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Mega-Cities, Mega-Disasters and Disaster Mitigation

Mega disasters result when a natural mega event, such as a high intensity earthquake, typhoon, hurricane or Tsunami, or a human-induced large-scale event strikes a mega-city, possibly leading to multi-event catastrophes. Multiple events such as fires, floods, breakout of diseases, and release of toxins to the environment start a chain reaction of failure of services, communication and transportation and other similar life lines of a mega-city. Together with such physical failures, loss of human life and human suffering, long-term disruption of life in general lead to a mega-disaster.

From the viewpoint of disaster mitigation or reduction, mega-disasters may be considered in three parts. Before, during, and after a mega event becomes a mega-disaster. All the training, education, and preparedness that take place can help mitigate the scope of the disaster with appropriate responses by everyone. Such preparedness requires close collaboration of technical, social, and legislative components of a civil society. Focusing only on the engineering aspects, vulnerabilities of infrastructure need to be identified and strengthened to reduce the possibility of a chain reaction of events.

Strengthening the widespread vulnerabilities that exist in many of the well established mega cities require resource that may not be readily available and, thus, requires mega will supported by sound risk assessment methodologies.

When considered from a technical viewpoint, a mega event consists of energy build-up, energy transport, and energy dissipation. The engineering aspects of energy release or dissipation at a mega-city involves infrastructure and has been well considered. The forecasting of natural mega events still needs further understanding, particularly, of the source during energy build-up and release.

Since different mega events have different time scales during which energy is built up and transported, they need different considerations. For instance, the ratio of the time it takes to build up energy before an earthquake to the time it takes to deliver it is inverse of, say, that of a hurricane. Notwithstanding the slower development of energy build up before an earthquake, forecasting it with a useful lead time and certainty is still not available. As an example of what can be investigated, the relative motion at the fault lines exhibit “micro” stick-slips that have been measured using sensors placed deep in earth. These are not unlike micro stick-slip that develops between the flat surfaces of two solid bodies. A better understanding of the latter may lead to the same of the former.

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Mega-City/Mega-Disaster Reduction: Persistent Challenges in Response and Recovery Management

Typical emergency response operating philosophies use a functionally-oriented command and control system to direct response and recovery following any sort of emergency event. In the U.S. this is systematized in national doctrine as the National Incident Management System (NIMS), which has at its core the Incident Command System (ICS). NIMS/ICS is an “all-hazards” approach intended to be employed to manage incidents of all types and of all sizes. This and other conceptually similar approaches around the world have a long and strong track record of success at enabling effective incident mitigation. Chief among the advantages of such systems is a commonly understood set of management conventions that allows numerous disparate agencies to work together seamlessly.

The way contemporary incident command and management systems are designed presumes that management requirements scale linearly from small, simple incidents to very large very complex incidents. The notion is that smaller incidents use a collapsed version of ICS, whereby only those functions warranted by the incident are staffed, and single individuals may assume several functional responsibilities. For larger, more complex incidents, or as a small incident grows larger and more complex, command and control structures expand to meet the demands of incident response. For very large incidents, multiple incident management teams each direct portions of the incident and are harmonized by superordinate command, control, and coordinating structures. Thus the management approach applied is essentially the same, regardless of the size and complexity of the incident.

In fact, however, though current incident management operating philosophies succeed well during moderately-sized or well-understood disaster events, they are inadequate in the face of very large, very complex incidents like Hurricane Katrina. Instead of scaling up to address these incidents, management systems persistently fail in substantial ways. Disaster after disaster, after action reports document management challenges that frustrate the effectiveness of response and recovery efforts. This means that a major gap in preparedness for Mega-City/Mega-Disasters (MCMDs) is an assured management infrastructure to guarantee effective command, control, coordination, and communication. In particular, there are three areas where the capability of current management systems is insufficient:

Leadership. MCMD scenarios are plagued by unclear, multiple, duplicative, isolated, and sometimes conflicting and uncooperative command structures. Large incidents demand that robust command and control structures emerge out of the initial chaos that inevitably ensues when disasters strike so that resources may be brought to bear quickly and effectively to save lives. Typically, though, these incidents also involve a multitude of agencies from many disciplines and jurisdictions—and even from several different nations—each of which directs its own resources. Since each entity has legitimate missions, responsibilities, and authorities, each uses its own command and control process to take charge, in a legitimate attempt to meet the needs the agency faces and solve the problems it is supposed to solve. Absent a pervasive approach to which all participants subscribe, however, confusion results. Note that the term "command and control," does not assume structures that are unitary, rigid, or static. In fact, successful management requires collaboration, flexibility, and adaptability across multiple diverse actors. Likewise, management approaches need not be imposed, but may develop organically. Thus the practical challenge and research puzzle is how coherent joint management networks can emerge in MCMDs where there are a very large number of organizations involved who don't know each other and don't habitually work together.

Communications. Our systems of coordination are predicated on being able to garner and disseminate information to support collaborative decision-making and enable joint operations. A major challenge of large disasters is that they destroy our physical infrastructure, including our communications systems. Despite the known limitations and fragility of the existing infrastructure, we lack contingency plans for how to communicate when technology fails (or is destroyed). And beyond this, communications isn't entirely (or even fundamentally) a technology problem. Communicating requires that people have useful, actionable information and that they are willing to share it with each other. Thus we face three research challenges: how to develop communications systems that will be available to us even during catastrophic events; how to create communications systems that work independent of technology; and how to generate the trusted relationships on which effective communications depend among people distributed across multiple, disparate, geographically distant organizations.

Logistics. Large-scale, long-duration incidents demand more resources–personnel, equipment, supplies, commodities, specialized capabilities–than any agency or government can maintain on hand, so these resources must be obtained rapidly when a disaster occurs. This makes resource identification, acquisition, management, and distribution a major function of incident management. Resources must be obtained “real-time,” but normal management systems are too slow and are not designed to obtain large amounts of supplies rapidly and to distribute them directly to the places where they are needed, especially when transportation systems are disrupted. Private sector resource distribution systems, which make expert use of techniques like just-in-time resource delivery, are not designed around the episodic and uneven flows associated with disasters. Thus the research challenge is how to design systems that can predict the resource demands that will be levied by a disaster, identify resources to fill these demands in real time, and plan delivery systems that will work under the conditions created by the disaster.

Absent robust solutions to these fundamental challenges, response and recovery to MCMDs will be severely hindered. Viable solutions necessarily rest on technological innovation, particularly in the form of predictive models, management information systems, and decision support systems. That said, these technological solutions must give explicit consideration to the implications for people and the ways in which people interact in organizations and management structures which are designed around current tools and technologies. In short, solutions must be both usable and useful, and research approaches must therefore involve scientists, technologists, engineers, social scientists, and emergency response practitioners in close partnership with each other.

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The Need to Plan for Recovery

The most under-investigated aspect of a disaster is the recovery phase. Unfortunately for many disasters in the United States the same impediments to recovery are faced time-and-again, and yet so many aspects are translational. This is especially true from a spatial perspective where the processes of mitigation and exposure are likely to reveal patterns on the landscape that will impact recovery. For example, consider the following recovery focused questions:

How can cities work through the “recovery gap”, the difference between accessible funds to rebuild and the actual money required – *at a community / street / individual building scale*? If there is an underlying social process then these recovery gaps should reveal spatial patterns. Can these patterns be used to predict recovery impediments even before a disaster?

How does urban health vulnerability influence recovery, either directly or indirectly through reduced mitigation and increased exposure? Again, can mapped patterns of health vulnerability be used to reduce both exposure and recovery impediments?

Is there a spatial pattern of recovery at the finest scale that influences return or subsequent abandonment? For example, should government funded recovery only occur in clusters, and if so, what is the minimum number of residences required to be successful?

Are there lessons to be learned from past disasters in terms of how communities react, how disparate wishes at town hall meetings can be reconciled, and how different recovery funds can be accessed? One would think so even though evidence suggests most disasters result in the reinventing of the wheel.

