



**The 2010 Canterbury and 2011 Christchurch
New Zealand Earthquakes and the 2011
Tohoku Japan Earthquake:**

Emerging Research Needs and Opportunities

Report from a Workshop held February 9 and 10, 2012

**EARTHQUAKE ENGINEERING RESEARCH INSTITUTE FOR
THE U.S. NATIONAL SCIENCE FOUNDATION**



The 2010 Canterbury and the 2011 Christchurch New Zealand Earthquakes and the 2011 Tohoku Japan Earthquake:

Emerging Research Needs and Opportunities

Workshop Report

Prepared by the Earthquake Engineering Research Institute from a
workshop held February 9 and 10, 2012

With funding from the National Science Foundation

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Any opinions, findings, conclusions, or recommendations expressed herein are the authors' and do not necessarily reflect the views of EERI, the National Science Foundation, or the participants' organizations.

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Cover Photo: Left: Christchurch, New Zealand (*photo: Ken Elwood*) Right: Miyako, Japan (*photo: Jay Wilson*)

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Executive Summary

On February 9 and 10, 2012, the Earthquake Engineering Research Institute (EERI) convened a workshop with support from the U.S. National Science Foundation (NSF) to identify themes and directions for research resulting from the September 4, 2010 and February 22, 2011 New Zealand earthquakes and the March 11, 2011 Great East Japan offshore earthquake and tsunami. All three of these earthquakes present major learning opportunities for the engineering and scientific research communities. These events are unique for the research community, in terms of both the unprecedented amount of data that are available from the events and what the data tell us. This uniqueness spans the concentrated, well-documented events in New Zealand to the truly complex event in Japan that included the earthquake (ground shaking, ground failure), tsunami, fires and nuclear incident with simultaneous and interacting effects and responses. The catastrophic and complex nature of these events and the non-linearity associated with such catastrophe hold important research implications. Data need to be examined and integrated across disciplines to truly understand the engineering, scientific, social and political consequences of catastrophe. These events highlight the clear need and unique opportunity to carry out broad-based programs of coordinated and collaborative basic research to evaluate the vulnerability of large urban areas to potentially catastrophic natural events, and then importantly, how to improve their resilience.

The workshop steering committee identified key research themes and key recommendations, which are listed here and explored in more detail in the following section, Introduction and Key Recommendations. The enormous amount of data generated by these events, and the opportunity to analyze such data are the foundation for the key research themes that emerged from workshop discussions.

Understanding key components of resiliency
Understanding the established and emerging role of information technology in mitigation and response
Understanding the many-dimensioned implications of the radiological disaster
Understanding socio-economic consequences of such catastrophic events

Key recommendations for future research, building from the unique, unprecedented opportunities presented by these events include:

- **Support perishable data collection**
- **Establish an interdisciplinary digital data center**
- **Advance modeling, computational, and analytic capabilities**
- **Support a holistic research program on vulnerability and resilience that integrates many disciplines and researchers, across the three countries**

These themes and recommendations are all explored in more detail in subsequent sections. The workshop presentations, reports from each break-out group and this report are all available at the workshop website: <http://www.eeri.org/japan-new-zealand-nsf-rapid-workshop/>.

Overview of the Two Events

New Zealand earthquakes¹

On September 4, 2010 at approximately 4:30 a.m. local time, an M_w 7.1 earthquake struck 40 km west of Christchurch, New Zealand on the previously unknown Greendale fault. Despite the magnitude of the earthquake there were no casualties and only two serious injuries; this is attributed to the time of the earthquake. Structural damage from the earthquake was minimal as Christchurch has a modern structural code with rigorous enforcement and the level of shaking was less than the design value. There was, however, significant damage to non-retrofitted unreinforced masonry buildings. Combined with residential and utilities damage caused by widespread liquefaction and lateral spreading, the total economic loss is estimated at \$4 billion NZ (\$3 billion US). Compared to the devastating M7.8 Hawke's Bay earthquake in 1931, the area seemed well prepared to protect human life against earthquake risks.



The PGC building in the central business district of Christchurch, after the February 22nd earthquake (photo: Elwood)

However, on February 22, 2011 at 12:51 pm, just 5 months after the September 4th main shock, a large (M_w 6.3) aftershock shook the city of Christchurch. This time the earthquake was centered much closer to the city center and occurred at midday. Both of these factors led to 184 confirmed deaths and an estimated economic loss of over \$20 billion NZ. Liquefaction was once again widespread and caused major damage to the city's lifelines with power outages a major concern for residents. The February aftershock resulted in much higher levels of ground shaking in

the city center, exceeding the design levels for short period structures. Structures in the region suffered from the long sequence of aftershocks and made them more susceptible to major damage from the February aftershock. Together, the higher levels of ground shaking and the long sequence of aftershocks resulted in major damage to buildings with all different types of structural systems. It is possible that up to 50% of the buildings in the Christchurch business district will need to be demolished. With such widespread damage, long-term recovery issues are critical for the region.

¹ This overview drawn from EERI special earthquake reports on the Canterbury and Christchurch events, available at http://www.eeri.org/site/images/eeri_newsletter/2010_pdf/EERI_NewZealand_EQRpt-web.pdf (Canterbury) and http://www.eeri.org/site/images/eeri_newsletter/2011_pdf/EERI_NewZealand_EQRpt_web.pdf (Christchurch).

Tohoku Japan event²

On March 11, 2011, at approximately 2:45pm local time, an M_w 9.0 earthquake struck at the subduction zone interface plate boundary between the North American and Pacific plates off the coast of Eastern Japan. The earthquake ruptured over an area of 400 km by 200 km, with at least a vertical movement of 3 m and a lateral displacement of 24 m. This earthquake was Japan's largest recorded and most destructive earthquake. This earthquake also caused a tsunami that inundated much of the Tohoku region as well as evacuations along the Pacific basin. The reported death toll was 15,703 people, with 4,647 people missing, 5,314 injured, and over 130,927 Japanese displaced during the earthquake and subsequent tsunami. Damage due to the earthquake was seen in steel and reinforced concrete structures mainly built prior to the 1970s. Retrofitted buildings from this time performed well. Liquefaction caused extensive damage to light residential and commercial structures. In some cases, there were relative settlements of 70 cm. In total, approximately 332,000 buildings, 2,100 roads, 56 bridges, and 26 railroads were either destroyed or damaged totaling the economic loss to over \$300 billion, making this the most expensive disaster of all time.

The subsequent tsunami that followed the earthquake caused most of the loss of life and damage along 600km of the eastern coast of Japan. It has been reported that 96% of the victims died from drowning. In the city of Rikuzentakata, water levels reached as high as 19m, destroying all but two large reinforced concrete structures. The highest recorded tsunami level was 38.9m at Aneyoshi Bay. Many of the coastal areas had pre-disaster risk reduction systems in place. Seawalls designed to stop tsunamis were not designed for such high water levels and were overtopped. Water reached as far as 5km inland in some areas. Some bridges made up of steel girders had their superstructures lifted off their piers and carried a significant distance inland. The tsunami affected the Pacific basin from Northern California, where one person died, to Chile. Perhaps the longest lasting effect the tsunami will have on Japan are the events that led to the nuclear disaster at the Fukushima Dai Ichi Nuclear Power Plant.



The disaster management headquarters for the town of Minamisanriku. About 30 officials gathered on the upper floor and roof on March 11. The tsunami completely flooded the structure and only 11 people survived. Note the location of high ground in the background (photo: L. Dengler).

² This overview drawn from six EERI special reports on the Japan event, most written with collaborating organizations: ASCE, ERI, FHWA, GEER, ITST, UJNR. All available at <http://www.eqclearinghouse.org/2011-03-11-sendai/reports/>. In addition, material on nuclear power plant taken from <http://www.yomiuri.co.jp/dy/national/T110607005367.htm>; http://www.nytimes.com/2011/07/19/world/asia/19beef.html?_r=3; and <http://www.reuters.com/article/2011/08/27/us-japan-nuclear-uninhabitable-idUSTRE77Q17U20110827>

Following the earthquake, the power plant's automatic safeguards shut down the nuclear reactors. Fifty-five minutes after the earthquake, the tsunami reached the power plant, destroying the plant's off-site capabilities of obtaining power. The backup generators functioned until the waters flooded the generators, leaving the reactor without any coolant. Subsequent explosions at the site further increased the worry of a nuclear incident. With the increase of temperature and pressure, the nuclear fuel began to melt down and eventually "melt-through" into the containment vessel. Cesium-134, Cesium-137, Iodine-131 have leaked into the air, soil, ocean, and food supply. The decontamination costs have been estimated at \$130 billion. It may be decades before people are able to return to the affected area.



Handling debris. Photo: T. Norton

The debris from the three affected prefectures (Iwate, Miyagi, and Fukushima) has been estimated at 24 million tons, excluding cars and ships. This is 1.6 times more than the debris from the 1995 Hanshin earthquake. Miyagi Prefecture estimates it will take two to three years to manage its 16 million tons of debris. This amount of debris is 20 times more than the waste generated by the prefecture annually. Much of the debris will be recycled. Some cities, such as Minamisanriku have had slower progress with their debris removal due to efforts to clear the water to reestablish their fishing

industry. There are environmental issues that are associated with debris removal. There are health concerns for workers who are handling the debris such as asbestos from older buildings. In Fukushima, debris contaminated with radioactivity will be a complex issue.

Key Findings and Recommendations

On February 9 and 10, 2012, the Earthquake Engineering Research Institute (EERI) convened a workshop with support from the U.S. National Science Foundation (NSF) to identify themes and directions for research resulting from the September 4, 2010 and February 22, 2011 New Zealand earthquakes and the March 11, 2011 Great East Japan offshore earthquake and tsunami. The complex nature of these three events and resultant disasters provide major lessons and research opportunities across many engineering and scientific disciplines. These earthquakes are among the most significant and relevant events for the earthquake community in the last several decades. Building codes in both countries are similar to the U.S. for concrete and steel buildings. There are many strong motion records (especially in Japan) that provide valuable data; the geologic setting and tsunami vulnerability for Japan is similar to the Pacific Northwest. There are similarities and lessons from the transportation, lifelines, and critical facilities sectors, and there are similar social and political issues in the response and recovery. The multifaceted and continuing nature of the response and recovery in these two countries will shape the call for further research across many disciplines, and will instigate innovations in cross-disciplinary and cross-cutting research initiatives.

