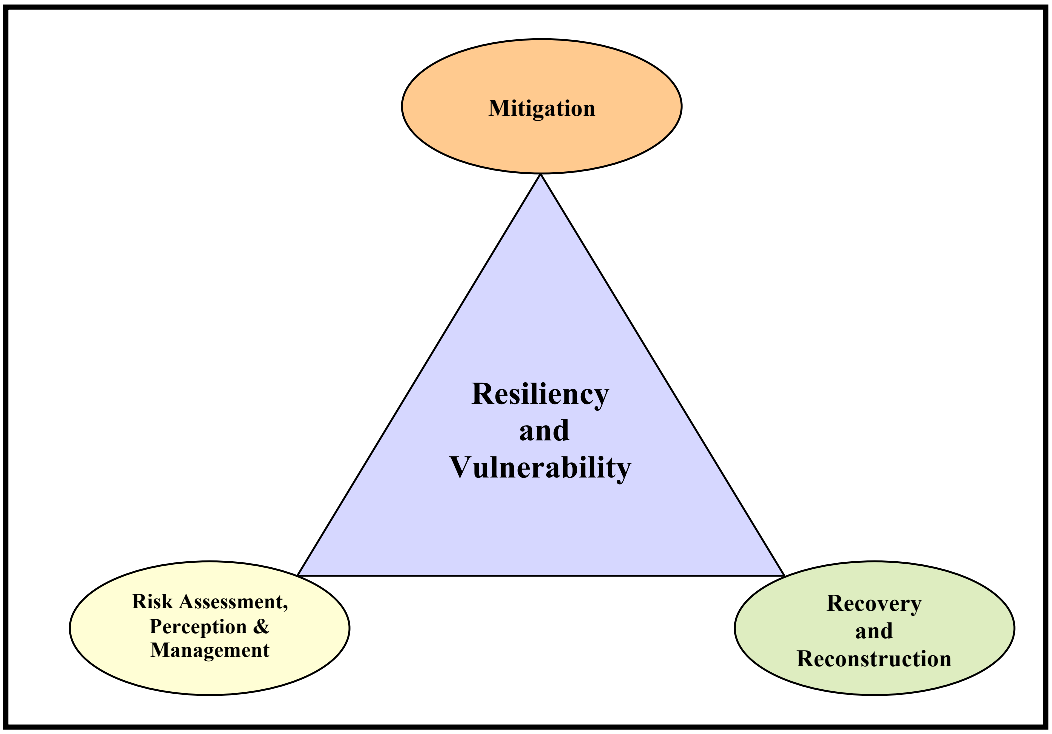

Figure 1. RAVON's Research Agenda

VI. RAVON's Research Agenda

The workshop identified a research agenda for RAVON's scientific and data collection activities. Not surprisingly workshop participants were able to identify nearly seventy research questions or issues that should be targeted as part of the observatory network's activities. The research questions generally clustered into three broad focus areas which themselves coalesce under the resiliency and vulnerability research theme. These focus areas are: 1) risk assessment, perception, and management strategies; 2) mitigation; and 3) recovery and reconstruction. Figure 1, provides a visual representation of a RAVON's research agenda composed of tripartite research focus areas, linked through its primary research theme targeting resiliency and vulnerability. The following provides a brief discussion of each, along with some examples of specific research questions.

A. Resiliency & Vulnerability: The concepts of resiliency and vulnerability themselves must be central to RAVON's research agenda. There are examples of theoretical and empirical work focusing on vulnerability and its measurement, particularly with respect to social vulnerability at aggregate levels (cf. Cutter, Mitchell and Scott 2000, Cutter Boruff and Shirley 2003; Birkman 2006). Nevertheless agreement on the definition and operationalization of vulnerability at all levels of scale and aggregation is far from resolved. There is also little work on the integration and measurement of both physical and social vulnerability (cf. Morrow 1999; Boruff, Emrich, and Cutter 2005; Borden, Schmidtlein, Emrich, Piegorsch, and Cutter 2007; Flax Jackson and Stein 2002; Chakraborty, Tobin and Montz 2005; Birkmann 2006) and on the direct consequences of multiple dimensions of vulnerability for losses and recovery at various levels of scale and aggregation (Peacock, Morrow and Gladwin 1997; Fothergill, Maestras, and Darlington 1999; Enarson, Fothergill and Peek 2006; Brody, Zahran, Maghella, Grover, and Highfield 2007; Zahran, Brody, Peacock, Vedlitz and Grover 2008). Resiliency also requires considerable theoretical development and refinement and there is a clear need to develop measures and indicators of resiliency. This work is only now just beginning, but is happening in relative isolation with little in concerted efforts on the part of researchers (cf. Birkmann 2006; Paton and Johnston 2006). Central goals of RAVON should be establishing concerted efforts to fundamentally address and promote conceptual clarification and modeling strategies as well as monitoring resiliency and vulnerability at multiple levels of scale and aggregation through time.