A common theme to these problems is one of geographic scale – although recovery plans for a megacity will obviously involve city, state and federal oversight, it could be argued that equally important is the understanding and empowerment of neighborhoods. Recovery cannot be evenly distributed – a prioritization of resources is required. How does that prioritization occur? Should there be a spatial frame to this organization based on the three previously mentioned recovery impediments?

In order to answer these questions academics need to be more fully involved in studying the recovery process. Unfortunately there are challenges to such work. Fine-scale data are required in order to assess recovery patterns, and make comparisons to pre-event baselines. These data may not be available or the researcher faces data release impediments. Fine-scale post-event infrastructure and building data are also hard to acquire, either originating from the immediate post-disaster period or as an assessment of building level recovery through time. New forms of fine scale spatial post-disaster data collection have been developed, yet many "academically-important" data sets are collected by FEMA and their contracting companies – the majority of which will never be accessible by academics.

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Bio-Inspired Smart Sensor Networks for Adaptive Emergency Response

One of the most urgent and important challenges confronting society today is that of addressing the vulnerability of our civil infrastructure to mega disasters. In 2007, there were 414 reported natural disasters globally, affecting 211 million people, killing 16,847, and leading to over $74.9 billion (USD) in damage (CRED, 2008). These staggering numbers highlight the social and economic costs that society must bear, costs that can be reduced by more effective response and recovery efforts.

The recent disasters such as Hurricane Katrina and the Haiti Earthquake have brought real-time images of destruction into our homes like we have never seen before. Technology has succeeded in bringing global attention to these tragedies leading to fundraising efforts focused on relief and recovery and policy changes designed to mitigate future tragedies. However, in terms of saving lives, the first few hours after an event are the most critical. In these times, technology has in a sense failed to achieve its potential. During the Haiti earthquake, CNN reported that many victims were texting relatives on mobile devices, but not being located or rescued by authorities. Indeed the world is inundated with a vast array of sensors and networking in the form of mobile phones. There is at least one mobile phone subscription for every two people in the world. That is to say in a mega city during a mega disaster, the distressed would likely have access to a mobile phone. This preexisting telecommunications infrastructure can be adapted to form a decentralized and flexible communication network in the event of a mega disaster. Moreover, biological principles can be employed to cope with problems that frequently exist in the chaotic and inhospitable environment of disaster relief operations.

Mobile phones currently possess capabilities to sense (neurons) and communicate (synapses). Sensed information paralleling biological systems such as sound, video, motion detection, and GPS are currently standard capabilities of “smart” phones. If the user themselves are responsive, such sensory input is extended to the extent of which a human can perceive. These mobile phones are capable of traditional long distance communication via cell towers, with the potential of short distance communication through ad-hoc networking. Through efficient acquisition and processing of data followed by distribution of task-relevant commands, mobile phones could provide a decentralized means by which to relay critical information to rescuers and survivors. Disaster-enabled mobile phones could be a part of survivor status assessments, survivor and hazard locating, rescue efforts for trapped victims, and controlled evacuations. Such an innovative extension and use of existing technology will require interdisciplinary cooperative efforts between civil engineering, computer scientists, sociologists, and neurobiologists.

User oriented solutions cannot be implemented without engaging the public in awareness and education campaigns. In prototyping a mobile phone assisted response and rescue plan, challenges for establishing the communication framework and methods for engaging the residents of these mega cities must be outlined. Professionals, including police, firemen, hospital workers, and government workers must be trained to use this technology as a tool alongside their normal response and rescue activities. Moreover, these professionals should be an integral part of creating the system such that their needs in a mega disaster are met. At the same time, we must remember that mega disasters are infrequent and chaotic. In this regard, such a system should remain as simple as possible from the user's perspective.

Pushes to include IT innovations in disaster management before, during, and after mega disasters has been the focus of considerable research. However, the hierarchical nature of many approaches is too inflexible to address the unpredictable and evolving needs of the distressed. Currently, real-time information is reported through voice communication with centralized emergency call stations. This centralized system is adequate for isolated emergencies, however quickly becomes overloaded during wide-spread disasters.

A dense network of smart sensors operating under decentralized networking protocol holds much promise as a flexible and efficient response and recovery tool. Utilizing the existing capabilities of mobile phones, this framework is much closer to fruition than otherwise possible.

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Mega-City/Mega-Disaster Reduction

I grew up in the northeastern part of the U.S., where "small talk" with strangers and acquaintances typically includes much reference to the weather. The northeast is characterized by four distinct seasons and a long, cold, and damp winter. To me, this constant chatter about the weather reflects the understanding of a group of people aware that they are both part of and dependent upon their natural environment, not removed from it, as I often sense in our Mega-Cities.

With their robust infrastructure and buildings, Mega-Cities are human-made environments which I've observed have a tendency to distance their inhabitants from the natural environment and insulate them from its day-to-day variations and hazards through controlled indoor environments and engineered routes to move people and trade into, around, and out of the city expeditiously. Faced with a Mega-Disaster, a challenge I see for existing and emerging Mega-Cities is strengthening their inhabitants' awareness and understanding of the changing natural environment their city remains a part of, and leveraging that increased knowledge to socially prepare and physically re-envision more hazard resilient and adaptable cities.

In visualizing what tomorrow's more hazard resilient and adaptable Mega-Cities could look like, I think of cities of yesterday, the social systems, buildings, and infrastructure they are comprised of as relatively rigid, absorbing stress and force. I visualize cities of tomorrow with buildings and infrastructure more capable of flexing against environmental stresses and deflecting force, and systems more readily capable of adapting to change with minimal energy expenditure. Some examples of the science and technology that may comprise these cities of tomorrow already exist today for us to borrow and build upon.

- Floating homes and communities in the Netherlands that rise with flood waters.[1]

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[1] Evans-Pritchard, Ambrose. (2004, September 8). Dutch find a cure for rising damp - a town full of floating houses. *The Daily Telegraph*. Retrieved April 5, 2010 from

- Building and site design incorporating both traditional and modern ideas for increasing hazard resilience and energy efficiency and minimizing environmental impact. For example: thick walls high in thermal mass painted white, as in southern Europe, to reflect and absorb heat, and "green roofs" and roof gardens to reduce storm water runoff and cool the air.[2]

There is a saying that the tree that survives the hurricane is the one that's learned to bend. I believe that Mega-Cities cognizant of the environment they are a part of, and equipped with social systems and infrastructure inherently capable of flexing to the stresses of that environment, will be the ones that withstand the Mega-Disasters of tomorrow.

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US-Taiwan Workshop on Mega-City/Mega-Disaster (MCMD)

There is definitely a need to formulate strategies for densely populated communities to become more mega-disaster resilient. Major natural and manmade disasters in recent years throughout the world have elevated the urgency to systematically examine the complex, interlocking mitigation and response issues, to establish and prioritize research foci and to identify the weak links of the organizational infrastructure responsible for safeguarding these disaster vulnerable mega-city and/or densely populated communities.

In recent years, many conferences and workshops have been organized on a variety of relevant topics such as understanding and forecasting extreme events; loss estimation methodologies for the physical and social infrastructure systems due to individual hazards; hazard mitigation technologies for constructed facilities; disaster preparedness and emergency management, etc. The outcome of these gatherings has been very limited from the MCMD perspective. Because the scale, nature, scope and complexity of the MCMD problem are also at a "mega-level," which were never addressed systematically by the funding organizations nor the academic research community. There are too many unknowns at all levels and involve too many disciplines.

It is highly desirable that this US-Taiwan Workshop gives emphasis to establish an overall plan involving a series of future MCMD workshops over the next few years, and a roadmap to systematically identify and prioritize the future research agenda. Important issues are addressed in several future workshops each by an expert group. For example, this workshop should identify the extreme events to be considered, but the state-of-the-art on methods to forecast the frequency of occurrence of the selected extreme hazards and their intensity or other disaster-specific topics would be addressed by appropriate expert group in future special workshops. This workshop should not talk about a new sensor, a control system or a nonlinear structural analysis method.