The workshop brought together grantees who received RAPID awards from NSF after both the New Zealand and Japan earthquakes (particularly those who received funding in response to DCL NSF 11-049), 16 researchers from Japan who received J-RAPID awards, several officers from Japan Science and Technology Agency (JST), as well as several other Japanese scientific organizations, 4 researchers from New Zealand, representatives of the National Earthquake Hazards Reduction Program (NEHRP) agencies and representatives of several other agencies with an interest in earthquake risk reduction and international programs. The workshop was inaugurated by the Director of the National Science Foundation and the ambassadors from New Zealand and Japan to the United States. The overall workshop goals were to: 1) define an umbrella framework from these events for a future research program, with a particular focus on how society should address larger-than-considered (catastrophic) events; and 2) define a list of research needs, with the specific objectives to:

- Establish links between RAPIDs researchers and develop opportunities for collaboration in future earthquakes
- Identify critical research needs leading to a white paper that will summarize research needs as a resource for US and international use
- Encourage NSF to support future research for these events
- Set up a mechanism for exchange of data among researchers
- Identify potential changes in codes and standards, including those related to policy, in countries affected by earthquakes.

The uniqueness of the events framed much of the workshop discussion. The ongoing Canterbury earthquake sequence, and in particular the 22 February 2011 earthquake, is very likely the most important seismic event for the earthquake engineering professional and research communities in the United States since the 1994 Northridge earthquake. The occurrence on a previously unmapped fault means that this event is relevant to any seismically active region, not just those with well-documented faults. Furthermore, the close similarity between US and New Zealand historical and modern construction practices means that the damage to the built environment in

Christchurch is directly relevant to anticipated damage to infrastructure given a similar earthquake on US soil. This earthquake sequence can be considered “the Big One” for Christchurch, a modest size city of 390,000 people, and may provide an opportunity to scale the effects up to estimate the impacts of the “the Big One” on much larger US cities in similar tectonic environments with similar construction. With estimated losses at roughly \$16 Billion NZ Dollars, or a staggering 8% of GDP, and the projected demolition of 30-50% of the Christchurch Central Business District, this earthquake challenges the focus of current building codes on life-safety protection and demands greater attention be paid to assessing resiliency and long-term impacts of catastrophic events.



Preparing for engineering inspections of buildings in the Central Business District in Christchurch. Photo: L. Peek

The 2011 Tohoku, Japan earthquake is unique from several perspectives. Most importantly for the research community, it was a truly complex event that included the earthquake (ground shaking and ground failure), tsunami, fires and the nuclear incident. The cascading, non-linear failures associated with the event made it a catastrophe. Not only did this earthquake cause significant damage from ground shaking, but most of the damage was a direct result of tsunami inundation and run-

up. This M 9.0 earthquake severely affected over 500 kilometers of coastline in Northern Japan. For a modern developed country, the impacts are enormous: close to 16,000 people were killed and over 4,000 are still missing and presumed dead. The majority (92.5%) of the fatalities are attributed to the tsunami. Over 115,000 buildings were completely destroyed, and the economic losses are estimated at between 16 to 25 trillion JPY (or \$200 Billion to \$300 Billion), making it the most costly natural disaster ever. And finally, the earthquake is continuing to cause further impacts through environmental damage (radiation), affecting the health and welfare of local residents, the safety of farming, fishing and agriculture, and long-term response and recovery activities.

Key Research Themes

The unprecedented amount of data, the uniqueness of the data associated with these events, and the ability and willingness of the research communities in the three countries to collaborate, provides the foundation for the key research themes and/or opportunities that emerged from the breakout group discussions. It was quickly apparent to workshop participants that these events present an unparalleled opportunity to integrate data across disciplines and develop research that is different and new from traditional discipline-specific and event-specific projects. Key research themes, presented below, in turn informed the four key research recommendations that emerged from the workshop. Individual break-out group discussions and recommendations are presented in Section 2 of this report.

Understanding key components of resiliency

Resiliency is related to the ability of a community to effectively recover to pre-event capacity following a devastating event, e.g., infrastructure, social and behavioral/psychological recovery. The earthquakes in Japan and New Zealand truly tested the resiliency of the affected communities. Participants at the workshop recognized the unique data available from both Japan and New Zealand to measure the resilience of the communities when faced with a catastrophic event that overwhelms the ability of a community to respond and may cause cascading failures. Such data include losses in the built environment, time and cost of reconstruction, collapse of supply-chain infrastructure, and population loss in both regions due to fatalities (Japan) and out-migration (New Zealand), as well as data on the social aspects of resiliency, including social capital, networks, information and communication capacity and access to resources. The evaluation of longitudinal impacts for catastrophic events is critical to determine if resiliency needs to be improved through expanded pre-event mitigation efforts or if the impacts from the events in Japan and New Zealand are considered manageable given their



Multiple span failures of a railway overpass and river bridge in Otsuchi (photo: Robertson/ASCE).

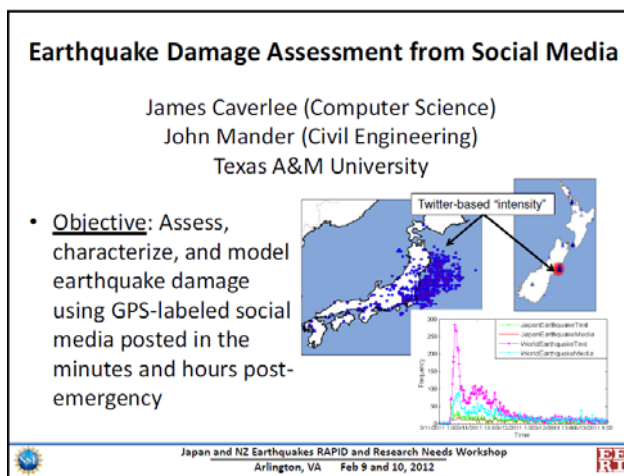
presumed low probability of occurrence. Such assessment is necessary in order to determine if and how building codes should address the reparability of structures in addition to ensuring life safety in major earthquakes. Assessment of impacts will also inform policy makers on the importance of protecting heritage structures against significant damage in major earthquakes. The Christchurch earthquake enables the evaluation of the impact of aftershocks, while the Tohoku earthquake, tsunami and subsequent radiological disasters provide unique data on the impact of cascading failures on resilience. Improved resilience is possible, and it may be critical especially for major supply-chain hubs such as Japan, where the disaster stalled production around the world. But it will come at a non-trivial cost to society and these unique events give the research community an opportunity to assess impacts and critically evaluate the need for improved resilience and what changes pre-event would result in greatest improvements in resilience in the future.

Understanding the established and emerging role of information technology in mitigation and response

Information technology played a major role in response and is playing a role in recovery after the New Zealand and Japan earthquakes. Use of ubiquitous devices such as mobile phones allowed for real-time rapid damage assessments of buildings, and facilitates remote collaborative investigation between experts and non-experts. Social media data and crowd

sourcing were used for rapid damage assessment, and played an important supporting role in providing information to response agencies in both Japan and New Zealand. Specifically, in New Zealand and Japan's earthquake disasters, they offered reliable shaking density trends and information about the severity of building damage.

Special robots were also used for collecting and assessing damage. They offered remote assessment via land, sea and aerial means. They were deployed to places where access is difficult or dangerous for humans. Unmanned marine vehicles performed better than divers in mission time, coverage, and accuracy. Aerial robots were used for 3D mapping and exploration of multi-story damaged buildings in both Japan and New Zealand. In Japan, robots, after being trained for three weeks to adapt to on-the-ground situations, were used to collect data on radiation levels and other data at the nuclear plants.



Slide from J. Caverlee Earthquake Damage Assessment from Social Media

Communication by local government to affected individuals during disasters remains challenging. In this multi-media world, how individuals access information in the immediate aftermath of the earthquake affects perception, and thus response and recovery efforts. Access to information creates different individual perceptions of community resiliency. During the New Zealand and Japan earthquakes public officials had to improvise to communicate via social media; they also had no plans to coordinate with digital volunteers. The public who were directly affected searched for information across multiple

sources. They established their own information flow and found that local citizen reports were most useful. Digital volunteers sought out and posted open data onto locally relevant maps.

With the abundance of first hand citizen knowledge shared via social media technologies, along with updates, advisories and directives from official government sources, as well as data automatically collected by technical means (e.g., robots and sensors), methods for collecting, combining, managing, sampling, and analyzing such disparate data must be advanced. However, it remains a real challenge to maximize the value of socio-technical systems for response and recovery purposes. For example, although social media such as Twitter can play an important role in sharing information and coordinating disaster response efforts, social media can also be used to spread false information. In fact, after the 2011 Tohoku earthquake in Japan, Twitter users transmitted rumors about disaster-related information, such as radiation and supplies, sometimes causing unnecessary alarm. To mitigate the spread of false information during catastrophe, we need better understanding of how people interact with technologies. More data are helpful only with intelligent use and interpretation of data sources.

Effective disaster mitigation and response efforts require real-time information-decision support technology that can rapidly assess the situation and identify people in immediate danger, as well as swiftly communicate to citizens actions to be taken for their safety and the safety of others.

In the aftermath of radiological disasters, there is a role for IT in providing the capability to quickly identify those who need medical treatment because of contamination or exposure; to recommend and facilitate practical steps to minimize risk; register people for long-term health monitoring; and service the displaced population on day-to-day needs. *The interplay between technical and social aspects cannot be overemphasized.*

Understanding the many-dimensioned implications of the radiological disaster

The Tohoku earthquake, tsunami, and subsequent radiological incidents offer a first glimpse of the devastating impacts of cascading failures and a catastrophic event in an advanced industrialized society. This is the first major hydrologic release of radiation isotopes and is the largest-ever release to the oceans. The cause was not a single event, but rather a cascading failure and the release persisted for a sustained period.

It was estimated that more than three-quarters of the radioactivity fell on the ocean. Although the levels of radioactivity up to 400 miles offshore were found by some marine radioactivity experts to be well below biological thresholds of concern to the small fish and plankton, levels of radioactivity found in fish are not decreasing and there appear to be hot spots on the seafloor that are not well mapped. Ongoing studies by independent teams of researchers have to be conducted to better understand the source of radioactivity released (caused by dumping water on the reactors versus the fires and explosions at the power plant). More importantly, long term health and environmental impact must be assessed.

In Japan, while citizens have been educated about evacuation and response for earthquakes and tsunamis, there is a serious lack of knowledge about strategies and emergency guidelines for radiological emergencies, rapid screening and decontamination, even for those living close to nuclear plants. During the Fukushima disaster, citizens learned very little through public media or from government officials. There was also conflicting information from Japan and the US (e.g., on the radius for evacuation), which clouded mitigation efforts for radiation exposure and health risks.

There is a good understanding, from measurements, of the spatial deposition of radiation on land. However, uncertainties remain in terms of the full range of isotopes released thus far, and how far this has propagated into the food chain. The modeling of atmospheric dispersion is mostly associated with land and not with the ocean, although atmospheric dispersion is observed and reported on a global scale. There is evidence that some release to the ocean occurred but data coverage is relatively poor. The recently found hot spots on the seafloor underscore the difficulty in dispersal assessment. Some critical data have been collected regarding timelines

Collaborative Research: The Japan March 11 2011 Earthquake, Tsunami Inundation and Initial Spread of Fukushima Dai-ichi Radionuclides on the Pacific Ocean: Model Assessment

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Objective:
Model assessment of March 11 Initial M=9 and M=7.9 earthquakes, the resulting tsunami wave generation, propagation and coastal inundation along northern Honshu Island, and the initial pathways and changes in Cs-237 concentrations as the contaminated cooling waters enter the coastal waters at the Fukushima Daiichi nuclear facility and spread across the shelf to deeper water.