B. Risk assessment, perception, and management strategies: RAVON must focus part of its research agenda on risk assessment and perception and their consequences for guiding hazard vulnerability risk management strategies and disaster resiliency. By risk assessment one means estimates by scientists and engineers on the likelihood and consequences of disasters of different magnitudes and the degree of uncertainty surrounding these estimates. The focus of risk perception is on how individuals, groups and organizations view the risk and in what ways this may differ from experts (e.g. fear, dread, catastrophic potential, "it will not happen to me"). Risk management strategies for reducing vulnerability and creating resiliency require the development of policies that take into account both risk assessment and perception and include economic incentives (e.g. subsidies and fines), insurance, compensation, regulations (e.g. land use restrictions) and well-enforced standards (e.g. building codes). Strategies for addressing vulnerability and resiliency issues will often require private-public sector partnerships. (Kunreuther 2001)

Examples of risk assessment, perception and management research questions.

- What psychological, emotional and socio-economic factors shape and constrain individual and organizational choices through time and how can these factors be taken into account when developing risk management strategies?
- How do risk perceptions of residents, government officials, community leaders, and other interested parties change through time and differ across communities and regions, particularly with varying levels of disaster impact and "experience"?
- How prevalent is insurance and coverage types in different communities and among different socio-economic/demographic groups and how do these fluctuate as markets adjust to changing risk assessments?
- How do individual and group behaviors change prior to and after disasters and how long lasting are these changes, if any?

C. Mitigation: Mitigation generally refers to practices or actions that are undertaken before hazard impact that provide "passive protection at the time the impact occurs" (NRC 2006:86). The term is most often associated with practices undertaken by various governmental entities, whether municipal, county, state or federal, and includes physical or structural actions such as building levees and dams to non-structural related to land use and building code policies and strategies (Burby 1998). However mitigation practices can also be applied to households and businesses, although in this context the literature often refers to these actions as hazard adjustments, and might include a household's evacuation plan, gathering supplies, or purchasing hurricane shutters and insurance (Lindell and Perry 2000; Peacock 2003b; Kunreuther 2006).

Prior to the Bush administration and 9/11, the U.S. was investing heavily in hazard mitigation planning, yet it still seeks to promote it through various policy mechanisms. For example, all local governments are encouraged through federal incentives to prepare hazard mitigation plans under the Disaster Mitigation Act. All states are required to prepare state mitigation plans under the Act. However, little is known about the content, quality, variability and performance of plans over time. There have been a few periodic or one-time studies of specific mitigation planning programs (Godschalk, Beatly, Berke, Brower, and Kaiser 1999; May, Burby, Ericksen, Handmer, Dixon and Smith 1996), but little is known about how the quality of plans change over time, the factors driving these changes, and the short- and long-term impacts of plans and on mitigation outcomes (e.g., land use change, shape of urban form, acquisition and relocation, infrastructure improvements, restoration of ecosystem mitigation services). Very little is also known about the prevalence of mitigation actions by households or businesses. There needs to be a fuller understanding of the factors that lead homeowners and businesses to adopt cost-effective mitigation measures and the economic incentives for encouraging individuals and firms to adopt these measures.

Examples of mitigation research questions.

- What factors influence the adoption of long-term mitigation measures or hazard adjustments by individuals, households, organizations, and communities and how do these influences change through time and across hazards?
- What roles can insurance and other private/public programs and initiatives play in promoting adoption?
- How do stakeholder agendas and their relative political and economic power and influence shape community and state level planning decisions and policies?
- What role do plans and planning processes have on reducing vulnerability and increase resiliency and how is their effectiveness shaped by different legal and legislative environments?