Based on my very limited experience from working on multi-extreme hazard design of bridges, I would say that the emphasis of this first workshop should concentrate on developing only one or two themes at most (the last two). In my opinion, the most important theme for MCMD now is disaster preparedness and emergency management to minimize casualties. It is not too closely related to the type of disaster, so it does not require the integration of experts from different scientific disciplines. The next most urgent theme for MCMD is a vulnerability assessment method of the physical and organizational infrastructure. This is very tricky because community vulnerability is a dynamic process. Both these themes should only include necessary and relevant technologies, excluding those applicable at the lower systems levels (e.g. structural control).

Two years ago in planning of a post-mega earthquake workshop, I proposed a new focus for discussion to establish several levels of minimal casualties to aid in the development of policies and planning decisions for dense urban communities. It was rejected by engineering researchers, as they typically are conditioned to use no structural collapse as the bottom line. However, in preparing for a potential mega-disaster, a mega-city has to be realistic and willing to accept the possible outcome of a limited number of casualties when developing mitigation policies and response strategies. I suggest that this first MCMD workshop address this issue as well.

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US-Taiwan Workshop: Advancement of Societal Responses to Mega-Disasters Afflicting Mega-Cities

Recent large-scale disaster events, including the Indian Ocean Tsunami (2004), Hurricane Katrina (2005), the massive earthquakes in Sichuan, China (2008) and in Haiti (2010), as well Typhoon Morakot in Taiwan (2009) have raised our awareness regarding the impact and consequences of these events on a global scale. Moreover, they have brought to the forefront the imperative need to develop effective mitigation and preparedness strategies, including enhancing societal response at all levels, aimed at reducing or alleviating the consequences of such events. Risk and disasters are socially constructed phenomenon; they are influenced by the social and political structure, the availability of resources, stratification and inequality, population pressures (i.e., population growth, density, and distribution), and environmental degradation, among other factors. There are a number of important research areas, which warrant our immediate attention, especially when focusing on the impact of mega-disasters on mega-cities, as outlined below.

Changing Demographic Patterns: The changing demographic landscape, on a global scale, calls for a reassessment regarding our understanding of the societal impacts and consequences of disasters. During the past 60 years, the world population has experienced significant growth, reaching 6.8 billion inhabitants in 2009. Population movements have resulted in expanding settlements in regions with greater exposure to disasters. Also, mega-cities experience unique vulnerabilities including weaker social networks, limited escape routes, and high levels of poverty, especially in developing countries. Significant population influx to major urban areas impacts societies' ability to cope with disasters, generating difficulties in providing shelter and supplying food, water, and medicine to disaster victims. Surges in population density can also result in transformations in the natural landscape (e.g., deforestation), putting populations at greater risk. Population groups mostly settle near coastal regions, in poorly-managed floodplains, and other hazardous zones, thus increasing their vulnerability to disasters. However, researchers have paid limited attention to the interface between changing demographic patterns and disaster impacts and outcomes.

Impact of Disasters on Business Closure and Relocation: Disasters can have an intense and devastating impact on local economies, particularly if businesses do not receive the necessary economic support and disaster relief aid from governments, or do not have adequate insurance coverage. Extensive research is needed to better understand the indicators of business vulnerability and resiliency, as well as the characteristics that impact disaster preparedness and recovery among business owners; on how business closure and relocation vary according to the business sector and the characteristics of business owners, such as class, race/ethnicity, sex, age, household structure, and available resources; and on the role of government in providing resources and support to businesses, focusing not only on disaster response and recovery, but also on mitigation and preparedness.

New and Emerging Technology and Disasters: The successful design and implementation of new technology to better predict and respond to hazard events will ultimately depend on our ability to respond to and integrate the feedback of end-users, including community organizations and leaders. Technology matters, but what *really* matters is the application of the substantive knowledge that we generate regarding how individuals respond (or not) to severe hazard events, and how can we improve their response in order to minimize the devastating impacts associated with these events. Further research is needed on how we can actively engage end-users in identifying their risks, in disaster planning and management, in the development of new technology, and in the communication process. Moreover, we must respond to the needs, interests, and the limitations that end-user communities confront, if we are to minimize the loss of life, injuries, and damage to property.

Risk Communication: Most communication interoperability issues before, during, and after disasters are not technical. The National Research Council (2005:2) argues that better human organization, willingness to cooperate, and the willingness of government to listen to those at local levels are critical factors in making better use of information technology for disaster management. It is also important to highlight that access to multiple sources of information can create confusion and uncertainty among the public, particularly given inconsistent, contradictory, and inaccurate information. There are also technological failures or malfunctions that impact communication of risk information, which adversely impacts public response. Moreover, system interdependency and cascading events increase the population's vulnerability to disasters. The communication of risk information must take into account the societal context and processes in which these events occur. We must continue to expand our knowledge regarding how people and organizations perceive and respond to forecasts, warnings, and risk information, especially in an international context.

Developing Integrated Warning Systems: With continued improvements in monitoring, detection, and mass communication technology, the social and organizational features of integrated warning systems are of paramount importance in saving lives and reducing property damage. These systems should focus on emphasizing communication, education, and raising awareness, as well as responding to the needs of the population at risk (e.g., "people-centered" warning systems). This will also require enhancing communities' economic capacity and paying particular attention to issues such as poverty, inequality, and sustainable development.

Enhancing Resiliency of the Health Care System**:** Hospitals are in the business of handling emergencies, crises, and disasters and yet major disasters (such as Katrina and the earthquake in Haiti) reveal the vulnerabilities of already deteriorating health care systems. Moreover, these disasters present extraordinary sets of demands, which health care systems are not able to manage or respond to. However, disaster research focusing on the impact and consequences of major disasters on health care systems is limited, especially in the context of mega-disasters in mega-cities. Disaster planning and management strategies must consider how medical and health care facilities will maintain their operations and functionality in the absence of essential services and during the disruption of their inter-organizational systems. Planning, access to adequate resources, networking, effective communication and coordination, as well as training and education of medical staff is essential if we are to develop a resilient health care infrastructure that will be able to provide the much needed medical services to populations impacted by disasters. There is also an immediate need to focus on the physical and structural aspects of hospital buildings, including compliance with building codes that will increase their resiliency to high winds, floods, and earthquakes.

Governmental Response to Disasters: Many major disaster events, such as those mentioned above, bring to the forefront the inefficiency of governments in dealing with events of such magnitude. These situations also highlight the reactive rather than proactive nature of governments, placing emphasis on disaster relief rather than on mitigation and preparedness. Additional research is needed not only focusing on government preparedness and response, but on their role in building disaster resilient communities.

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Opportunities for Sensing and Actuation Technologies for the Mitigation of Mega-Disasters

Recent natural disasters including the Indian Ocean Tsunami (2004), Hurricane Katrina (2005), Sichuan Earthquake (2008) and Typhoon Morakot (2009) have all elevated the public's awareness in the vulnerability of large urban areas (*i.e.*, megacities) to natural hazards. The degree of physical destruction, the spatial impact of the events, and the lingering social and economic issues that result has led many to term theses events as "mega-disasters". Three factors make the occurrence of mega-disasters more likely in the future: 1) population growth in already dense urban centers; 2) poor construction quality of infrastructure systems in developing nations; and 3) deterioration of aging infrastructure in developed nations. Clearly, multidisciplinary solutions are direly needed to mitigate the effects of mega-disasters.

The safety of the civil infrastructure systems that society depends upon for its prosperity can be dramatically enhanced through the ubiquitous adoption of sensing and actuation technologies. The recent technological advancements in the information technology domain have resulted in many new sensing modalities that can be used to address the risk posed by natural hazards. The same wireless networks that provide users the convenience of untethered access to the internet can also be used to cost-effectively collect data from sensors installed throughout the natural and built environments. In particular, networks of wireless sensors can be used to monitor the environment (e.g., weather conditions, environmental loadings imposed on structures) as well as the physical behavior of infrastructure systems. The placement of dense networks of sensors will result in large sets of data that can lead to data-driven decision making. Data derived from dense wireless sensor networks installed throughout urban environments can also lead to improvements in understanding the loads imposed on infrastructure, assessment of their vulnerabilities to natural hazard scenarios, and real-time assessment of their conditions after a natural hazard event.