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Slide from C. Changsheng Collaborative Research: The March 11 2011 Earthquake, Tsunami Inundation and Initial Spread of Fukushima Dai-ichi Radionuclides on the Pacific Ocean: Model Assessment

for evacuation, screening, health status, and radiological awareness tied to demographic information of the local population and workers, and to subsequent psychological and medical impacts. However, more quantitative data on these relationships would be very helpful.

Although technology played a significant role in quantifying the level of risk within the Fukushima nuclear power plant (i.e., use of autonomous robots), there appeared to be confusion within surrounding communities with regard to proper evacuation and/or protective measures. Early research suggests that some of this confusion is due to lack of effective communication strategies – both before and after the disaster – especially on actions that should be taken during radiological disasters.

Strategic planning and operations capabilities for emergency response and medical preparedness for radiological incidents is one of the critical cornerstones for US Homeland Security, along with biological and chemical incidents. The Japan incident *underscores* the paramount importance of these activities. The needs are widespread, as many nations use nuclear plants for energy generation.

Understanding socio-economic consequences of such catastrophic events

A major theme among many of the research studies discussed at the workshop is the role of social science research in helping to explain the short- and long-term impacts of these events. Social science research covers many field and topics, including behavioral studies, social vulnerability assessment, economic analyses, and policy analysis. The Tohoku, Japan and Christchurch, New Zealand earthquakes have important social science and policy lessons for the U.S. Specifically, what are the lessons learned from Japan due to multiple hazards and catastrophic impacts? In this event, we not only observe the impacts caused by ground shaking and ground failure effects, but also those caused by a devastating tsunami, and longer-term effects which are still accumulating even now, i.e., radiation effects from the damaged Fukushima Nuclear Power Plant. Preliminary research indicated that many people did not take appropriate protective actions, and understanding why is a critical research need.

From New Zealand, there are lessons that can be learned from the long sequence of damaging aftershocks. From research that is being performed, we are beginning to understand how people in affected areas both obtain and use information. How do they make decisions with regard to health, jobs and resettlement? There is also the opportunity to study the impact that earthquake insurance has on the reduction of earthquake losses and the ability to facilitate or impede recovery. In the Christchurch earthquake, the vast majority of homeowners are

Opportunities for Future Research

- What new questions raised by these events require basic research?
 - The differential scalability of constructions and logistical operations, construction operations scaled up well, logistics did not
 - How best to integrate social and technological aspects
- What new data are available as a result of these events?
 - Enhanced insight of the differences between Disasters / Catastrophes
 - Enhanced understanding of post-disaster logistic operations
- What unique aspects of these events require the development of a focused research program?
 - Diagnosis and characterization of actual disaster response (logistical) operations, needed to identify lessons learned on a systematic basis
 - Foster researcher/practitioner/disaster relief agency cooperation
- What are the important lessons from these larger than expected events for the U.S.?
 - Catastrophes and Disasters require qualitatively different responses
 - The importance of preparing for catastrophic events
 - The importance of planning for local distribution (the most difficult part)



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Arlington, VA Feb 9 and 10, 2012



Slide from J. Holguin-Veras RAPID: Field Investigation on Post-Disaster Humanitarian Logistic Practices under Cascading Disasters and a Persistent Threat: The Tohoku Earthquake Disasters

covered under a national insurance program (EQC) or by commercial carriers. In contrast, very few homeowners in Japan are covered by earthquake insurance³. There are important lessons to be learned here, particularly for California, which has its own earthquake insurance authority (CEA).

Social science research that is underway will help to better quantify the effects of these very large and significant, but vastly different events. By studying the response of communities in each of these two countries, it is possible to gain a better understanding of the implications for the U.S. Since all three countries are advanced industrialized countries with modern seismic design standards and codes, we believe that many of the lessons will apply directly to the U.S.

Key recommendations

The workshop steering committee met immediately following the workshop and advocated for four major, overarching recommendations for future research that emerged from the RAPIDs workshop. All of these recommendations build from the research themes and the notion that these events have generated not only an unprecedented amount of data but also a unique and compelling opportunity to use data in new and unique ways.

Support perishable data collection

The National Science Foundation is to be commended for enabling researchers to collect important perishable data through the RAPID grant program.

Based on the workshop discussions, it is clear considerable data still remains to be collected. NSF is strongly encouraged to continue supporting the gathering of data from these two important events. For the Christchurch earthquake this includes, but is not limited to, building damage data correlated with repair/demolition decisions, testing of in-situ or extracted building components prior to demolition, instrumentation of buildings to



Overturned cold storage building in Onagawa. Photo: G. Chock/ASCE.

identify response in ongoing aftershocks, in-situ measurements for sites with repeated liquefaction in aftershocks, documentation of decisions made and their impact on recovery, and longitudinal documentation of community recovery. For the Tohoku earthquake and subsequent tsunami, perishable data still to be collected includes impacts of multiple events (earthquake, tsunami, radiation release) and cascading failures on community recovery, the performance of coastal defense structures, vertical tsunami evacuation buildings, and retrofitted buildings, timelines for evacuation and screening of affected population, and evaluation of the extent of isotope release in the environment. Some of these data must be tracked over time while other

³ (14% to 17%, see - http://money.cnn.com/2011/03/13/news/international/japan_earthquake_cost/index.htm).

data can be collected immediately before further recovery efforts in the affected communities remove the data source. Along with the data collection, a logical next step is supporting advances in analytics, modeling, computation, and real-time capability in tackling these big datasets. These data will all be invaluable in assessing the impact of similar events on US communities and developing a *Disaster Resilient America*.

Establish an interdisciplinary digital data center

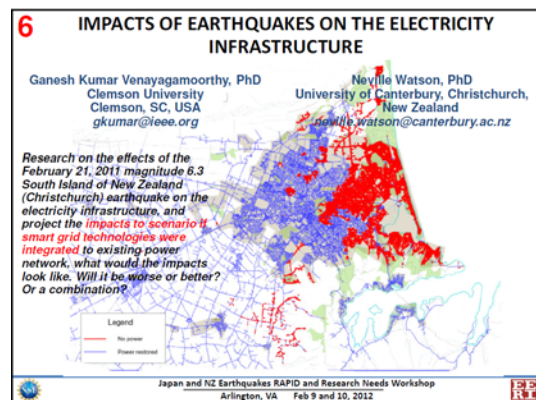
The notion of a multi-institutional, interdisciplinary digital data center was discussed during one of the final sessions of the workshop. This concept – which could be driven by a cooperative program between the U.S., Japan, New Zealand, and other interested countries – would generate a long-term research program that would focus on the development of a robust, digital platform capable of:

- Handling numerical/computational/simulation models(with descriptions of parameter-selection processes)
- Supporting an evolving taxonomy
- Allowing for modular construction
- Storing images and video, as well as quantitative and qualitative data
- Supporting image recognition (similar to OCR)
- Adapting rapidly to meet changing user requirements
- Allowing for simple transfer to other platforms to ensure longevity (interoperable)
- Supporting quick searches across all types of data
- Accommodating needs of all relevant disciplines
- Generating academic recognition (citations)
- Accommodating legal requirements or limitations
- Accommodating privacy and human subjects requirements
- Supporting crowd-sourcing (e.g., rapid damage assessment), and
- Offering automated translation (language and units)

Advance modeling, computational, and analytic capabilities

Along with the establishment of the data warehouse, it is also critical to develop sophisticated models that utilize the data, and to advance computational and analytic approaches to solve the models.

Methodologies and systems modeling must be developed to capture the large-scale, complex, heterogeneous, and evolving data associated with these events – from pre-event indicators, to structural failure, to human behavior. The solutions must be scalable, able to decipher the data rapidly to uncover important knowledge that can help predict future events with confidence, and that can support important policy and operations decisions that will help to mitigate the human and economic costs. The



Slide from K. Elwood NZ Structures Group

multi-faceted nature of these events demand technological advances that cut across multiple disciplines.

Large scale simulation and system models, ones that allow incorporation of heterogeneous data sources, temporal factors, and uncertainties, are critical for modeling and understanding these extreme events. The models must be scalable and offer realistic depictions of the situations. These models should exploit powerful distributed computing to take advantage of the distributed sources of information and to facilitate the strenuous computational burden.

Optimization and decision support models that can help with modeling extreme events, predicting cascading effects, and incorporating on-the-ground chains of events with human behavior are of paramount importance. Such models will provide policy makers and emergency planners with scenario analysis and decision-making capabilities to anticipate the variety of ways in which events may unfold and how interventional steps may impact the well being of those affected and the infrastructure of the locale. They must have real-time decision capacity, and they should perform in-data computation as data evolves. Advances in sophisticated optimization algorithms are a must so that models can manage the multitude of decision variables for sound operations and decisions. Modeling and optimizing critical infrastructures are essential. Optimized public health and emergency infrastructure can help save lives, improve operations, and mitigate traumatic impact. In addition, power grids, supply-chains, and communications are among the fundamental cores that must be optimized and maintained for successful and rapid response and recovery.

Predictive models for knowledge discovery, pattern recognition and source validation must be advanced. These models must overcome existing limitations in data incorporation, scalability and knowledge analytics. They must incorporate cognitive human factors and social media knowledge. They should be multi-media accessible where users can access and validate around the world and on-the-ground in real-time.

Dispersion models for radiation materials remain critically challenging. Computational models must be advanced to effectively incorporate the many disparate uncertain factors that can predict the source and level of release from resulting radiation range and dispersion characteristics. Such models are critical for response and recovery efforts. Environmental and long-term health impacts must be considered.

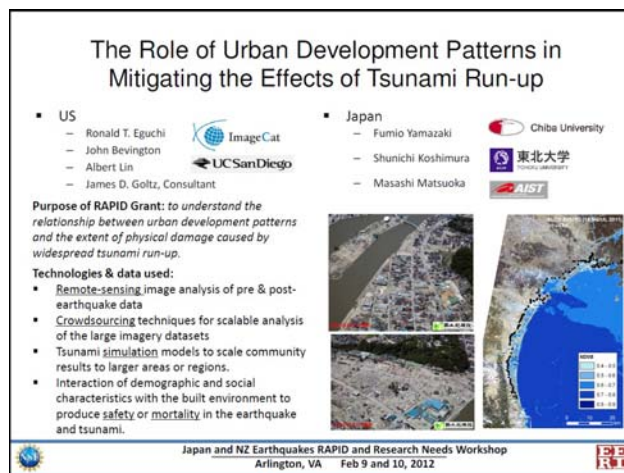
Complex agent-base system models can model on-the-ground populations and individual reactions, behavior, and responses to extreme events. They are often computationally challenging. So, design must take into account granularity of data modeling to strike a balance between realism and the need for speed for prediction and decision purposes. These models can be coupled with socio-economic decision analysis models for assessment of impacts and short and long-term recovery efforts.