D. Recovery and Reconstruction: As part of the first assessment of disaster research Mileti, Drabek and Haas (1975) noted that there was little research focusing on post disaster recovery and reconstruction. The following decade saw a number of major efforts focusing on a variety of issues including community reconstruction and recovery efforts (Haas, Kates, and Bowden 1977; Bates 1982), post disaster housing (Quarantelli 1982), household recovery (Drabek and Key 1984; Bolin 1976 and 1982), and longer term aggregate impacts (Wright, Rossi, Wright, and Weber-Burdin 1979; Friesema, Caporaso, Goldstien, Lineberry, McCleary 1979). These and other efforts were an important beginning, however slightly more than ten years after the first assessment Drabek (1986) suggested that long-term recovery issues were still the least studied and understood. The 1990s saw the publication of work that provided a more comprehensive understanding of recovery issues (c.f., Blaikie et al. 1994, Bolin 1994; Berke and Beatley 1997; Bolin and Stanford 1998; Dahlhamer and Tiernery 1998; Peacock, Morrow, and Gladwin 1997; Comerio 1998) and yet, Tierney, Lindell and Perry (2001:100) noted that the entire recovery "process remains significantly understudied, and little research has looked at post disaster housing patterns across social classes, racial/ethnic groups, and family types." More recently the NRC's (2006:146) assessment of NEHRP funded research, noted that the program's focus was on preparedness and response and not on recovery. Without a more complete understanding of recovery and reconstruction key dimensions of resiliency will remain missing. Indeed, without sufficient data on short and long term recovery with respect to households, housing, businesses, and other components of our communities, developing and validating models of community resiliency or assessing the effectiveness of recovery policy and planning will remain elaborate conjectures.

Examples of specific recovery and reconstruction research questions.

- How do households transition through the housing recovery process following a major natural disaster and do these processes differ for households occupying different forms of pre-disaster housing and having different tenure status?
- What roles do different forms of aid and recovery resources (e.g. savings, insurance, government programs, etc.) play in household, housing and business recovery?
- What factors shape household post-disasters decisions on whether to leave or rebuild/repair their home and how does mitigation fit in the latter strategy?
- What are the long-term impacts of disasters of various types and magnitudes on individuals, households, businesses, and communities and who are the winners and losers in the recovery process?

In sum, the research agenda of the observatory will have as its primary research theme the measurement, assessment, monitoring and modeling of natural disaster resiliency and hazard vulnerability. This primary objective will be enhanced by targeting three research focus areas: 1) risk assessment, perception, and management, 2) mitigation, and 3) recovery and reconstruction. While RAVON's research agenda is of course critical, workshop participants also felt it important that the agenda be closely coupled with guiding principles for data collection activities to ensure that RAVON's full scientific potential is reached.

V. Guiding Principles for Data Collection Activities

As discussed above, resiliency and vulnerability science demands the creation of an observatory to overcome the often severe and debilitating weaknesses inherent in traditional research approaches. As mentioned above, past and extant research projects are generally limited to cross-sectional data collection techniques employing widely varying sampling strategies with disparate measurement protocols and analysis techniques. Attempts by the research community to integrate, pool, or otherwise use these data for additional analysis or model development are often doomed from the outset because of uncertainties surrounding the data collection strategies, incompatibilities in measurement and sampling approaches, and a lack of metadata if the data are made available in the first place. In light of these problems and to maximize the probability of RAVON successfully implementing its mission to address the core research theme and focus areas outlined above, workshop participants felt it was critical to establish a set of guiding principals for data collection activities. The following provides a brief discussion of these principles.

A. Time dimension: Time is a critical dimension for data collection activities to be undertaken by RAVON. The major limitation of traditional research is that it is generally a one shot cross-section design or in a very few cases panel studies of very short duration or limited sample size (Bates 1982; Bolin 1982; Drabek and Keys 1984 Peacock, Killian and Bates 1986; Bolin 1982). Only in a few cases were time series data utilized, but in each case the time intervals were less than optimal and problematic aggregate data were employed (Friesema, Caporaso, Goldstien, Lineberry and McCleary 1979 and Wright, Rossi, Wright and Weber-Burdin 1979). Almost non existent are pooled cross-sectional studies utilizing the same or very similar instruments (cf. Cross 1990). In principle RAVON must focus on the development of long term longitudinal data sets, where long term refers to data collection over decades not simply years. The appropriate time intervals between data collection activities might be yearly or, given the rapidity of change with respect to some phenomena, quarterly, monthly, or perhaps even weekly.[9] The creation of large scale longitudinal data are critical for developing appropriate models of change and are also fundamentally important for monitoring changes in vulnerability and resiliency. Indeed, the monitoring of changing patterns of resiliency and vulnerability, including risk perception, mitigation, and recovery or reconstruction, will be critical not only for the advancement of the science, but also to facilitate the ability of local communities to monitor their own progress.

B. Standardization: RAVON should seek to ensure comparability across data collection efforts being undertaken through time and across sites. Investing in the development of protocols for data collection and measurement of all key concepts and across units of various levels of scale and aggregation will be critical. Protocols must be flexible to ensure comparable measurement in multiple socio-political environmental settings and across hazards. Protocols must also be revisited and reevaluated periodically to incorporate new and refined instrumentation with the goals of enhancing validity and reliability. The development of new protocols should also include prescribed techniques for translation and modification between old and new techniques. Protocols must be made available to the larger research community regardless of affiliation with

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[9] In come cases it may be necessary to employ tracking surveys, compressing the data collection time interval just before and after a major natural disaster such as a hurricane or flooding event.