Another advancement of the information technology era is the cell phone; cell phones offer the convenience of anytime, anywhere access to telephony service. The recent generation of "smart" cell phones also illustrates the utility of sophisticated software applications that store personal information (*e.g.,* contacts, calendar) on the phone, utilize sensors embedded in the phone (*e.g.,* GPS positioning on maps) and offer internet-enabled tools such as email and texting. With 4 billion cell phones in use globally, they are capable of being used as a powerful regional data-collection network. Currently, these data-collection networks are only starting to be recognized as a tool for sensing society. Non-profit InSTEDD (Innovative Support to Emergencies, Diseases and Disasters) and for-profit Sense Networks both are exploring means of collecting (passively and actively) data and information from cell phone users to assist emergency response efforts to pandemics and natural calamities such as earthquakes. For example, cell phones can serve as a basis for determining the number, location and state of structural inhabitants following a natural hazard event. Other mobile phone sensor modalities including sound, picture and video open additional data types that could contribute to first responder's post-event decision making. While comparatively little research has been conducted on the use of cell phones, their ubiquitous availability renders them a potentially powerful, yet untapped data source.

The aforementioned advances in sensing and telemetry technology now make it possible to install dense sensor networks (potentially millions of sensors) throughout an urban region. However, an important question to ask is, "what does one do with all of the data that can be created by these ubiquitous sensing environments?" Unfortunately, the tools necessary for data interrogation have not kept pace with the rapid development of the sensing and telemetry technologies that make the data possible. With current data management approaches proving difficult to scale to such large data sets, new research aimed at using data mining, machine learning, and pattern classification methods for identifying subtle changes in data are direly needed. Scalable cyberinfrastructure solutions will need to be created that can manage large flows of data, store data, and to autonomously convert data into information of value to decision makers that are involved in natural hazard event planning and response.

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The Evolving Landscape of MCMD Information Flow

Geospatial information -- information about what is where -- plays an invaluable role in all aspects of emergency management, from preparedness and response to recovery and mitigation. Because of the costs associated with its production, geospatial information has traditionally been created and distributed by government agencies, with some assistance from the private sector, in a top-down, radial pattern. In recent years new technologies, including GPS and GIS, have dramatically reduced the cost of acquiring and disseminating geospatial information, effectively to zero, and have also dramatically reduced the time delays involved. The term *neogeography* describes a world in which there is no longer any effective distinction between amateur and expert, since the skills and tools needed to produce geospatial information are in effect available to all.

Nowhere are these changes more apparent than in the domain of emergency management. While citizens used to rely on official sources for current information on the progress of disasters, evacuation orders, and the locations of shelters and other facilities, today much of this information is being generated and disseminated by citizens. The general public provides a dense network of observers who are typically enabled by devices that range from cellphones to computers, and connected through broadband networks. By contrast government agencies cannot field large numbers of observers, and must rely instead on remote sensing and other technologies with fine spatial resolution -- but such technologies are impacted by smoke, cloud, infrequent overpasses, and many other constraints.

Moreover official information must be verified before it can be disseminated, a process that inevitably takes time in what are often time-critical situations. Numerous examples of the transition from agency-dominated to citizen-dominated information flow can be found, ranging from recent wildfire emergencies in Santa Barbara to the base mapping that has supported the Port-au-Prince relief effort.

This new landscape raises numerous issues, perhaps the most important being accuracy. Rather than guarantee accuracy, crowd-sourced data invites the user to balance timeliness with accuracy, accepting risky data that is available now rather than reliable data that may not be available for some time. False positives are more likely than false negatives, but are more acceptable because the associated risks are less severe. The geospatial nature of the information also invites several specific strategies for addressing accuracy, including the importance of context, the difficulty of faking geospatial information, and the role of the crowd in driving toward consensus.

A variety of literatures are relevant, including the literature on trust, on uncertainty in geographic information, and on spatial data infrastructures. Systematic research is just beginning, and is starting to yield some important insights.

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Mega-City/Mega-Disaster Reduction

I would suggest that Mega-city/Mega-Disasters will continue to happen around the world....it is not *IF* but rather *WHEN*! Given that as a premise, the real question then is how do we prepare for, respond to, recover from and mitigate Mega-Disaster?

I believe that if we do not complete the full-circle at the individual, local, state and national levels then the victims of these mega-disasters will not become survivors but rather they will end up being victimized twice....once by the disaster and once by a bureaucracy that failed at all levels. In the background materials there were some excellent examples of where Mega-city/Mega-disaster responses were impeded by governments, agencies and populations being less than fully prepared for the "next one". More recently this was once again demonstrated in Haiti where simple communication, education, planning, coordination and mitigation would have lessened not only the impact of this earthquake but provided a much more effective response and recovery effort. That did not happen in Haiti and in my view the victims have been victimized twice.

The question remains, what can we do as we focus on Mega-city/Mega-Disasters? The answers start with each individual understanding that they are part of the solution, that they are a resource and not a liability, that they must be prepared, they must have a plan...planning is the key and not necessarily the plan itself; governments must expand their team to include the private sector, non-governmental organizations (NGOs) and local citizens, they must develop and enforce stricter construction codes and they must pre-identify highly vulnerable buildings in disaster prone areas (whether it be from flooding, fires, earthquakes, tornadoes, hurricanes, typhoons or any other natural disaster). We at all levels of government along with the private sector and the local citizens must work in a coordinated and collaborative manner. Each of us understands that all disasters are local but Mega-city/Mega-Disasters require a Mega-Response working with everyone working in a coordinated and systematic way. The Incident Command System (ICS), the Unified Coordination Group (UCG) and the Area Command (AC), coupled together with a deliberate planning system and an executable Incident Action Plan (IAP), are the cornerstones of success and will turn victims into survivors.

Our challenge is to build these systems at all levels of government and across all societies as natural disaster know no boundaries; Mega-Disasters will continue to happen and our challenge is to mitigate their impacts through workshops like this one.

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Societal and Infrastructure Resilience: Strategic Planning for Rapid and Organized Emergency Response, Recovery, and Rebuilding

In order to consider the challenge posed by the workshop organizers it is worth to first review some of the most recent major natural disasters to see what if any lessons can be discerned to assess what, if anything could have been done in anticipation. The events that come to mind is are the great earthquakes and associated tsunamis, hurricanes and typhoons, and massive floods. The one thing they all have in common is that they are created by well known geologic and atmospheric process and as such there is ample evidence in the geologic record for the past occurrence of these events. What is it then that puts large human populations at risk from these events and how do these events differ in terms of their impact?

The most immediate and most readily apparent difference is the ability to issue warnings and to make preparations in response to the warning. At present, while we can assess the vulnerability of a region to earthquakes, we do not have the ability to predict them. In contrast, hurricanes, typhoons, and floods can be forecasted days ahead. As a result the kind of response planning used to deal with events that can be anticipated in the aggregate, but not specifically predicted, such as earthquakes, effectively differs from the type of preparations that are possible for events that are predictable.

Let us consider the most recent large earthquakes such as the Chi-Chi Earthquake of 1999, the M 9.0 Sunda Trench earthquake and tsunami of December 6, 2004; the Wenchuan Earthquake of May 12, 2008, and the most recent M 7.2 earthquake in Haiti and the M 8.8 earthquake in Chile. None of these earthquakes occurred in a zone or location that has not been previously identified as a seismogenic zone, however, there was an enormous difference in the number of casualties and damage to infrastructure. In the case of the Wenchuan and Haiti the recurrence interval of past events was sufficiently large as to imply unrealistically low expectation of vulnerability and the loss of life was the result of a lack of adequate codes to assure seismically safe infrastructure. In the case, of the Sunda Trench earthquake, the enormous loss of life was principally the result of a massive tsunami on a scale that has not been observed for 100's of years. In contrast, the casualties were relatively low, for the density of population in the affected region in the Chi-Chi Earthquake, and remarkably low in the most recent earthquake in Chile, because modern infrastructure in both countries has been built to a very high standard of earthquake resistance. Thus, it is readily apparent that appropriate building codes when properly implemented are highly effective in this case.