We emphasize the need for a systems approach in developing such computational models where interdependencies are key elements for scientific advances, translational needs, and applicability.

Support a holistic research program on vulnerability and resilience that integrates many disciplines and researchers, across the three countries

The cascading nature of these disasters, in particular the Japan event with the earthquake, tsunami, nuclear power plant and the failure or inefficiencies of infrastructure and social services, led to catastrophe. Understanding that this can happen in the U.S., and that society is not prepared, leads to the recommendation that there is a clear need and unique opportunity to carry out broad-based programs of coordinated and collaborative basic research to evaluate the vulnerability of large urban areas to potentially catastrophic natural events, and to improve resilience. The possibility of catastrophic losses changes current thinking on mitigation and requires more research in terms of resilience and the capacity to change and adapt. The Japan and New Zealand events provide an extraordinary context for the development of such a broad, integrated research program. All three countries are advanced industrialized countries with many of the same vulnerabilities and strengths, all three countries have highly qualified and interested researchers and stakeholders who would be willing to collaborate, and there are lots of high quality data from both Japan and New Zealand for many issues of interest. A focused research campaign to create a more resilient America would include:

- the development of a framework from which to judge and quantify resilience in both broad and narrow terms;
- a holistic and balanced approach for measuring hazards and vulnerabilities;
- standardized methodologies for quantifying economic, social, and health impacts;
- strategies and tools for measuring, monitoring and evaluating post-disaster recovery; and
- broad-based contributions from researchers from many NSF directorates, including (but not limited to) engineering, social sciences, geosciences, and computer and information sciences.



Slide from R. Eguchi - *The Role of Urban Development Patterns in Mitigating the Effects of Tsunami Run-up*

Once such a program is established, it can easily be extended to include information and participation related to other catastrophic earthquakes, such as Chile. To be most effective, the recommendation is to support several coordinated projects rather than a large number of independent and uncoordinated projects. A possible theme for such a program in the U.S. is “preparing for the big one”, focusing on the Pacific Northwest, with an ultimate goal that the supported research contributes to assessing vulnerability and improving the resilience of the United States.

It was noted that the above is very much in line with a current NSF goal of establishing a *Community Resilience Observatory*. The concept of RAVON (Toward a Resiliency and

Vulnerability Observatory Network) was first proposed in 2008 in a joint National Science Foundation and U.S. Geological Survey workshop that brought together leading researchers from the disaster research community to explore the creation of a new NSF observatory focused on resiliency and vulnerability⁴. This work in turn led to a more recent workshop and initiative, CaMRA (Creating a More Disaster Resilient America), which has proposed an NSF cross-directorate program on disaster resilience, vulnerability and risk reduction⁵. Recommendations are that this new program should focus on natural and technological hazards; the program must focus on interdisciplinary research; the program should stimulate comparative hazard research; and the program must facilitate long-term data collection activities.

More detail about the initial findings from the RAPIDs and the research recommendations from individual breakout groups are provided in the sections that follow.

⁴ Peacock, W.G., H. Kunreuther, W.H. Hooke, S.L. Cutter, S.E. Chang, and P.R. Berke, 2008. *Toward a Resiliency and Vulnerability Observatory Network: RAVON*. HRRC report 08-02-R. College Station, TX: Hazard Reduction and Recovery Center, Texas A&M University.

⁵ Peacock, W.G. et al. 2011. *Creating a More Disaster Resilient America (CAMRA): The Findings from a Workshop on a New Cross-Directorate Program on Disaster Resilience, Vulnerability, and Risk Reduction* <http://archone.tamu.edu/hrrc/camra/report.pdf>.

Workshop Approach

The workshop was organized for researchers who received RAPID awards from the National Science Foundation, primarily in response to a Dear Colleague letter from the Director of NSF, DCL NSF 11-049. In addition, five researchers who were supported by the Earthquake Engineering Research Institute (EERI) through its two RAPIDs for New Zealand and Japan also participated. Approximately 18 Japanese researchers who each received J-RAPIDs and who coordinated their research program with U.S. researchers also participated. EERI and the Government of New Zealand through its Ministry of Science and Innovation supported the travel of four New Zealand researchers to participate in the meeting. In total, approximately 105 researchers attended the workshop.

Three researchers served as co-chairs of the steering committee: Ron Eguchi, ImageCat Inc., a remote sensing expert; Ken Elwood, University of British Columbia and co-team leader for the EERI reconnaissance team to Christchurch, New Zealand, a structural engineer; and Eva Lee, Georgia Tech, a complex systems modeler and high performance computing expert. Steering committee members included: Ross Boulanger (UC Davis); Ian Buckle, (Univ of Nevada Reno); Mary Comerio (UC Berkeley); Rachel Davidson (Univ of Delaware); Hermann Fritz (Georgia Tech); Tomonari Furukawa (Virginia Tech); Steve Mahin (UC Berkeley); Ian Robertson (Univ of Hawaii); Yasuaki Sakamoto (Stevens Institute of Technology); Jeannette Sutton (Univ of Colorado, Colorado Springs); Maurizio Tsugawa (Univ of Florida); and Jay Berger and Marjorie Greene (EERI).



Robotics breakout group discussion in the first afternoon

The steering committee was charged with designing the agenda and program for the workshop, assigning leaders and facilitators for the break-out sessions, and outlining future needs for research.

The workshop was organized for February 9 and 10, 2012, at NSF headquarters in Arlington, Virginia. Fifty-one RAPID (including J-RAPID counterpart) awards were represented at the workshop. With such a large number of awards, there was insufficient time for each project to present its own findings in detail. The steering committee decided to provide an overview of all the projects and then focus more on using this workshop as an opportunity to define an umbrella future research program from these events —both a list of research needs emerging from the events, and specific recommendations related to how society should address such catastrophic events.

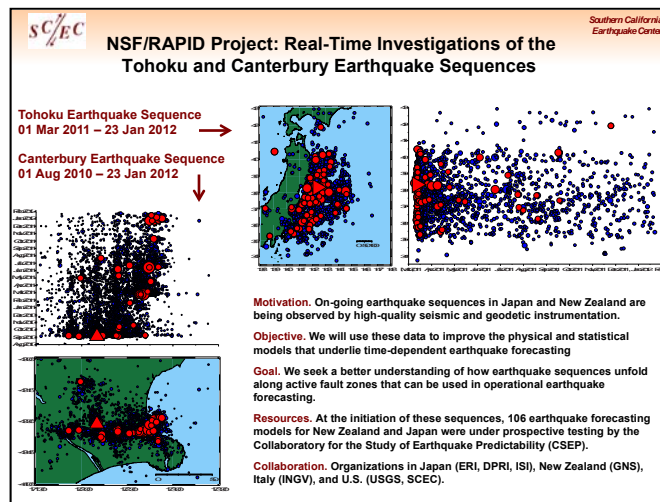
To that end, the first morning focused on providing an overview of the RAPIDs and a synthesis of findings and research needs coming from them. Several members of the workshop steering committee were group leaders and presented three slides from each project—one summarizing the project **objectives**, one summarizing up to two major findings, and one focused on opportunities for future research. For those projects where there was a counterpart J-RAPID

project, U.S. and Japanese collaborators worked together to develop the three slides for a combined presentation.

In addition to these brief presentations, RAPID awardees were asked to prepare a poster for their project. These posters were then made available for downloading at the NEEShub website (<http://nees.org/education/partners/rapid-2012>) , and were also available for viewing during the workshop at NSF.

See Appendix A for the workshop agenda. In addition to the brief presentations from each of the RAPID grants, the workshop was organized around several breakout sessions—the reports from each of these groups are summarized in the next section.

Representatives from the NEHRP agencies and other federal agencies and international organizations with an interest in earthquakes and their effects were invited to participate as observers. See Appendix B for a listing of workshop participants.



Presentation slide from T. Jordan RAPID grant on Real-Time Investigations of the Tohoku and Darfield Earthquake Sequences

Breakout Sessions

There were three sets of breakout sessions over the course of the two-day workshop. The first set of sessions was discipline- focused (corresponding to the groupings of the RAPID awards). The second set of sessions was organized around cross-cutting themes— preparedness and mitigation, response, and short and long term recovery. The third set of sessions was organized by event—New Zealand earthquake, Japan earthquake, Japan tsunami, and Japan radiological disaster. Each of these 16 sessions prepared a set of summary slides identifying new research questions raised and new data available as a result of the events. These slides are all available on the EERI Japan and New Zealand NSF RAPID Workshop <http://www.eeri.org/japan-new-zealand-nsf-rapid-workshop/>.

Breakout Session 1: Discipline-Focused

Structures 1: New Zealand



The group first identified the unique aspects of the Christchurch earthquakes. These included prolonged and continuing aftershocks, a large population of unreinforced masonry buildings, and soft soil conditions. The group noted that the resulting data from the events allows for research on the identification of successful structural details and retrofits, the performance of utilities, and the repair cost to property value ratio. Additionally, the group noted that new data, such as field measurements from ongoing aftershocks in damaged and undamaged buildings and the potential for destructive testing of components and buildings, is still worth harvesting from the affected areas. The discussion closed by emphasizing two broader impacts of the Christchurch earthquakes: a better understanding of what factors affect resiliency and a need for the reevaluation of performance levels.

3


Seismic Behavior of the Christchurch Women's Hospital

- Henri Gavin (Duke), Bob Nigbor (UCLA),
 - Wayne Lawson (CDHB NZ),
- Greg MacRae, Geoff Chase, Geoff Rodgers, Stefanie Gutschmidt (Canterbury NZ)

• The objective of this project is to collect perishable seismic response data from the base-isolated Christchurch Women's Hospital. The strong and continuing sequence of aftershocks presents a unique opportunity to capture high-fidelity data from a modern base-isolated facility. These measurements will provide quantitative information required to assess the mechanisms at play in this and in many other seismically-isolated structures.