RAVON, thereby promoting data comparability throughout the field both nationally and internationally.

C. Comprehensive & representative views of place: One of the critical factors discussed at the workshop was that place and space matter when considering resiliency and vulnerability. RAVON data collection activities should seek to capture the full complexity of place based attributes composing the coupled socio-ecological systems in order to achieve a comprehensive and representative view of place. Particular attention should be given to capturing data on interactions among social units operating within a location and with respect to the vertical and horizontal linkages between place based units and units outside a given locale.

D. Build on existing efforts: RAVON should seek to build on and complement existing data collection efforts and activities to the extent that these efforts are consistent with measuring and monitoring dimensions of resiliency and vulnerability. One obvious connection would be with the United States Geological Survey (USGS) which is actively engaged in the development of data sets related to risk assessment, vulnerability and resiliency. The observatory network should promote special relationships to other agencies such as the U.S Census, Census Research Data Centers[10] (RDCs), Bureau of Economic Analysis, Census State Data Centers (CSDCs), U.S Army Corp of Engineers, Department of Commerce, NOAA, EPA, etc. to acquire, develop and maintain comprehensive longitudinal datasets. Similarly data are being collected by state, county and local governments can be highly useful in tracking and monitoring land-use, land-use restrictions, and land use changes. Where possible the observatory network should also seek to establish relationships with private (both for-profit and non-profit) organizations that are involved in data gathering activities. Finally RAVON should also seek to establish relationships with other environmental observatories and university based research projects to promote complementary data gathering and sharing activities. It should be noted that in all of these cases, the simple acquisition of data will not be sufficient. RAVON must insure that all necessary meta-data are also obtained and where possible assessments of the validity and reliability should be undertaken. Sufficient resources must be invested to appropriately merge, link, or concatenate data into comprehensive systematically structured formats that can make these data usable for the research community. Throughout these activities appropriate IRB clearances and procedures will be followed.

E. Data sharing: A critical function of RAVON should be to enhance data sharing throughout the research community. The observatory network must establish baseline measures on critical resiliency and vulnerability measures and must continue gathering data on a longitudinal basis to advanced scientific analyses, modeling, and monitoring. All of these data gathering activities and the creation of comprehensive data bases must feed into easily accessible data archives. Procedures and agreements must be developed by RAVON participating researchers for data sharing within and outside the network. The archives should include data, meta-data on all datasets, protocols utilized in data collection, modifications and instructions necessary to combine data into comprehensive datasets and example instruments utilized in the collection of

[10] RDCs are secure Census Bureau facilities located at partner institutions where researchers with Special Sworn Status (SSS) can access a limited amount of confidential Census Bureau data needed for specifically approved research projects.

primary data. There should be clear protocols for acknowledging the sources of these datasets, protocols, and instruments.

F. Additional data issues: There were additional issues related to data and data acquisition that were raised during the workshop and should also be considered. The following presents a brief discussion of some of these factors.

1. ***Models and measurement:*** Despite over three decades since the *first assessment* (Mileti, Drabek, and Haas 1975), the nation and field still lacks adequate measures for and inventories of what disasters cost the nation on an annual basis, which is critical for monitoring progress toward reducing vulnerability and enhancing resiliency. As noted by the National Science Board's report on hurricane research (2007) there is a high priority need to better understand the broad socio-economic impacts of hurricanes and mitigation measures, but to meet this need there must be a concerted effort to improved analytical models and measurements of these impacts.
2. ***Rationales for dataset development:*** Rationales will need to be developed to guide in dataset development. These rationales should provide guidance regarding the types of data that should be merged and assist in making difficult decisions related to data collection priorities. The latter will be important for guiding decisions related to assessing the relative cost and benefits of investing in particular types of data collection activities. Some data will be easily available, but of little benefit and therefore a waste of time and effort to include in archives, while other data will be much more difficult to obtain – perhaps requiring primary data collection activities – but critical for research needs.

3. ***Units of analysis and aggregation issues:*** RAVON should seek to promote the development of data sets on a variety of units of analysis, varying in scale and aggregation. Highly aggregated data are likely to distort and mask considerable variation and heterogeneity, making them of little utility in understanding disaster impacts and post disaster recovery. The general goal should be to gather data at the lowest level of aggregation – household, business, organization, parcel, municipality, etc. – and allow researchers to aggregate these data as needed. RAVON scientists should also seek to integrate data creating hierarchal datasets that will greatly facilitate the modeling of complex patterns of causality. So for example, individual data could be linked to household data, neighborhood data, community data, etc. Critical in this nesting will be the ability to spatially locate units of analysis.