In comparison to earthquakes, which can cause severe but highly localized damage, major storms and floods including tsunamis, while predictable, cannot be simply addressed by building codes. The regions affected tend to be extensive and all infrastructure within those regions is at risk. As a result, while adequate warning can be issued, warnings in themselves are not enough if the infrastructure is not designed to avoid the areas of the highest risk and effective means of evacuation are not provided as one of the options. So, in this case, land use and urban planning plays a very important role.

As there are differences in the way the various events occur there are as well important differences that have to be considered in terms of post-event, post-disaster, response. For example, while it is quite readily feasible to built earthquake resistant fire stations, police stations, hospitals and other critical facilities which then can be immediately operational after a major earthquake, inundation by tsunami, floods, or debris flows is best managed by moving the critical resources out of the threatened zone. A direct consequence is that post-earthquakes local jurisdictions can retain full effectiveness, whereas in areas affected by tsunamis, hurricanes, typhoons or floods, much of the assistance has to come from the outside as much of the infrastructure is flooded or buried. Recognition of this basic difference is essential to adequate post-event planning.

In all of the above, it is important to consider the socio-political and socio-economic landscape. Human society is relatively well adapted to deal with immediate crises or to plan for events that are clearly regular enough in ordinary life. However, the challenge facing our society at every level is how to deal with events that are rare enough that the may occur once or never in an individual's life time.

Thus the workshop needs to consider the broader societal issues while trying to put forth specific ideas that could be adopted by communities and governments in order to provide a more resilient and responsive infrastructure.

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Mega City/Mega Disaster Reduction

Responding to and recovering from the socio-economic impacts of a catastrophic or extreme event in major metropolitan areas requires comprehensive efforts ranging from developing citizen preparedness and involving all regional stakeholders in rigorous planning, to adopting more stringent building codes and increasing the capacity to respond effectively. These are difficult and expensive challenges that will be driven largely by the real and perceived risk.

As is often the case, however, the high consequence, low probability event confronting most mega cities today will not elicit the sense of urgency or purpose needed to affect real change. Perhaps then, the greatest challenge to mega disaster reduction is to create the interest, involvement and leadership at all levels of government and non-government prompting the development of comprehensive action plans, and then maintaining the momentum required to implement the plan.

To enable such regional planning efforts it is essential to create collaborative consortia that bring together the key stakeholders from all segments of government, non-profits, business, academe and the community. Gaining everyone's involvement is necessary to establish an enabling rapport and trust among the participants that will foster information sharing and coordination. These regional consortia are also essential to identifying and assessing preparedness shortfalls, endorsing the activities chosen for implementation, and undertaking individual and collective solutions to address the gaps.

Beyond constructing the planning framework that addresses catastrophic events on a regional basis, perhaps more importantly, is the need to maintain the momentum that will ensure enduring advancement of the planning efforts. This becomes especially difficult as key stakeholders come and go, budgets ebb and flow and the once catalytic events that precipitated planning efforts grow more distant in the public psyche.

Stakeholders, whether government or non-government, are typically professionals in demanding managerial positions who engage in preparedness activities on a part-time or volunteer basis, or who move on to other activities after a short period of time. As a result, meaningful progress toward a culture of preparedness will ultimately depend on the willingness of these key regional stakeholders to aggressively take on communal planning and implementation, and to set up a systemic means of collaboration required to ensure ongoing success in propagating disaster resilience.

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Mega-Cities/Mega-Disasters

There are a number of recent natural disasters that can be used as examples to underscore the lack of advanced planning, the inability to quickly respond, the lack of coordination among differing agencies and organizations, the loss of needed lifelines (ranging from communication, food, water, electricity, health services, and sanitation) and other basic needs (public safety of fire, police & emergency response), not to mention the longer term issues of rebuilding. In a recent study of southern California medical services, it was found that only 29% of the hospitals in Los Angeles had a surge capacity that exceeded 20 beds. Sixty percent of the hospitals had to divert patients to other hospitals at least 20% of the time, because of the lack of capacity and less than half of the hospitals maintained more than 10 isolation rooms. Over the past decade, the number of pediatric beds declined by 19%, even when the child population increased. Now, it is common that hospitals move very sick pediatric patients from their hospitals in order to make way for even sicker children, due to the lack of free beds. What one can conclude from these facts is that the hospital system could not respond to a large influx of patients due to an emergency, regardless of the need (pandemic, earthquake, etc.). In fact, the lack of local capacity to handle anything out of the norm has been lost. The reason for this is that there are no incentives to provide emergency capacity. This means that outside emergency response capabilities are as important in LA as in Banda Aceh.

Susan Cutter has developed a social vulnerability index (SoVI) to hazards, but what are lacking are metrics for net emergency needs for an area as well as metrics of the capability of meeting those needs locally, regionally, and nationally. To explain this further, how long would it take to inspect bridges in LA after an earthquake and where would these inspectors come from? How long would it take to set up emergency medical service hospitals and how could they be accessible across a city? These types of measurements would need to be made across spatial and temporal domains and would help in making an appropriate response to a disaster. Developing disaster response capability metrics would also be helpful in advanced planning, in order to arrange appropriate shelter capacity and supplies storage to reduce the emergency needs (not supplied by local resources) to a level that can be supplied in a timely way from resources outside the region of the disaster.

Haphazard/ad hoc response to an emergency may fritter away limited resources and contribute to the overall problem, rather than mitigate it. It is clear that in past disasters (e.g. Haiti) the transport of water and food to places of high demand were hindered by choke points in the transport/supply system. Even building temporary housing and sanitation services (e.g. latrines) has been slow enough that Haitians are now experiencing the spring rainy season with little protection. The effects of this disaster will play out in slow motion for months and years to come, as the ability to handle the basic needs has been constrained by infrastructure, transport, and capital resources. We need better models for optimizing the delivery of disaster resources, planning and designs to provide enough resilience in infrastructure to ensure access/delivery of needed supplies, backup systems for communication, etc. In fact, even the placement of tent cities should be carefully thought out so that their locations can be easily supplied, rather than adding to the logistics problems already generated by the disaster. It is clear that a concerted, long term effort should be funded in disaster research, planning, mitigation, and infrastructure design.

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Challenges in Evacuation Route Planning for Incident Management

The recent loss of lives and traffic jams (Figure 1) for tens of miles as hurricanes Rita and Katrina approached the Gulf coast demonstrate the enormous difficulty in evacuating urban areas [6]. Besides hurricanes, evacuation may be necessary due to other potential disasters, e.g., fire, terrorism, and nuclear or chemical plant accidents. Thus, the local emergency management community engages in evacuation route planning and required drills, e.g., fire-drills in schools and large office buildings.

Figure 1: Hurricane Rita Evacuation (Best viewed in color), Source: National Weather Service, Dallas News.

During emergency evacuation, transportation scientists, first responders and other stakeholders pose many questions requiring spatio-temporal computations, e.g., what are the best routes (or transportation modes, shelters, timeslots) to evacuate affected locations? How many evacuees are likely to use each route, shelter, and logistics facility? Challenges arise due to violation of key assumptions behind transportation planning tools, e.g. microscopic traffic simulators, and popular shortest path algorithms. For example, transportation planning tools (e.g. DYNASMART, TRANSIM) rely on game-theory-based Wardrop equilibrium [9] among selfish commuters, who may change routes between trips to/from work. However, evacuation traffic may not exhibit such behavior. In addition, common shortest path algorithms (e.g. Dijktra's, A*) are based on dynamic programming and thus assume a stationary ranking of alternative routes [1,8]. A community may prefer a freeway-based evacuation route during non-rush-hours, but a different route during rush-hours, since the ranking of alternative paths changes over time possibly due to congestion. In addition, these routing algorithms do not account for capacity constraints of transportation links, particularly when the number of evacuees is large.