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Slide from H. Gavin *Seismic Behavior of the Christchurch Women's Hospital*

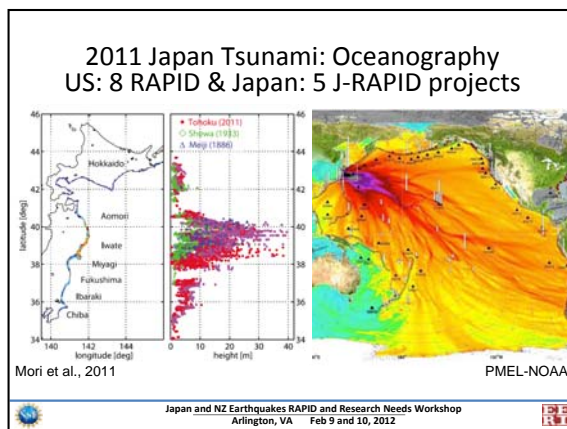
Structures 2: Japan

From a structural perspective, the Japan events were unique in the following ways: two extreme events (near-source shaking followed by tsunami impact), multiple aftershocks, an extensive amount of quality data, and alarming felt vibrations in tall buildings. The group also highlighted the importance of resiliency. Both the earthquake and tsunami exceeded the design considerations for structures. The group identified four issues that present opportunities for future collaboration: improving the analytical modeling for extreme loads, improving the performance of tall buildings, understanding tsunami hazards and mitigating the associated risk, and using the extensive data available to validate numerical models and retrofit techniques.

Geotechnical

The geotechnical group emphasized that the quantity and quality of observations from the events in Japan and New Zealand provide an unparalleled opportunity to investigate key geotechnical/earth science questions that require basic research. An unprecedented set of strong motion records and geodetic data is available from the M9 subduction zone event in Japan that can be used to inform physics-based models and empirical relations. The widespread occurrence of liquefaction in the New Zealand events, along with integrated GIS of buildings and lifelines systems provides information about their performance across a broad range of shaking levels and ground displacement that can be used to guide probabilistic assessments. The events also provide data for the nonlinear seismic site response due to both long-duration and near-fault ground motions. Studying this data is important as the unusual sequence of highly damaging earthquake events in New Zealand and Japan has implications for regions such as Southern California and the Pacific Northwest.

Oceanography/Tsunami



Slide from Mori et al. 2011 Japan Tsunami:
Oceanography US: 8 RAPID & Japan: 5 J-RAPID projects


The oceanography group presented nine research priorities that came out of their discussion on the tsunami in Japan. The priorities are as follows:

- Understand how dynamic rupture during an earthquake affects seafloor deformation and also how this deformation affects the tsunami runup?
- Provide a better distribution of offshore tsunameters, seafloor GPS, etc. in order to do tsunami inversions
- Use our new knowledge to revise probabilistic seismic hazard models
- Understand the impact of the tsunami wave train on coastal damage (Why did so many coastal “defense structures” fail? How can we better design these structures? How do these structures operate during failure?)
- Better study deposits from previous tsunamis –recalibrate geologic events in other regions (e.g., Cascadia). (Need enough information to understand along-shore variations)
- Better understand co-seismic subsidence along the coastal zone
- Understand how to take into account these massive events during construction of highways, evacuation routes, nuclear power plants, etc.
- Use radionuclide tracers to better understand the ocean circulation in the Pacific. Radioactive leaks continue; how does radioactivity accumulate in fish, etc.?
- Understand the impact of bottom roughness and sediment on tsunami deposits

Social Science


The social sciences group raised many questions in relation to the effects of the disasters in Japan and New Zealand. These questions covered a range of issues from human response and decision making among public officials, responders, volunteers, and members of the affected public, to revisiting effective definitions of resiliency, preparedness, response, and recovery, especially in relation to metrics for measurement and analysis. The group was also concerned with how new data can be collected for comparative research across events and locations, and developing common standards for data collection and sharing among researchers. In addition, several examples were provided by researchers where transmitted rumors about disaster-related information, such as radiation and supplies, caused unnecessary alarm. To mitigate the spread of false information during a disaster, there needs to be a better understanding of how people interact with technologies.

The group also discussed ways to empower or develop a framework for locally affected individuals to assist in resiliency enhancements and rebuilding efforts across the entire disaster spectrum. And finally, group participants revisited the idea that silos exist between the behavioral sciences and engineers of all types, noting that there is a need for data integration across disciplines to assist in the recovery process.



Key Findings

- On-the-ground:
 - Lack of strategies and emergency guidelines for rapid screening and decontamination for both workers and citizens
 - Lack of knowledge of radiation safety and emergency response processes, even for those live very close to nuclear plants
- Advances:
 - Collected some critical data related to radiological emergency response processes
 - Information-decision support system developed helps with large-scale radiological emergency response (social, logistics, policies)



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Slide from E. Lee Population Protection and Monitoring in Response to Radiological Incidents

IT 1: Communications

The IT communications group compiled a list of research needs for communication before, during, and after a disaster. Needs include robust, resilient, and trustworthy systems that integrate social science and technological capabilities for disaster communications including, ubiquitous sensors (e.g. cameras, satellites, personal communication devices), the integration of multi-modal media, and real-time decision support systems. There was strong recognition for integrated social science and technological research efforts to improve capacity for robust early warning

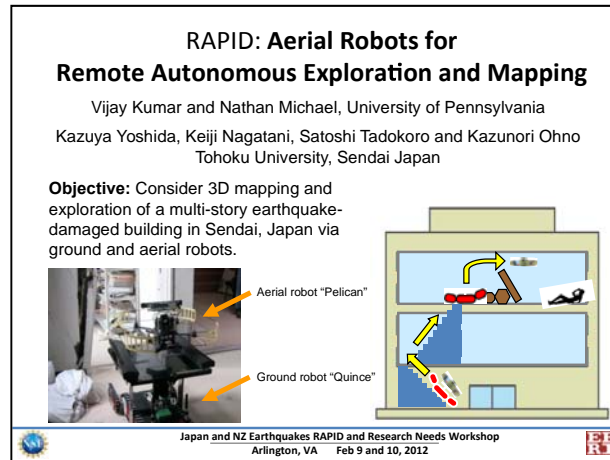
systems. The group also emphasized that the research efforts in these areas should be multi-disciplinary to increase knowledge of socio-technical systems and facilitate efficient sharing of information in an emergency.

IT 2: Robotics

The robotics group provided a summary of the instances where robots were deployed. In Japan robots were used on land to inspect partially collapsed buildings and the Fukushima Daiichi nuclear plant, under water to perform port inspections and aid in victim recovery, and aerial robots were also used to inspect the Fukushima Daiichi nuclear plant. The lessons learned from

these deployments were that mobility, sensing capability, and the human interface is important, accessibility may be limited, there can be a lack of trust for autonomy, and victim recovery was very difficult after the tsunami. Given their experiences the group identified five issues for intensive research for future disasters. These issues are:

- Mobility, sensing, mapping, operation, autonomy
- Cooperation of multiple/heterogeneous robots and organizations
- Human/robot interaction
- Communication
- Training and exercise



Slide from V. Kumar RAPID: Aerial Robots for Remote Autonomous Exploration and Mapping

The group ended by discussing mechanisms to share data and encourage collaborations. Existing mechanisms include academic societies, conferences, workshops, and tutorials. Proposed mechanisms are a Disaster Challenge, moving towards standardization of data sharing and archiving, and workshops with practitioners and civil disaster researchers.

Discussion Panel on Data Sharing

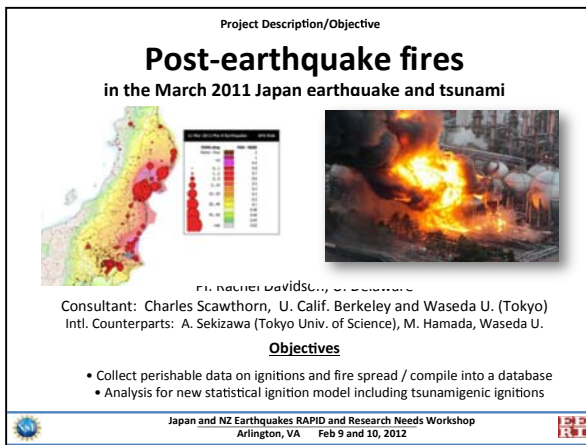
Both the New Zealand and Japan earthquakes prompted a large amount of international collaboration among researchers. For this reason, data sharing is an important topic for all involved. On the second morning of the workshop a panel was organized to lead a discussion on “Data Sharing across countries, among researchers”. The panel consisted of one person from each of the following countries: US, New Zealand, and Japan. Each panelist gave a brief presentation of their data sharing efforts and then the session was opened for discussion. There was much lively discussion about the process and difficulties involved in data sharing. Some of the topics discussed were: legal issues involved with sharing damage information about private buildings, the timeline for publishing reports, the challenges of accessing primary data, and taking advantage of perishable data from social media.

Breakout Session 2: Cross-cutting themes

Preparedness and Mitigation: New Infrastructure

There is great opportunity to learn how to enhance the performance of infrastructure in the wake of these two disasters. Data from instrumented buildings can be used to determine if design objectives were met and to improve models. New performance objectives can be defined to decrease future economic loss based on the repair costs of damaged structures in the affected regions.

Preparedness and Mitigation: Existing Infrastructure



Slide from R. Davidson *Post-earthquake fires in the March 2011 Japan earthquake and tsunami*

These events have provided volumes of new data that give a more complete picture of the physical, economic, social, and political effects of catastrophes on infrastructure. This big picture view can help to educate the public and increase awareness about the importance of mitigating damage to existing infrastructure. The data from these events, such as information about structural performance, damage to telecommunication infrastructure, and fatalities, can also be used to bridge the gap between knowledge of social behavior and the technical assessment of risk.

Response and Short Term Recovery

Lessons learned from these events are directly applicable to the U.S. where similar design and construction standards are used. Furthermore, because recovery in both Japan and New Zealand are expected to be long and extended processes, there will be ample opportunities to collect data and information and to develop methodologies on effective response and recovery. A major focus for research should be on developing meaningful approaches for measuring, monitoring and evaluating both post-disaster response and short-and long-term recovery. What is needed are suitable metrics that can serve as benchmarks for recovery, on small, medium and large community scales. Furthermore, data that are collected from Japan and New Zealand should be used to calibrate and validate quantitative models of recovery, many of which were developed in response to U.S. disasters, e.g., Hurricane Katrina.

Research on response and early recovery needs to also include attention to the psychological effects of serial disasters (such as the ongoing shaking in New Zealand) and catastrophic disaster events as it relates to community resiliency and long term recovery. Psychological impacts need to be assessed across the lifespan, noting the long term repercussions of traumatic events on entire generations of children and youth.

Special attention should also be placed on utilization of new and emerging technologies which have demonstrated potential for rapid and widespread data collection. Many examples of using social media were discussed during the workshop; some applications suggest new and possibly effective methods of collecting perishable data (photos) that can be used to document damage and impacts. Attention must be given to communication issues across technological channels in the absence of critical infrastructure and the ability to relay information to the most vulnerable populations following a devastating event. Additionally, several research projects discussed how remote sensing can be applied to quantify significant regional impacts immediately after an event and changes over time producing data that can be used to measure recovery progress.