4. ***Spatial issues:*** As noted above, place and space are critical for resiliency and vulnerability; therefore it will be critical to locate social actors and system spatially in order to fully understand objective and perceptional dimensions of resiliency and vulnerability. Hence, to the maximum extent possible all data should be spatially located in as refined a spatial unit as possible.

5. ***Secondary and primary data:*** RAVON must be involved in ***both*** secondary and primary data collection activities. There is a virtual cornucopia of secondary data that can be systematically gathered, linked and structured. These data include census data (block, block-group, tract, place, PUMS, etc.), parcel and/or tax portfolio data, real-state sales

data, land-use data, hazard data, etc. RAVON must invest in gathering and systematically organizing these data for the research community. However, RAVON's researchers must also engage in primary data collection, particularly on critical units of analyses such as households, businesses, local governments, etc. These data should be collected using panel sampling design or by utilizing techniques to ensure the pooling of cross-sections through time. There are strengths and weaknesses in both approaches, particularly when the focus is on the changing nature of populations in particular spatial locations. The former will provide detailed information on how units change through time while the latter will provide excellent estimates for how change is registered in representative samples of units drawn from populations located in the same area or region. Both forms of primary data are necessary and when combined and integrated with secondary data they can provide excellent resources necessary for fully developing resiliency and vulnerability science. It is important to note that relatively recent advances in quantitative methods within the social sciences now provide researchers with a full range of tools to analyze these data.

VI. Structure, Governance & Implementation.

In addition to the research agenda, participants also discussed how RAVON might be structured and governed. Indeed, it was important to participants that the observatory not be a highly centralized network, controlled by only a few researchers, but rather a distribute network, drawing on the strengths and diversity of the research community. This section provides a discussion of RAVON's potential structure and governance, paying particular attention to the primary function of its governing structure – coordination. The final section provides a brief discussion of how RAVON might be implemented following a stage like development scenario.

A. The Structure of RAVON: There are many examples upon which to model RAVON. Some examples include: the National Center for Ecological Analysis and Synthesis (NCEAS, http://www.nceas.ucsb.edu/); the Long Term Ecological Research Network (LTER, http://www.lternet.edu/sites/lno/ or http://lno.lternet.edu/); and the National Environmental Observatory Network (NEON, www.neoninc.org).[11] NCEAS has a very decentralized structure. The Center coordinates research through calls for proposals, and its key functions include data repository and metadata development. But the databases in the repository appear to be uncoordinated and investigator-driven. LTER is designed as a network of centers that are strategically located (from an ecosystem diversity point of view) around the country. It seems to comprise a network of local-area observation nodes. But the nodes seem to have substantial autonomy. The data repository includes methods databases. LTER researchers are not always located at a regional node, but nevertheless are members of the research team for that node and the node attempts to coordinate and facilitate research at their location. Finally, NEON is national observatory intended to implement standardized data collection across the country. The nodes are located strategically across the country, and the data collection at each node is standardized, to include common field instruments for long-term data collection, networked

[11] There are other examples including the Water and Environmental Research Systems (WATERS) Network and earlier observatory initiatives such as the Collaborative Large-Scale Engineering Analysis Network for Environmental Research (CLEANER) and Consortium of Universities for the Advancement of Hydrologic Science (CUAHSI).

sensors, and the like. Notably, to allow flexibility, they also have a rapid deployment system of instruments that can be deployed in sudden events such as forest fires.

The general workshop consensus was that RAVON should consist of a network of locations, centers or nodes. However, rather than conceiving of the network as being composed of isomorphic nodes, all essentially carrying out similar activities but different locations, participants identified at least three types of nodes within the observatory network: *regional, thematic*, and *living laboratory* nodes.

Regional nodes will carry out coordinated data collection activities related to natural hazard vulnerability and resiliency. Each node should have a degree of autonomy in that it might be engaged in unique research activities targeting particular dimensions of resiliency and vulnerability. However there should also be a core set of research activities, coordinated across the network, that are undertaken by each regional node. Criteria for selection of regional nodes should include:

1) Ideally there should be an existing, resident group of researchers with a credible track record who are interested in participating as a node. The strengths and quality of potential nodes should be based on: a) a track record of excellence in research with a bias toward innovation versus incremental research; b) a credible strategy for continuing research excellence; c) demonstrable links between the researchers and a community of practice and d) an articulated, credible commitment that builds confidence that the work proposed will be robust and sustained over a period of decades.
2) There should be some degree of regional distribution around the U.S., North America and ultimately globally. Criteria for determining regional distribution should include: a) bio-physical environmental characteristics including hazard types, areas with chronic low level disasters, past experience with high impact disasters, and relatively high likelihood of high impact, low probability events; and b) socio-political environments insuring diversity in legal, political, socio-economic, cultural, and demographic characteristics.
3) Localities or regions with strong interest or potential for involvement of local community leaders and practitioners should be given priority to better ensure the relevance and applicability of monitoring activities and research.