Currently, evacuation route plans are often hand-crafted for selected scenarios, since algorithms methods [5] based on linear programming take unacceptably long time (e.g., hours or days) to recommend best evacuation routes for large metropolitan areas (e.g., Houston). These methods address time-varying ranking of routes by using the time-expanded graph (TEG) representation. As illustrated in Figure 2(B), TEG replicates a graph representing the transportation network across various time-points in the evacuation time-period. Additional edges are added to link network copies across time. Link capacity and travel-time constraints are modeled as linear constraints. Linear programming formulation is used to derive solutions. Post-processing is used to derive evacuation routes. While this approach is reasonable for small towns, it does not scale up to larger problems. Consider metropolitan transportation networks with millions of nodes and edges with evacuation lasting hours or days. TEG representation leads to excessive duplication of the transportation network across time-points and a very large set of linear constraints, which increase computational time to hours or days. In addition, this approach needs an estimate of upper bound on total evacuation time to determine the number of copies of transportation network needed in a TEG representation. Incorrect estimate of upper bound on total evacuation time may lead to either a failure to produce any solution or excessive computational costs.

Our recent work on the Capacity Constrained Route Planner (CCRP) [7] introduced a novel representation, namely, Time-Aggregated Graph (TAG), which eliminates redundant information to yield a more compact representation than TEG. As shown in Figure 2(C), TAG models node/edge attributes as functions of time rather than fixed numbers. Thus node/edge capacities, node occupancies, etc. are modeled as time-series. Second, it iteratively considers all pairs of sources and destinations. Each iteration schedules evacuation of a group of evacuees across the closest source-destination pair. Special graphs construction is used eliminate redundant computation in this step. Non-stationary ranking of alternative routes during an evacuation is addressed by a linear-cost earliest-arrival-index on input TAG with travel-time-series [3,4].

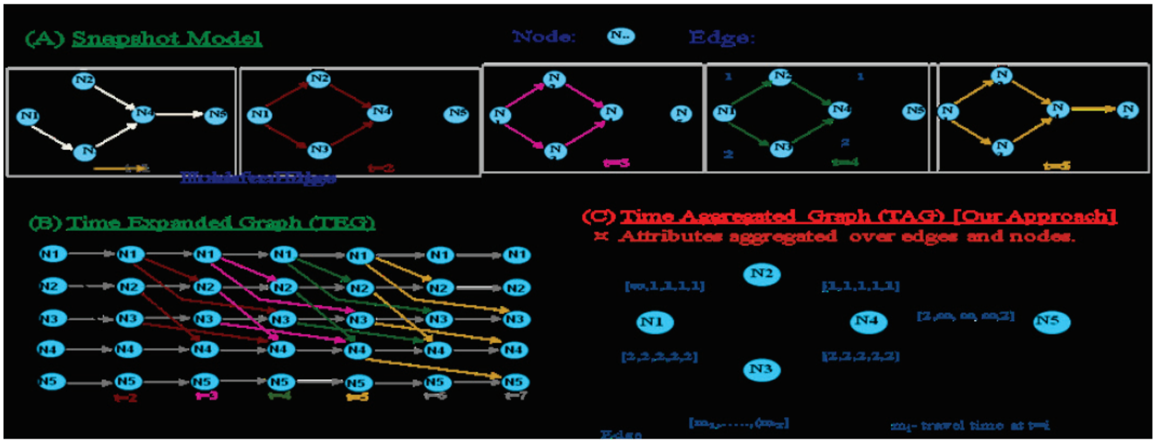

Figure 2: Representations of Time-evolving Transportation Networks (Best viewed in color)

Experimental results [7] with Minneapolis-St. Paul metropolitan scenarios show that CCRP is an order of magnitude faster than competing methods. Evaluation with the Monticello, MN, nuclear power plant scenarios (Figure 3) show that CCRP lowers evacuation time relative to existing hand-crafted plans by identifying and removing bottlenecks, by providing higher capacities near the destination and by choosing shorter routes. It was used to plan evacuation routes for many homeland security scenarios around multiple locations, time-of-the-day, and transportation modes. It facilitated a transportation science discovery that encouraging able-bodied evacuees to walk (instead of letting them drive) reduces evacuation time significantly (by a factor of 3) for small area (e.g., 1-mile radius) evacuations.

Figure 3: CCRP improved evacuation routes for Monticello Nuclear Power Plant (Best viewed in color)

There are many interdisciplinary research challenges related to the evacuation planning problem for the following reasons. Recently, I was invited to deliver the annual Dangermond lecture at U.C. Santa Barbara, which accorded a unique opportunity to talk to evacuees of the recent Santa Barbara fires, and evaluate assumptions of CCRP in the context of forest-fire evacuations. CCRP assumes that individual evacuees will act independently. However, Santa Barbara evacuees preferred group evacuations of members of a household. For example, parents went to schools to pick-up children before leaving town. Third, CCRP looked for system-optimal evacuation routes, which may not be equitable for special-need groups (e.g., children). These insights beg the following question: "How do we develop computationally tractable evacuation planning models that honor the constraints of equity in evacuation, household requirements and the non-stationary route rankings?"

Modeling household cooperation and equitability are complex social science issues, which may not be amenable to computer algorithms. In collaboration with social scientists and policy makers, we need to characterize decision-support roles for computational methods. For example, computation may shortlist alternative evacuation plans along with relevant metrics (e.g., total evacuation time, equity, fairness) to reduce the enormous set of possibilities in front of decision makers and aid decision making process. Even to play such a role, current evacuation planning algorithms will need to be revised possibly as multi-objective optimizations. A novel approach may be based on eliminating solutions which are inferior to other solutions on all (or almost all) objectives. Recent computing literature is exploring skyline query processing for location based services to address similar problems. It may be useful to bring these approaches to evacuation route planning problem.

Of course, traditional optimization approaches may be considered using a total ranking of objectives, or simultaneous consideration of a weighted sum of different objectives. Under the former paradigm, transportation network and shelter capacities may first be divided among population segments in an equitable manner using preliminary models of equitability from policy makers and social science researchers. Then, households within each population segment may be assigned to appropriate shelters with available capacities for that segment. Finally, routes may be recommended for individuals within each household to reach a common shelter possibly by getting together at some place in between. If this paradigm of dealing with equitability first and household constraints later leads to unacceptable evacuation-routes, then one may investigate other ways, e.g., combining equitability and household constraints into a unified measure of solution quality, and exploring algorithms to improve the unified solution quality measure.

Other challenges include exploration of new ideas to expand transportation system capacity or to manage demand. For example, contra-flow [6] may be used to reverse direction of a majority of inbound lanes of a highway to increase outbound capacity. Governors of Texas and South Carolina asked for use of contra-flow during Hurricane Rita (2005) and Hurricane Floyd (1999). Hurricane evacuation plans in Florida and New Orleans include contra-flow plans. However, current contra-flow plans are hand-crafted and computational methods may improve those further [2] while meeting resource constraints. Phased evacuation [6], where more vulnerable areas are evacuated before less vulnerable ones, has the potential to reduce overall evacuation times by reducing congestion, which decreases highway capacity. New Orleans evacuation plans include phased evacuation. However, the plans are hand-crafted and computational methods may be helpful. For example, evacuation route planning methods may be generalized to recommend evacuation schedules taking into account conflicts among evacuation routes of various communities. Computer tools may allow concurrent evacuation of communities whose evacuation routes do not have conflicts. This may improve current phased evacuation plans.

It is important to improve modeling of other transportation modes such as public transportation by characterizing their capacities, speeds, etc. We also need to improve accuracy of input datasets related to numbers and locations of evacuees and available (rather than maximum) capacity of transportation networks possibly by using emerging datasets from cell-phones, global-position systems, and sensors on highways.

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Mega-City/Mega-Disaster Reduction: Reducing Social Vulnerability and Enhancing Disaster Resilience

More than 50% of the world's population is now urbanized. With the exponential growth in many of these urban areas, the number of megacities is increasing rapidly. In the largest megacities (those with more than 10 million inhabitants) nearly 75 percent of them are located near the sea, or a major river, or a delta, and more than half are located in active seismic zones. Estimates for 2015 suggest that more than 600 million people would live in the world's megacities, with the majority of the megacities located in developing countries. As urban growth expands the footprint of megacities, they are merging into mega-regions such as Hong Kong-Shenhzen-Guangzhou region, Nagoya-Osaka-Kyoto-Kobe; Rio de Janeiro-Sao Paulo; Megalopolis (Boston-Washington). Given the rapid rate of growth in the megacities and mega-regions, the disaster risks will increase in the next decade placing more people in harm's way with untold billions of dollars in infrastructure located in highly exposed areas. The complex and dynamic interaction between social, economic, political, and environmental processes insures that when a disaster strikes one of these megacities or mega-regions, there will be catastrophic losses of lives, property, and economic wealth resulting in major humanitarian crises.