Long Term Recovery

Unique factors associated with long term recovery in both Japan and New Zealand include high levels of damage in countries with well-developed codes and planning standards, cascading failures, and the impact of catastrophic events on the capacity to respond to subsequent disasters. The group identified many research topics that have surfaced in the Japan and New Zealand events. The most important are:

- Understanding and redefining the long-term recovery process and recognizing a “new normal”
- Developing a model for “pre-event recovery planning”
- Understanding how response actions impact short and long term recovery
- Identifying tolerable impacts and acceptable risks

New data available from these events that can inform these research areas are baseline and longitudinal documentation of the decision-making process, the impacts of previous events on current recovery, and the disconnect between pre-event standards and what happened in recovery. The group concluded their discussion by highlighting the impact of population aging and migration on community resilience and the importance of understanding a national scale of positive and negative long term economic impacts.

Breakout Session 3: By Event

New Zealand earthquake

RAPID: Liquefaction and Its Effects on Buildings & Lifelines in the Feb. 22, 2011 Christchurch, New Zealand Earthquake


PIs: Jonathan Bray, UC Berkeley, Thomas O'Rourke, Cornell U, & Russell Green, Virginia Tech
GSRs: Josh Zupan, UC Berkeley; Clint Wood, U. of Arkansas; Brad Wham & Serozhah Milashuk, Cornell U.

With: Misko Cubrinovski & Brendon Bradley, U. of Canterbury, Brady Cox, U. of Arkansas, Liam Wotherspoon, U. of Auckland, & Iain Haycock, McMillan Drillers

International Students: Merrick Taylor, Simona Giorgini, Kelly Robinson, & Duncan Henderson, U. of Canterbury

Stakeholders & Partners: Christchurch City Council, CERA, EQC, NHRP

OBJ: Surveying the re-occurrence of liquefaction, documenting cases of liquefaction-induced ground movements, and evaluating the effects of liquefaction on lifelines and buildings provide invaluable information that will advance our understanding the effects of earthquakes.



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Slide from J. Bray RAPID: Liquefaction and Its Effects on Buildings & Lifelines in the Feb. 22, 2011 Christchurch, New Zealand Earthquake

events when tagging buildings, and how to recover when a major city loses its city center. The group concluded by emphasizing the importance of U.S. collaborations with New Zealand as the two countries have many commonalities including similar built environments, code and design philosophies, and tectonic and soil conditions.

Japan earthquake #1

This group decided to focus on how developing a multi-institutional, interdisciplinary digital data center can be used to greatly advance the field of earthquake engineering. This concept – which could be driven by a cooperative program between the U.S., Japan, New Zealand, and other interested countries – would generate a long-term research program that would focus on the development of a robust, digital platform capable of:

- Handling numerical/computational/simulation models (with descriptions of parameter-selection processes)
- Supporting an evolving taxonomy
- Allowing for modular construction
- Storing images and video, as well as quantitative and qualitative data
- Supporting image recognition (similar to OCR)
- Adapting rapidly to meet changing user requirements
- Allowing for simple transfer to other platforms to ensure longevity (interoperable)

The earthquakes in New Zealand demonstrated the damaging effects of widespread liquefaction and a sequence of design-level events. Data from the events on multiple faults provide information about attenuation relationships, stress drop, directionality, and source depth. Performance of buildings, including URM and heritage buildings, have provided the most complete set of fragility data yet collected. In a community where there was no existing disaster experience, important lessons can be learned from the recovery process, including insurance policies, the effects of a sequence of

Project Description/Objective

- **RAPID Title:** Evaluation of the Performance of Bridges During the Great East Japan Earthquake
- **US Researchers:** Ian Buckle, David Frost, Wen-huei (Phillip) Yen, Lee Marsh, Shideh Dashti
- **International counterparts:** Kazuhiko Kawashima, Shigeki Unjoh, Jun-ichi Hoshikuma
- **Objective:** To investigate
 - Effectiveness of design and retrofit procedures implemented since Kobe
 - Vulnerability of bridges to tsunami impacts
 - Linkage between duration and damage




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Slide from I. Buckle RAPID: Evaluation of the Performance of Bridges During the Great East Japan Earthquake

- Supporting quick searches across all types of data
- Accommodating needs of all relevant disciplines
- Generating academic recognition (citations)
- Accommodating legal requirements or limitations
- Accommodating privacy and human subjects requirements
- Supporting crowd-sourcing, and
- Offering automated translation (language and units)

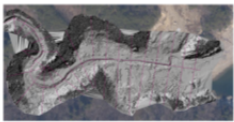

Japan earthquake #2

This group explained how the Japan and New Zealand events provide an extraordinary context for the development of a holistic research program on vulnerability and resilience that integrates many disciplines and researchers, across the three countries. A focused research campaign would take advantage of the fact that all three countries have highly qualified and interested researchers and stakeholders who would be willing to collaborate, and there are lots of high quality data from both Japan and New Zealand for many issues of interest. The ultimate goal of the program would be that the supported research contributes to assessing the vulnerability and improving the resilience of the United States.

Project Description/Objective	
<ul style="list-style-type: none"> • NSF Rapid: Impact of Debris Generated from the 2011 Tohoku, Japan Tsunami (CMMI-1138668) • US Researchers: Clay Naito, Dan Cox, Kent Yu, Ron Riggs and Marcelo Kobayashi • International counterparts: Daiki Tsujio (Pacific), Prof. Norimi Mizutani (Nagoya University) 	 <p>Project Objectives Acquire field data on tsunami generated debris and document cases of impact on structures in Japan. Assess the type and size of debris demands typical for coastal communities. Assess structural damage patterns generated as a result of impact events. Validate models developed as part of an ongoing NEES study.</p>
<p>Japan and NZ Earthquakes RAPID and Research Needs Workshop Arlington, VA Feb 9 and 10, 2012</p>	

Slide from C. Naito Impact of Debris Generated from the 2011 Tohoku, Japan Tsunami

Japan tsunami

Flow Dynamics/Morphological Impacts of March 11 Tohoku Tsunami, Japan	
<p>USA: Victor R. Baker, Jon Pelletier, Luke McGuire, Univ. of Arizona JAPAN: Takashi Oguchi, Yuichi S. Hayakawa, Hitoshi Saito, Akitoshi Kobayashi, Univ. Tokyo</p> <p>Objective: Understand the catastrophic geomorphic effects of the March 11 Tohoku-Oki Tsunami on the Sanriku Coast, Japan, using 2-d Hydraulic Modeling and Terrestrial Laser Scanning</p>	
	
<p>Japan and NZ Earthquakes RAPID and Research Needs Workshop Arlington, VA Feb 9 and 10, 2012</p>	

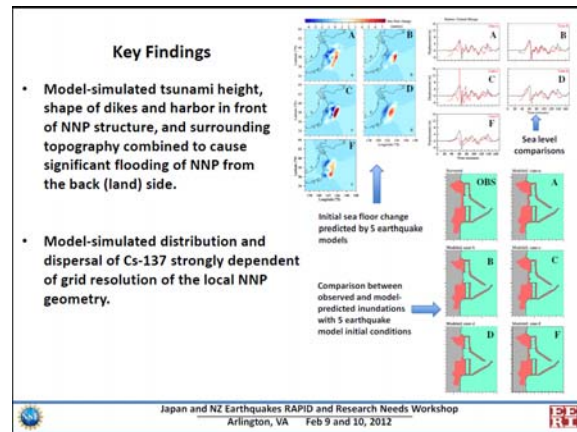
Slide from V. Baker Flow Dynamics/Morphological Impacts of March 11 Tohoku Tsunami, Japan

The tsunami was a once in one thousand year event that occurred in a well-prepared area and showed the limitation of warning systems and has a continuing impact on the environment. These unique aspects of the tsunami show that the following areas require basic research: sea-wall protection and evacuation systems, post-event recovery studies, the resiliency of communication networks, sea floor deformation/tsunamis source studies, and inverse engineering research to estimate the hydrodynamics of tsunami flooding. New data from these events that can aid this research are tsunami height survey data, voluminous data for

time-history tsunami modeling, and measurements of the offshore tsunami profile. Lessons to be learned from this event include that human response to a tsunami is varied, guidelines are needed for vertical evacuation, and that paleo-tsunami information plays a key role in understanding the potential magnitude of a catastrophic event.

Japan radiological disaster

The radiological disaster following the earthquake and tsunami in Japan was unique in many ways. It was the first major hydrologic release of radiation, there was significant use of robotics in the response, and there was more transparency and better access to data. New data from the disaster includes the deposition and atmospheric dispersion of radioactive materials and social data related to the evacuation, screening, and health of the local population. It should be recognized that the time-scales for both the development of, as well as the response to, the radiological disaster may be quite decoupled from those that pertain to both the earthquake and tsunami events in New Zealand and Japan. Areas for further research include: determining what the appropriate emergency response is, how to take advantage of predictive capabilities, determining the appropriate initial and long-term radii for the exclusion zone, and what the fate of the radionuclides is. The group finished with four important international lessons: a lack of public education hinders public understanding, it is time to revisit nuclear power plant safety and technology, training in schools similar to earthquake and tsunami training is necessary, and fleets of response robots are needed.



Slide from C. Changsheng Collaborative Research: The March 11 2011 Earthquake, Tsunami Inundation and Initial Spread of Fukushima Dai-ichi Radionuclides on the Pacific Ocean: Model Assessment

Concluding Remarks

There is no doubt the Christchurch and Tohoku events will have long-lasting effects on the people of Japan and New Zealand. Just as the 1971 San Fernando, the 1989 Loma Prieta and the 1994 Northridge earthquakes were catalysts for major building and lifeline design and construction changes in the U.S., these events will be catalysts for earthquake hazard mitigation activities not only in the affected countries, but around the world. Specifically, on how we confront multi-hazards and their inter-connected effects, the long-term social disruption caused by large catastrophes and the impact of technologies in improving response, recovery and mitigation activities.



Tsunami height marker, 1960 Chile tsunami, Ofunato Town (in 2010). The sign reads: "Disaster attacks when you forget" (photo: R. Eisner).

It is our hope the research discussed in this two-day workshop serves as a roadmap for researchers, practitioners, government officials, and the public in how to manage these larger than expected events, especially the significant consequences that result both spatially and over time. The unique opportunities afforded by the workshop through multiple-themed breakout sessions, and multi-discipline foci, had a significant impact in helping generate the final recommendations of the workshop.

The workshop organizers thank the National Science Foundation for their support and guidance before, during and after this multi-lateral meeting. We also thank the participants of the workshop from Japan, New Zealand and the U.S. for their passionate commitment to share their observations, experience and research in this open forum, and for helping advance our understanding of the impact such large events have on global societies.