Regional nodes might better be considered regional hubs that coordinate researchers at a number of universities or research centers who are undertaking integrated data collection activities within a geographical region.[12] Some researchers themselves may be located anywhere, but would travel to the region during field work activities. Ideally there should be a physical location for the node (hub) in the region which would act as a headquarters coordinating activities and would work closely with entities (state, county, and municipal governments, etc.) within the region.

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[12] In a sense this structure would not simply be a nodal network, but rather a network of star structures structure with regional or "center" hubs connecting sub-nodes representing researchers at other universities/organizations that are coordinated through the local/regional hub, which in turn is connected to the larger network structure.

Thematic nodes might include existing centers or mission based agencies such as the USGS that are currently engaged in activities that can directly support the mission of RAVON. The USGS is perhaps an example of a thematic node in that it is already carrying on resiliency and vulnerability analysis and generating spatial datasets at a relatively high level of aggregation across the nation and at a more refined datasets for specific locations such as the Oregon coast and Hawaii. The inclusion of the USGS as a thematic node could greatly enhance the coordination of data collection activities between RAVON and USGS. In a similar vein, the National Hazards Center at the University of Colorado is already serving an information clearance function for the hazard and disaster research and practitioner communities and hence could facilitate information clearance functions for RAVON. Such a thematic node could also facilitate information sharing among researchers working within RAVON by providing yearly opportunities to present research papers and posters at the annual National Hazard Workshop and the Hazard and Disaster Researcher's meeting held immediately following the Workshop.

Living laboratories nodes would be nodes established in areas impacted by a natural disaster. The establishment of living laboratory nodes would be undertaken and agreed upon by the entire observatory network given disaster opportunities that may present themselves. These may be established as a supplement to a current regional node, should a disaster impact the region already covered by an existing node or as a new node. The resources from all or part of the network can, with NSF approval, be utilized to rapidly act upon these opportunities as they present themselves. These should not be established as short term nodes, but rather as long-term investments by the network to capture and collect data on impacts and long term recovery. The exact procedures for making the decision to establish a living laboratory node will be worked out as part of the network's charter. However there was a sense of the workshop participants that creating one of these nodes should require a unanimous decision by RAVON's executive committee in conjunction with NSF program officers.

B. Governance: RAVON should be governed by an executive committee made up of the directors or representatives of the various nodes participating in the network. The executive committee members will expand as the number of network nodes increases. There should be an elected chair of the executive committee serving for two or three years and one of the nodes will act as a technical directorate for the network, providing logistical and administrative support for the overall network administrative functions. One of the first activities of the executive committee should be the development of a charter and constitution for the network.

Coordination across a spatially distributed network will be the key governance activity undertaken by the network. A critical element of this coordination will be concerned with data collection and archiving.[13] Again, implicit in the notion of the creation of an observatory network structure is that data collection efforts will be occurring simultaneously at multiple sites or nodes. While it will be important to allow for data collection activities to be responsive and

[13] The archiving of these data can be important because revisiting and reanalyzing "historical" datasets might be particularly fruitful. For example, advances in generalized linear models, hierarchical linear models, and panel analytic techniques provide a greater range and flexibility for researchers to undertake appropriate analyses with all forms of recovery measures.

malleable to the unique socio-political and bio-physical environments of node located, it will also be critical that consistent and systematic measurement protocols are developed and maintained in order to ensure comparability through time and space. Furthermore, it will be important to develop protocols and techniques for translating or converting data, where possible, in to consistent formats, metrics, and projections. This is very likely to be the case for secondary data. Hence a critical role of the observatory network will be to develop and ensure the use of standardized data collection protocols, conversion techniques, and storage/archiving protocols. It is likely that a specialized technical committee or set of committees should be established to develop these protocols and to insure quality control across data collection sites. The network should establish committees to enhance its operation with respect to these activities. Some of these will be standing committees, while others may be ad hoc.

Creating and developing collaborative partnerships with federal and national level entities, regional entities such as local communities, non-profits, foundations, public agencies as well as universities will also be important for RAVON success at both the national and local levels. As such, nodes in the observatory network should seek to coordinate and build on ongoing data collection efforts by organizations (universities, public agencies, foundations, private nonprofits) within their regional areas. In addition, creating partnerships with local entities might better ensure that that the science generated by RAVON helps reduce vulnerability and enhance resiliency. The networks should also support outreach and education in local communities not only with schools, but with organizational constituents operating within each observatory's jurisdiction. Nodes should seek to generate demonstrable links between a research community and a community of practice promoting success in coordination between researchers and practitioners leading to greater community resilience, and should develop clear strategies and actions for long term sustainable coordination between researchers and practitioners in future years. Both of these activities might be facilitated by the creation of a national advisory committee for the network as a whole and local advisory committees for regional network nodes.