There are two key principles in disaster risk reduction: 1) mainstreaming disaster prevention and mitigation into normal policies addressing social welfare, quality of life, infrastructure, and livelihoods; and 2) incorporating an all-hazards approach into planning and action. Disaster reduction is not only about reducing risks and exposure, but also includes systematic efforts to analyze and manage the causal factors of disasters by lessening societal vulnerability, improving land and environmental stewardship, improving preparedness, and enhancing societal resilience.

For many regions, the ability to limit exposure has already been achieved through building codes, land management, and structural mitigation, yet losses keep increasing. For disaster reduction to become more effective, megacities will need to address their societal vulnerability and the driving forces that produce it (rural to urban migration, livelihood pattern changes, wealth inequities). Many megacities have reached their tipping points, and are seriously compromised their ability to prepare for and respond to disasters, let alone recover from them.

To lay the groundwork for disaster risk reduction actions in megacities, we need to produce the following as a first step in an actionable agenda.

Spatial Assessments of Vulnerability. We need to understand the existing societal vulnerability and the inequalities in that vulnerability within the megacity or mega-region as baseline information. The impact of a disaster may be greater on the most vulnerable populations within the city, and these most vulnerable populations may reside in the areas with the highest exposure to natural hazards. Spatial assessments of vulnerability are now required in the U.S. as a part of the hazard mitigation planning at the state and local levels. These spatial assessments highlight the intersection of hazard zones, social vulnerability, and elements of the built environment (buildings and infrastructure) that interact to produce the overall vulnerability of the place. Systematic efforts to spatially assess the vulnerability (hazard, social, and built environment) of megacities at sub-city scales, provides the baseline information for policy decisions. A one-size fits all strategy for disaster risk reduction will be ineffective and not reduce the impacts of disasters for all sub-populations or areas. The mapped results are instructive for policy decisions in ascertaining mitigation alternatives, as in some instances it is not high levels of hazard exposure that are producing the disaster risk, but rather the social vulnerability of the people who live there. This necessitates very different intervention or mitigation strategies (e.g. poverty reduction), versus those that simply reducing exposure (e.g. elevating buildings).

Pre-Event Planning for Post-Disaster Recovery. A second area of need is the development of plans (pre-event) for how to move forward in post-disaster recovery. Such planning necessitates thinking about existing resilience (of buildings, of society, of the natural system), and ways that such resilience can be enhanced. It requires visioning and thinking about the driving factors of vulnerability and how to address them pre-and post-event, through such mechanisms as land use planning and control, resettlement, improved livelihood strategies, and so on. Such planning also needs to focus on community resilience, necessitating information on local governance structures, stakeholders and sectors knowledge, adequacy of basic services (transportation, water, sanitation, public health), social, financial, and natural capital, and institutionalization of range of social safety nets. These must be tailored to the conditions of the most vulnerable groups. The absence of adequate plans for enhancing existing resilience and moving towards a more disaster resilient and sustainable city (pre-event), will lead to reactive post-event actions that are bound to repeat past mistakes and failures and instead of reducing disaster risk, may ultimately increase it as megacities recover and reconstruction proceeds.

There are significant scientific challenges in the provision of actionable information for megacities as they struggle to reduce the impacts of disasters. The most significant challenge is to address spatial and temporal scale disconnects between science, planning, and decision making. Planning is done locally, sometimes regionally but within relatively short time horizons. Decision-making occur at all spatial scales, but is often temporally-limited based on the election cycles within countries, provinces, states, or cities. Research on disaster vulnerability and resilience requires long-term and sustained data collection activities to monitor changes in disaster risk and those factors influencing such change. The typically isolated one-time post-event case study is insufficient for advancing the science of these dynamic changes in vulnerability and resilience. To remedy this, a regional or international effort is required to establish observatory networks that will engage in long-term systematic data collection activities to monitor vulnerability and resilience, which in turn will permit improvements in analytical and modeling capabilities of disaster risk reduction and post-event recovery. The establishment of such regional observatories (such as the proposed RAVON in the U.S.) will not only enhance the cumulative knowledge base on hazards vulnerability and resilience, but it will help guide the implementation of effective disaster reduction measures.

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Mega-City/Mega-Disaster Reduction

At the Institute for Business and Home Safety, IBHS, an emphasis is placed on mitigation of the built environment. Much of the damage and related injuries, deaths and disruptions to communities can be reduced by having a physical infrastructure that is better able to resist the event. Table 1 outlines some preliminary thoughts on the elements that affect the performance of the physical infrastructure and organize them in terms of an event timeline.

Table 1. Elements that Affect the Performance of the Physical Infrastructure

	event phase		
Changes in …	Before	During	After
Where you build	➢Land use planning ➢Protective barriers ➢Understanding risks ➢Laws & regulations ➢Incentives/disincentives	➢Event magnitude ➢Evacuation ➢Communication	➢Access to services ➢Access to property ➢Power availability ➢Community planning ➢Risk mitigation
How you build	➢Code adoption ➢Adequacy of code ➢Test standards & ratings ➢Code plus construction ➢Code enforcement ➢Education & certification ➢Public awareness ➢Incentives	➢Life safety ➢Shelter ➢Continued operation ➢Property damage	➢Recovery time ➢Extent of damage ➢Emergency repairs ➢Use of property ➢Rebuilding better ➢Code improvement ➢Community resiliency ➢Recovery costs
How well you maintain	➢Incentives/disincentives ➢Public awareness ➢Education	➢Extent of damage ➢Scale of damage ➢Loss of function	➢Recovery time ➢Recovery costs

Clearly there are many other layers to both the problems and solutions that have to be interwoven in order to mitigate the impacts of a disaster striking a major urban area. Ultimate, each layer must involve actions that change the status quo so that individuals, communities and regions are more resilient when an event occurs. Perhaps a similar matrix can be developed outlining actions that need to be taken before, during and after an event to empower people to take responsibilities for themselves and their neighbors in the immediate aftermath and that help organize the post disaster response in such a way that needs are identified and resources deployed quickly and efficiently.

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Leveraging Cyberinfrastructure to Achieve Hazard Resilient and Sustainable Communities: Lessons Learned in the Technology Adoption Life Cycle

In our increasingly interconnected society, the impacts of natural disasters can ripple regionally and even globally. Sadly, our response to date has failed to leverage the intellectual and computational resources being developed globally to decrease these hazards' threats to life, to infrastructure, to ecosystems, and to local and global economies. This has largely stemmed from a deeply engrained habit of executing research using limited local resources scattered physically throughout university, government, and private research laboratories as well as industry and trade organizations. Additionally, this traditional approach to research and even education fails to acknowledge the intersection of this work with economics, public policy and social science.

Recently the United Nations has called for "e*nhanced k*nowledge/technology transfer through cyberinfrastructure," a sentiment shared by the US National Science Foundation in its prototyping of several engineering virtual organizations (EVOs) in an number of disciplines, including civil engineering. These efforts have sought to incentivize sharing of resources in the form of databases, computational and experimental tools, and full-scale data to usher in a 21st Century Research Paradigm capable of truly responding to the threats of natural hazards. Further, these efforts recognize that the nature of many these hazards as well as the complexity of the societal systems they impact requires a dramatic expansion of the intellectual and cyber-infrastructure supporting research at the intersection of numerous disciplines. Not only can such EVOs create an accessible venue where diverse stakeholders can be engaged to realize an integrated computational platform far more powerful than the sum of its parts, but they facilitate the evolution of social networks that can catalyze new interdisciplinary, international collaborations.