Appendix A: Workshop Agenda



EERI

Japan and New Zealand RAPIDS and Research Needs Workshop

February 9 and 10th, 2012

National Science Foundation • Arlington, VA • Room 375

Agenda

Thursday, Feb 9

- | | |
|--------------------------|--|
| 7:30 am | Continental Breakfast and Poster Set-up Room 375, Stafford I |
| 8:00-9:00 am | Welcome & Introductions (moderator: Ian Buckle, UNR & president-elect EERI)
Dr. Subra Suresh, Director of National Science Foundation
H.E. Ichiro Fujisaki, Ambassador of Japan to the United States
Rt. Hon Mike Moore, Ambassador of New Zealand to the United States
Dr. Takayoshi Mamine, Executive Director, Japan Science and Technology Agency |
| 9:00-9:40 am | Presentations: Research Programs from New Zealand and Japan (moderators: Joy Pauschke and Clive Woods, U.S. National Science Foundation)
Kelvin Berryman, GNS Science New Zealand
Mitsuhiko Oi, Japan Science and Technology Agency |
| 9:40—9:45 am | Workshop Objectives and Program |
| 9:45—10:00 am | BREAK |
| 10:00 am-11:30 am | RAPID Presentations by Group Leaders (moderator: Jack Moehle, UC Berkeley)
10:00 am GEOTECHNICAL & EARTH SCIENCES projects [Japan & NZ]
Ross Boulanger, UC Davis
10:30 am OCEANOGRAPHY [Japan] (Hermann Fritz, Georgia Tech)
11:05 am STRUCTURES Group #1 [New Zealand] (Ken Elwood, Univ of British Columbia) |
| 11:35—12:15 pm | Poster Viewing |
| 12:15—12:45 pm | Lunch (provided. \$10 charge for NSF staff & U.S. RAPID awardees) |
| 12:45--2:45 pm | RAPID Presentations by Group Leaders (cont.; moderator: Jack Moehle, UC Berkeley)
12:45 pm STRUCTURES Group #2 [Japan] (Ian Robertson, Univ of Hawaii)
1:25 pm SOCIAL SCIENCES [Japan & NZ] (Mary Comerio, UC Berkeley) |

1:45 pm INFORMATION TECHNOLOGY Group #1 [Japan & NZ]
(Eva Lee, Georgia Tech)
2:15 pm INFORMATION TECHNOLOGY Group #2 [Japan & NZ]
(Ron Eguchi, ImageCat)

2:45 – 3:15 pm	Questions and Discussion (moderator: Eva Lee, Georgia Tech)
3:15--3:30 pm	Break/Room Transition
3:30-4:45 pm	Breakout Session 1 (7 Discipline-Focused groups). See separate sheet for assignments.
4:45-5:00 pm	Break/Room Transition
5:00-5:45 pm	Breakout #1 Report Back (moderator: Roberto Leon, VirginiaTech)
6:30 pm	Buses leave hotel for reception at “old” residence of the Ambassador of Japan (2516 Massachusetts Avenue NW, Washington, DC, 20008) Return at 9 pm

Friday, Feb 10

7:30 am	Continental Breakfast available in Room 375, Stafford I
7:50 am	Room 375--Sign up for break-out group 2
8:00 -9:00 am	Panel: Data Sharing across countries, among researchers (moderator: Ken Elwood, Univ of British Columbia) 5 minutes of remarks from each, then group discussion: Steve Mahin, UC Berkeley: US Kelvin Berryman, GNS Science: New Zealand Hitoshi Shiohara, Univ of Tokyo: Japan
9:00-9:15 am	Break/Room Transition
9:15-10:45 am	Breakout Session 2 (cross-cutting themes—5 or 6 groups) Overarching theme of resilience in larger-than-expected and more complex events (unique research opportunities) <ul style="list-style-type: none"> ▪ Preparedness and mitigation (incl codes and land use policies) <ul style="list-style-type: none"> • New infrastructure • Existing infrastructure ▪ Response ▪ Recovery (short term) ▪ Recovery (long term)
10:45-11:00 am	Break/Room Transition

11:00--12 noon	Breakout #2 Report Back (moderator: David Johnston, GNS Science, New Zealand)
12 noon—1:00 pm	Lunch on own (posters available for viewing)
1:00-2:30 pm	Breakout Session 3 (by event—NZ earthquake, Japan earthquake (2 groups), Japan tsunami (2 groups), Japan radiological disaster). See separate sheet for assignments.
2:30-2:45 pm	Break/Room Transition
2:45 -3:45 pm	Breakout #3 Report Back (moderator: Satoshi Tadokoro, International Rescue System Institute)
3:45—4:30 pm	Wrap-Up/Identification of Next Steps and Future Directions (moderator: Ron Eguchi, ImageCat) Summary remarks from other NEHRP agencies Joy Pauschke, National Science Foundation Bill Holmes, Rutherford & Chekene (& FEMA) John Filson, USGS Closing remarks from conference co-chairs Ken Elwood Eva Lee Ron Eguchi
4:30—5:00 pm	Meeting of Steering Committee to discuss writing assignments/workshop report

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Appendix C: Summary of RAPID Awards

GEOTECHNICAL AND EARTH SCIENCES					
#	Rapid Grant for:	Principal Investigator(s)	Collaborator(s)	RAPID**	Summary
1	Japan	Boulanger, Ross; Sitar, Nick	Hamada, Masanori; Ishihara, Kenji; Koushu, Takaji; Konagai, Kazuo; Sugano, Takahiro; Towhata, Ikuo	Geotechnical Engineering Reconnaissance of the March 11, 2011, Tohoku Earthquake, Japan	This Grant for Rapid Response Research (RAPID) award funds field reconnaissance with Japanese colleagues that will focus on capturing perishable data, documenting high-value case histories, and assisting in geotechnical characterization at key sites in regards to the March 11, 2011, Mw = 9 Tohoku Earthquake. The earthquake was followed by a tsunami that caused tremendous damage and loss of life. The damage caused by this Mw = 9.0 event and the subsequent tsunami provides a number of important lessons for the Pacific Northwest and the West Coast of the United States. The wealth of strong motion data from the Japanese networks dwarfs those from any of the previous subduction zone events, providing numerous opportunities for studying the ground motion characteristics and the effects of very long-duration shaking on ground failure and local site response patterns. Coordinated by Geotechnical Extreme Events Reconnaissance (GEER)
2	NZ	Bray, Jonathan; O'Rourke, Thomas; Green, Russell	Cubrinovski, Misko; Bradley, Brendon; Cox, Brady; Wotherspoon, Liam; Haycock, Iain	Liquefaction and Its Effects on Buildings and Lifelines in the February 22, 2011 Christchurch, New Zealand Earthquake	This Grant for Rapid Response Research (RAPID) award provides funding to investigate the effects of liquefaction on the built environment during the 22 February 2011, Mw=6.1 Christchurch, New Zealand, earthquake and the 4 September 2010, Mw=7.0 Darfield, New Zealand, earthquake with the goal of capturing perishable data that would lead to the development of enhanced analytical procedures for evaluating the hazard holistically. The intense ground shaking and resulting soil liquefaction from the Christchurch earthquake damaged many buildings, lifelines, and engineered systems. The Central Business District (CBD) of Christchurch is still in ruins. The 22 February event is particularly meaningful, because it occurred just 5 months after the Darfield earthquake, the epicenter of which was approximately 40 km from the CBD. Whereas the 22 February event killed almost two hundred people, the September event resulted in no deaths. Additionally, although the 4 September event caused widespread liquefaction-induced damage in the Christchurch area, it did not produce significant liquefaction-induced damage within the CBD. Coordinated by Geotechnical Extreme Events Reconnaissance (GEER)
3	Japan	Cox, Brady	Boulanger, Ross; Sitar, Nick; Kayen, Robert; Wood, Clinton; Moss, Robb; Zekkos, Dimitros; Mason, Ben; Ishihara, Kenji; Tokimatsu, Kohji; Abe, Akio; Tohyama, Kazushi; Mr. Kota	Cone Penetration Testing (CPT) and Spectral Analysis of Surface Waves (SASW) Testing at Seismograph Stations with Liquefiable Soils Affected by the Tohoku Earthquake, Japan	This Grant for Rapid Response Research (RAPID) award is for a detailed study that focuses specifically on characterizing the soil conditions at a select set of strong ground motion recording stations that are underlain by liquefiable soils in regards to the March 11, 2011 magnitude 9.0 Tohoku, Japan Earthquake, which ranks as one of the largest in recorded history. On this visit, Cone Penetration Testing (CPT) and Spectral Analysis of Surface Waves (SASW) testing at key strong ground motion recording stations where liquefaction occurred were identified as priority research tasks that the US could contribute to joint US-Japan reconnaissance efforts. The GEER Advance Team visited 14 strong ground motion recording stations underlain by liquefiable soils in the Kanto Plain region, including several with both downhole and surface recordings. Peak ground accelerations at these stations ranged from 0.14 to 0.22 g, and surface evidence of liquefaction was observed at 7 of them. In addition, the Port and Airport Research Institute has indicated they have several strong ground motion recording stations further to the north, where shaking was stronger, that are underlain by liquefiable soils, including some with ground improvements. These key ground motion recordings represent a unique set of data that captures the dynamic response and liquefaction of soft soils during long-duration shaking produced by this M9.0 earthquake. Coordinated by Geotechnical Extreme Events Reconnaissance (GEER)

4	Japan	Weiss, Robert; Lynett, Patrick		Observations of Sediment Scour and Deposition in the Vicinity of Ports and Harbors from the 11 March 2011 Japan Tsunami	This grant supports an interdisciplinary, coastal impact survey of the tsunami that focuses on Pacific islands and other selected far field locations to reconstruct the tsunami characteristics, as well as sediment dynamics during the event. Engineering evaluation and sedimentary studies are jointly done in and near harbors, ports, and coastal infrastructure to provide a comprehensive assessment of this event. In the vicinity of infrastructure the team determines the runup, inundation distance, and flow depth. During the engineering evaluation, the team measures scouring around infrastructure, if accessible, and interviews eyewitnesses about the timeline of tsunami arrival, inundation dynamics, and the hydrodynamics in ports, harbors, and marinas as a consequence of the tsunami.
5	Japan & NZ	Jordan, Thomas; Beroza, Gregory		Real-Time Investigations of the Tohoku and Darfield Earthquake Sequences	The earthquake sequences excited by 2010 Darfield (New Zealand) and 2011 Tohoku (Japan) are natural experiments being conducted in two distinctive and well-instrumented tectonic laboratories. This NSF project supports U.S. scientists to participate in these experiments by collaborating with their Japanese and New Zealand colleagues. The international project team is gaining new knowledge about short-term earthquake predictability, which is a major unsolved problem of physical science.
6	NZ	Li, Yong-Gang		Recording Fault-Zone Trapped Waves from Aftershocks of the M6.3 Christchurch Earthquake Sequence in New Zealand to Document the Subsurface Damage Zones	In order to document the complicated subsurface structure of the damage zones caused by the sequence of the 2010 M7.1 Darfield and the 2011 M6.3 Christchurch earthquakes in the Canterbury region of NZ's South Island, the investigator proposes to record fault-zone trapped waves (FZTWs) generated by aftershocks, and use the FZTWs to image the rupture zones composed by damaged fault rocks at seismogenic depths. Because the amplitude and dispersive feature of FZTWs are sensitive to the geometry and physical properties, and the location of aftershocks (within or outside) of the low-velocity fault-zone waveguide formed by severely damaged rocks in these two earthquakes, observations and numerical modeling of recorded FZTWs allow us to learn more about (1) the width, velocity reduction, Q value and depth extension of damage zones of the 2010 M7.2 and 2011 M6.3 earthquakes, (2) the shape of subsurface rupture zones with the principal slip plans of the mainshocks, and if the two rupture segments are connected at seismogenic depths, (3) the difference in rock damage magnitude caused by these two earthquakes occurring at different depths with different sizes, (4) the fault healing with time after the mainshock.