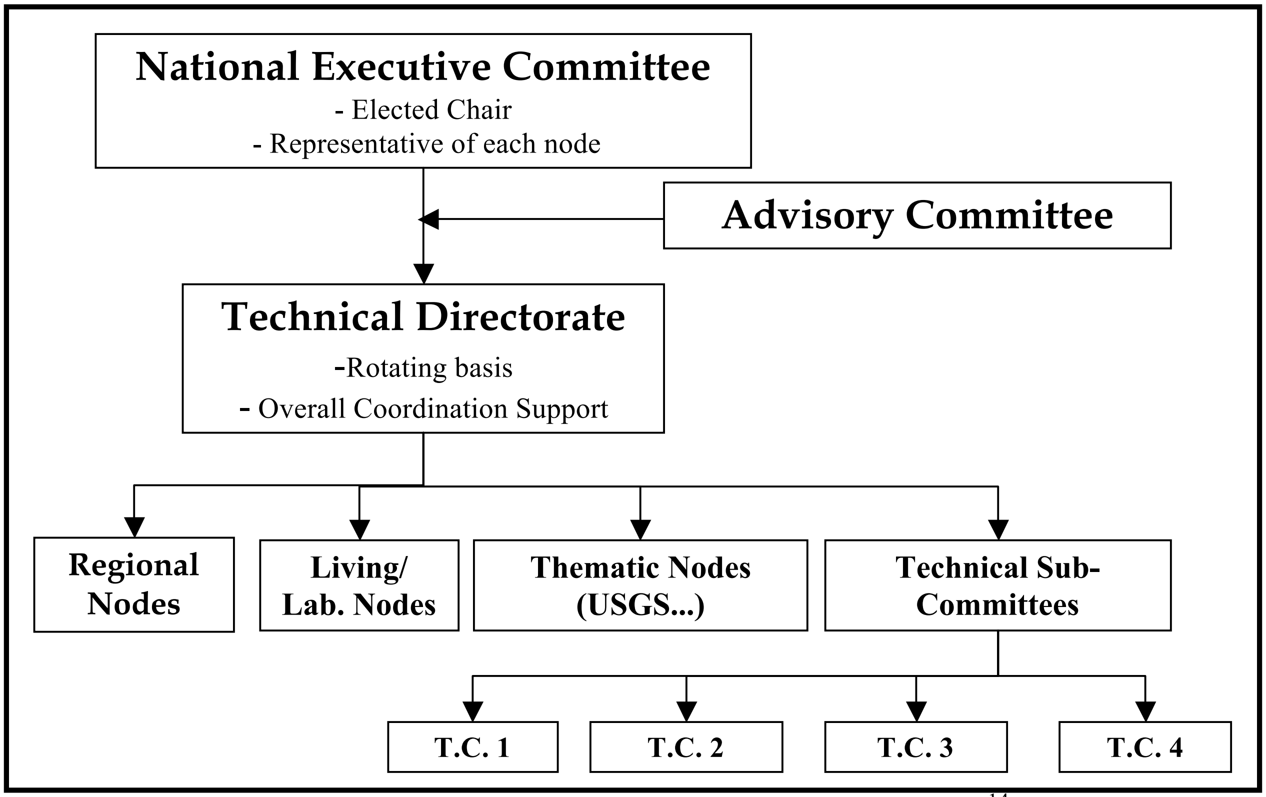

Figure 2. Example of RAVON's Organizational Structure[14]

Figure 2 offers a visual representation of RAVON's structure. Overall governance could be coordinated by a national executive committee supported by a rotating technical directorate which itself would be housed at one of the network nodes and a national advisory committee. The meat of the science would take place at regional and thematic nodes. There would also be a set of technical sub-committees which would develop data protocols, monitor data collection activities, and archive and distribute data to the network and broader research community.

C. Implementation of RAVON: As a distributed network is seems reasonable to assume that the implementation of RAVON should be phased in through a multi-year process which will also allow for its executive committee and governance structure to be created as a phased process as well. It is likely that additional planning workshops will be necessary to fully development an implementation strategy, nevertheless a possible scenario might consist of an initial phase in which 5 to 6 nodes were established through an RFP process. These initial nodes should have base funding of approximately 400K per year. Selection of the observatory network nodes will be based on criteria outlined above, although it is conceivable that a thematic node might also be funded during the initial phase. The PIs on these projects will serve as the initial steering committee and provide assistance to NSF related to the next round of nodes selected and begin the development of the observatory network's charter and constitution. Technical committees should also be tasked with the development of protocols to be implemented throughout the network. The following year 3-5 additional nodes should be established, again employing an

[14] The authors would like to thank Himanshu Grover, PhD candidate at the Hazard Reduction and Recovery cent for developing the initial organizational diagram upon which this version was based during the workshop.