However, though well-intentioned, seeding EVOs with participants and resources and then providing incentivization and governance to sustain and grow these EVOs has proven challenging. Therefore, while scalable cyberinfrastructure and global virtual collaboratories will undoubtedly play a crucial role in the enhancing the hazard-resilience of Mega-cities, these efforts will have limited success without appropriate consideration of the psychology of participants/collaborators and the needs and technology readiness of end users/stakeholders, as well as the natural reluctance on the part of many researchers to freely share proprietary data sets and resources. Therefore, any viable effort must also understand how the *Technology Adoption Life Cycle* enables discontinuous innovations to be realized and must be informed by social science to identify appropriate niche groups to seed the virtual collaboratory and appropriate education and outreach mechanisms to foster its growth.

Our experiences with the founding of an EVO dedicated to mitigating the hazards associated with wind-driven events (VORTEX-Winds), the foundation of an integrated cyber platform for risk modeling and assessment for hurricanes (CYBER-EYE), and the launch of a new Cyber-Enabled Discovery and Innovation Project on open-sourced approaches to the design of Civil Infrastructure using Citizen Engineers will be shared at this workshop to underscore both the power of cyber-enabled collaboration, as well as the barriers that arise both in both achieving scalable, secure and trustworthy work flows while the traversing technology adoption chasms presented by both collaborators and end users.

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Seismic Design for Resilient City

Introduction

The Industrial Revolution started in the 18th century in Britain. We exceeded modern ages, and had arrived at the present age. Now, People in the world are living in the multistory apartment houses and making jobs in the high-rise office buildings, too. The earthquake hardly occurs in Britain, France, and the east coast of the United States. The civilization extended to the west coasts of the United States and Asian countries, it came to build a lot of buildings. Population increased in the big city. Then, many big seismic hazards have happened in the 19th and 20th centuries.

Difficulties in reducing seismic disasters

Human life is about 80 years and building life is 40 to 100 years. Interval of big earthquake hitting one place is 100 to 2000 years. Optimists tend to think next big earthquake will not come while they are alive. It is easy understood that reducing seismic disasters is so difficult.

Seismic design of buildings

Each owner of a building thinks the performance of only his building in seismic design. The owner and structural engineers of his building consider the occurrence of big earthquake in his building life span. When the life span of building is shorter, the design earthquake level would be smaller automatically.

Seismic design for urban city

The seismic issues of a city cannot be solved if the seismic resistance of its individual building is determined only from the relationship between the life of a single building and the earthquake occurrence in its life span.

Could you apply largest level of earthquake to design of a building?

A criticism would arise from society if individual building is to be designed for the largest level of earthquake ground motion. Actions to legally demand excessively high seismic performance are interpreted as a violation of property right of people. Then, we need new technology having high performance without expensively cost.

Conclusions

Engineers and Researchers in the field of the earthquake engineering did many researches in these 100 years. The developments of the seismic isolated structures, the passive controlled structures and seismic retrofit technologies were advanced. We have high-speed computers and good software. We can use high & low strength steel, high strength concrete and new materials for building structures. Hereafter, we have to consider not only individual building but also the city, when we want to design resilient city against big earthquake. We have to apply these new technologies to all buildings in all earthquake prone countries.

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Disaster Recovery and Mitigation Planning: A Comprehensive Approach to Societal and Infrastructural Resilience

In the years since Timmerman (1981) first applied the concept of resilience in the disaster/hazards context, disaster resilience has emerged as an often employed yet rarely defined concept in the hazards and disaster literature. Many definitions draw heavily on perspectives suggested by the Resiliency Alliance[3] 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). In the disaster context, resilience can be defined as the ability of social systems, along with the bio-physical and infrastructural systems upon which they depend, to resist or absorb the impacts (deaths, damage, losses, social impacts etc.) of natural hazards, to rapidly recover from those impacts and to reduce future vulnerabilities through adaptive learning and strategies.[4]

With this definition providing context, strategic planning for rapid and organized emergency response, recovery and rebuilding that seeks to promotes social and infrastructural resilience must be based on at least three critical dimensions. First, any strategic planning must have as its foundation a comprehensive and detailed understanding of current of social and physical vulnerabilities based upon sound research, mapping and modeling. In a very real sense it must be based on a comprehensive understand of "place." Second, strategic planning for rapid and organized response, recovery and rebuilding must not only insure that response efforts minimize the losses associated

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[3] http://www.resalliance.org/1.php

[4] This definition is a slightly modified version of one proposed by RAVON (Peacock, Kunreuther, Hooke, Cutter, Chang, Berke. 2008) and generally consistent with definition proposed by 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 200.

with impacts because of effective and sound emergency response practices, but just as importantly the recovery and rebuilding activities must not replicate or reproduce preexisting vulnerabilities. This is often the Achilles' heal of recovery and rebuilding efforts; in an attempt to undertake these activities rapidly, all to often preexisting vulnerabilities are not only reproduced, but sometimes exacerbated (i.e., preexisting social inequalities can be exacerbated). Third, we must stop digging. It is often said that when you are in a hole, the first step toward getting out of the hole, is to stop digging. All to often, particularly in large urban systems, development patterns and trends – as reflect in terms of land use patterns, infrastructure development, and social policies and structures – are continuing to dig an ever deeper and larger hole in that they are generating ever higher levels of social and physical vulnerability. In short, strategic planning for social and infrastructural resilience must, of necessity, incorporate effective mitigation action planning to shape not only tomorrow's actions following a disaster, but also today's actions that can reduce social and physical vulnerabilities and enhance a systems ability to resist and absorb a future hazard event.

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Planning for a "Whole Community" Response to a Worst Case Catastrophic Event

In today's global environment, we all face hostile nation states, terrorist groups, pandemic influenza outbreaks, and the entire gamut of manmade and natural disasters. At FEMA, we stand ready to respond immediately to all types of emergency situations and disasters to deliver needed assistance to protect the health and safety of the survivors.

An incident of catastrophic proportions has the potential to imperil millions of people, devastate multiple communities simultaneously, and create far-reaching economic and social effects. In such events, the scope of needs will be large, immediate, novel and profound, and the entire national emergency management, public health, security, law enforcement, critical infrastructure, medical and all other components in the Federal, state, local, tribal, private and public sectors that make up the "whole community" must be prepared to respond in ways that lie outside the normal paradigms in which we have traditionally operated.

National efforts to ensure resilience in the U.S. are focusing on improving existing catastrophic event preparedness capabilities, but with a renewed conviction to plan for the most extreme disasters. We are building on the strengths of local communities and citizens and integrating the public as a critical resource and definite part of the solution. The faith based communities, fraternal and trade associations, and the broader marketplace are all viewed as important to collaboration and are included in the planning efforts. While the impact of catastrophes will certainly be felt at the Federal and state level, the impacts have the potential to be most devastating at the community level. Therefore, our catastrophic response strategy is being designed to quickly stabilize communities, and calibrated to support their timely recovery and return to municipal self-sufficiency. We recognize that only through close cooperation with all partners can we begin to close gaps and agree on the most critical objectives. Engaging the "whole community" is essential.

FEMA is coordinating and facilitating development of detailed horizontally and vertically integrated catastrophic response plans for earthquakes, hurricanes, biological attacks and other threats. Our planning assumptions for catastrophic disasters are based on the “maximum of maximums” or worst case scenarios and are designed to challenge preparedness at all levels of government, and force innovative, non-traditional solutions as part of the response strategy to such events. A planning effort currently underway in the U.S. is focused on a catastrophic earthquake impacting eight states in the New Madrid Seismic Zone. This initiative integrates plans at all levels of government with an overarching national-level earthquake plan and is providing the basis for a fundamental re-tooling of all-hazards catastrophic incident guidance.

In conclusion, effectively and rapidly responding to and recovering from the impact of a catastrophic disaster is one of the greatest challenges faced by all levels of government. In the U.S., we are taking planning and preparedness to a higher level and will not accept the easy way out. We recognize our success depends on the collective and collaborative efforts of the “whole community” and we can accept nothing less if we are to provide stronger and more agile disaster response capabilities.