RFP process and a coordinating grant might be awarded to one of the network nodes establishing the technical directorate for RAVON. The technical directorate coordinating grant should be a 3 year grant, with new or renewal grants based on coordinated efforts between the steering committee and NSF program officers. Approximately 5 years after the initial round of nodes was established, the steering committee will recommend an additional phase of network growth.

VII. Conclusion:

In many respects the *Second Assessment* (Mileti 1999) marked an important watershed for natural hazards research in the United States. First it brought into clear focus one of the over arching implications emerging out of multiple steams of natural hazards and disaster research which was that any understanding of disaster impacts in general and increasing disaster losses in particular would not be found by continuing to focus simply on the nature of the hazard agents themselves. Rather, in very simple and stark terms the second assessment stated that that "the choices that are made about where and how human development will proceed actually determine the losses that will be suffered in future disasters" (Mileti 1999:27). The second assessment therefore demanded fundamental shifts in hazards research to a focus on how the actions of human social systems shape and determine disasters and a broader understanding of the consequences of the interactions and relationships between human social systems, their built environment and the bio-physical environment.

In the almost decade since the publication of the second assessment, researchers in the field have responded. Vulnerability research now increasingly includes not simply hazard exposure and the physical characteristics of hazard agents themselves, but also social factors are now also seen as critical dimensions in vulnerability analysis and assessment. Even more recently, disaster resilience has emerged as a critical focus area demanding, not simply the modeling of how complex social systems resist, rebound and respond to disaster, but also a broader ecological perspective, placing social systems in interaction with bio-physical systems to better assess changing vulnerabilities and ultimately resilience. The emergence of vulnerability and resilience science in the hazards field has brought into even shaper focus the once chronic, but now acute limitations of current approaches to hazards research.

RAVON offers the possibility of transforming the nature of research on natural hazard vulnerability and disaster resiliency. It provides a mechanism for dramatically altering the nature of the resiliency and vulnerability science by providing the opportunities to develop comprehensive long term data sets in multiple locations that will make possible temporal and comparative investigations that researcher will never be able to undertake given normal funding opportunities and structures. In addition, RAVON offers a necessary and fundamentally important complement to NSF's existing environmental observatories by directly addressing the human and social structures and dynamics driving anthropomorphic environmental changes. Resiliency and vulnerability science will undoubtedly progress without RAVON, but progress will be slow, fitful and, given ever accelerating losses, painful. With RAVON or a RAVON like observatory network however, there is the possibility of generating solid resiliency and vulnerability science that can better inform and promote more resilient communities in the future.

Appendix 1: The Workshop

During mid-June, 2008 a two and a half day workshop entitled, *A Workshop on the Concept of a National Hazard Vulnerability and Resiliency Observatory Network*, was held at Texas A&M University. The workshop was funded by the National Science Foundation and the United States Geological Survey and hosted by the Hazard Reduction and Recovery Center at Texas A&M University.

The workshop was organized by a steering committee whose members were: Philip Berke (University of North Carolina – Chapel Hill), Stephanie Chang (University of British Columbia), Susan Cutter (University of South Carolina), William Hooke (American Meteorological Society), Howard Kunreuther (Wharton School – Penn) and Walter Gillis Peacock (Texas A&M University), who served as chair of the committee.

In addition to the steering committee, workshop participants included: Richard L. Bernknopf (USGS), Samuel D. Brody (Texas A&M University), Raymond Burby (University of North Carolina – Chapel Hill), Ann Margaret Esnard (Florida Atlantic University), Tom Gunther (USGS), Jamie L. Kruse (East Carolina University), Michael K. Lindell (Texas A&M University), John C. Pine (Louisiana State University), Carla Prater (Texas A&M University), George O. Rogers (Texas A&M University), Kimberley Shoaf (University of Califorina – Los Angeles), Arnold Vedlitz (Texas A&M University), William Wallace (Ressresler Polytechnical Institute), and Nathan J. Wood (USGS).

The steering committee and participants were greatly assisted by a team of graduate and undergraduate students from the Hazard Reduction and Recovery Center. Sarah P. Bernhardt was the conference coordinator and organizer and the other students involved were Himanshu Grover, Rahmawati (Ama) Husein, Gabriel Burns, Jung Eun Kang, Yi-Sz Lin, Joseph S. Mayunga, Wesley Highfield, and Walter M. Peacock.

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