7	Japan	Segall, Paul	Johnson, Kaj	Evaluation of the potential of large aftershocks of the 2011 Off the Pacific coast of Tohoku earthquake	This study aims to evaluate the potential of the occurrence of large aftershocks near the source region off the Pacific coast of the 2011 Tohoku Earthquake by analyzing all the available geodetic data. Specifically, the triangulation, trilateration, leveling, tide gauge data collected in recent several decades as well as the GPS displacement data collected in recent 16 years are re-evaluated to compare the amount of slip and afterslip of the Tohoku-oki earthquake and the slip deficit rates of the pre-earthquake period in order to ultimately estimate the slip deficit that was not fully released by the earthquake. The Japanese team is responsible for the evaluation of the potentials of the aftershock generation and the US team is responsible for development of the analysis methodology. The complementary works done by the both teams enable evaluation of the potential of maximum-possible aftershocks, which is expected to contribute to disaster mitigation through seismic and tsunami simulations.
	J-RAPID	Fukushima, Yo	Miyazaki, Shinichi; Hashimoto, Manabu	Evaluation of the potential of large aftershocks of the 2011 Off the Pacific coast of Tohoku earthquake	This study aims to evaluate the potential of the occurrence of large aftershocks near the source region off the Pacific coast of the 2011 Tohoku Earthquake by analyzing all the available geodetic data. Specifically, the triangulation, trilateration, leveling, tide gauge data collected in recent several decades as well as the GPS displacement data collected in recent 16 years are re-evaluated to compare the amount of slip and afterslip of the Tohoku-oki earthquake and the slip deficit rates of the pre-earthquake period in order to ultimately estimate the slip deficit that was not fully released by the earthquake. The Japanese team is responsible for the evaluation of the potentials of the aftershock generation and the US team is responsible for development of the analysis methodology. The complementary works done by the both teams enable evaluation of the potential of maximum-possible aftershocks, which is expected to contribute to disaster mitigation through seismic and tsunami simulations.

IT 1 (Communications/Augmented Reality)					
#	Rapid Grant for:	Principal Investigator(s)	Collaborator(s)	RAPID**	Summary
1	Japan	Durresi, Arjan	Barolli, Leonard; Takizawa, Makoto; Yoshitaka, Shibata; Koyama, Akio	Collaborative Research: Using Lessons from the Disaster in Japan to Develop Communications for Emergency Situations	This project supports collection of data about communication disruptions in Japan; treatment of such data to better understand the impact of telecommunication failures; and finally, solutions how to enhance the cellular system with ad hoc communications. The project is a close collaboration among PIs in the US, their collaborators in Japanese universities and cellular service providers in Japan.

2	NZ	Ergan, Semiha for Stamberger, Jeannie	Billinghurst, M.	Mobile Augmented Reality to Improve Rapid Assessments in Disasters	Following an earthquake, or similar natural disaster, a key problem is rapid and accurate on-site damage assessment to support local first responders; however, trained experts are typically remote from the disaster and it can be time consuming and expensive to bring them onsite. Accessing remote experts to improve the accuracy of rapid assessments is a promising method to streamline provisioning of emergency shelters and other resources. This project focuses on new methods for improved rapid assessment of earthquake damaged building structures in Christchurch, New Zealand. The methods are based on collaboration using augmented-reality (AR) imagery, mobile phone based sensor technologies and crowdsourcing techniques for guided remote data collection. A key element of the system is intuitive remote collaboration. Our mobile AR system can be used to connect a user in the disaster zone to a remote expert via audio and shared still images and/or video, helping them to rapidly collect data on building structural integrity. A user evaluation will be performed to compare the performance between the prototype and more traditional approaches (e.g., waiting for an expert to arrive on the ground), and assessment based on imagery recorded from an untrained and unguided user.
3	Japan	Jain, Raj	Barolli, Leonard; Takizawa, Makoto; Yoshitaka, Shibata; Koyama, Akio	Collaborative Research:Using Lessons from the Disaster in Japan to Develop Communications for Emergency Situations	During disasters, the telecommunication infrastructure are usually heavily damaged or overloaded, which leads to serious disruptions in the warning and rescue operations. Similarly, part of the Japanese cellular Early Earthquake Warning (EEW) system were damaged during the March 11th earthquake and tsunami. This collaborative project proposes to study the disruption of emergency communications during the last disaster in Japan and investigate corresponding solutions. In particular, the project has the following three integrated objectives: 1) To study the cellular EEW system of Japan and its use in the March 11th earthquake in Japan; 2) To study the communication problems that were encountered leading to disruptions in warning and rescue operations; and 3) To explore tower-less phone-to-phone direct communication mode that can make the cellular phone communications much more resilient during disasters.
4	Japan	Lee, Eva	Susuki, Atsuo	Population Protection and Monitoring in Response to Radiological Incidents	This RAPID project, collecting rare and real-life data pertaining to radiological emergency response in Japan, builds on previous work that collects and processes a large amount of time-motion study data in the public health emergency response system planning and usage at Georgia Tech. The team will work with Japanese collaborators in their efforts in performing assessment of the recent series of disasters in Japan, as well as in assisting in the recovery. This team is experienced in using a real-time information-decision support system for emergency preparedness. The collection and the analysis of scarce data in the so-called Knowledge Data Bank for Radiological Responses, speaks to the importance and uniqueness of the proposed system. The final system will facilitate assessment of current operations performance versus pre-disaster preparedness. It will allow for the study, training, and enhancement of emergency response, as well as future planning for radiological incidents. The work provides a unique opportunity to collect on-the-ground emergency response data.

5	Japan	Pu, Calton	Kitsuregawa, Masaru	Automating Emergency Data and Metadata Management to Support Effective Short Term and Long Term Disaster Recovery Efforts	This RAPID project, collecting, processing, and disseminating appropriate sensor data, aims to contribute to an effective recovery. The work addresses the challenges of sensor data flood during an emergency, through integration, evaluation, and enhancement of current data management tools, particularly with respect to meta-data. Automation of data and meta-data collection, processing, and dissemination are expected to alleviate the time pressure on human operators. The fundamental tools support quality information dimensions such as provenance, timeliness, security, privacy, and confidentiality, enabling an appropriate interpretation of the sensor data in the long term. For the short term, the tools are expected to help relief the workers as data producers and consumers; for the long term, they will provide high quality information for disaster recovery decision support systems. Additionally, the cloud-based system architecture and implementation of the CERCS cluster of Open Cirrus provide high availability and ease of access for recovery efforts in Japan as well as for researchers worldwide. The integration of techniques from several information dimensions (e.g., data provenance, surety, and privacy) and the application of code generation techniques to automate the data and metadata management tools constitute the intellectual merit of the proposed research.
6	Japan	Sakamoto, Yasuaki; Tanaka, Yuko	Toshihiko, Matsuka; Honda, Hidehito; Michita, Yasushi	Minimizing the spread of false rumors in social media during a disaster	This project focuses on understanding the spread of false information during responses to natural disasters and on the development of new techniques to prevent the spread of false information in social media. The goals of this project are to better understand how false information is spread via Twitter after an emergency and to develop and evaluate new techniques to prevent the spread of false information. To achieve these goals, the investigators will build a visualization tool to measure the effectiveness of counteracting tweets that question the accuracy of false tweets and conduct experiments with university students in Japan and USA in which subjects' familiarity with and likelihood of spreading different types of false and counteracting tweets are measured.
7	NZ	Sutton, Jeannette	Johnston, David	When Online is Off: Communicating in Disaster Following the February 22, 2011 Christchurch, NZ Earthquake	The February 22, 2011 earthquake in Christchurch New Zealand, an aftershock of a larger earthquake in September 2010, caused significant infrastructure and economic damage, and life loss, to a modern city with similar population characteristics as US metropolitan communities. In the days and weeks following the earthquake, various risk communication strategies were utilized to reach individuals affected by the ongoing aftershocks, including online networked communications. By collecting data on access to and use of online information in this critical period following the earthquake, this project will advance knowledge about information and communication capacities as they affect coping and resiliency in the aftermath of disaster. Specifically, the project examines the effects of reliance on online communications on individual coping ability and community recovery, and on the role of networked online communication among those directly affected by disaster. These questions will be examined through a series of focus groups and a household survey in the disaster-affected area.

IT 2 (Visualization, Robots, and Remote Assessment)					
#	Rapid Grant for:	Principal Investigator(s)	Collaborator(s)	RAPID**	Summary
1	Japan & NZ	Caverlee, James; Mander, John		Earthquake Damage Assessment from Social Media	With RAPID funding, this project will link images posted during the emergency to actual damage assessments made in Christchurch for validating the quality of images. First, a sample of several thousand social media images from New Zealand will be assessed by domain experts and specifically structural earthquake engineers. The results of this project will have broad impacts, particularly in the development and deployment of a new rapid assessment tool for earthquake damage assessment based on social media. An additional broader impact is the ancillary development of training modules for increasing the effectiveness and image quality of future socially-generated image capture, which would greatly improve social computing for disasters. The methods and data generated by this project will be archived and made available for future studies.
2	Japan	Eguchi, Ronald; Lin, Albert; Bevington, John	Goltz, James D.	The Role of Urban Development Patterns in Mitigating the Effects of Tsunami Run-up	This Grant for Rapid Response Research (RAPID) project seeks to understand the relationship between urban development patterns and the extent of physical damage caused by widespread tsunami run up. The 11 March 2011 Tohoku, Japan earthquake caused significant damage all along the northeastern coast of Japan. In order to understand how the built environment can affect the performance of communities in a tsunami, the project will study at least nine communities in the Miyagi/Chiba/Ibaraki Prefectures "C areas ranging from minor to moderate damage to complete devastation. The central research question is: Can the urban topology of a community mitigate the effects of a tsunami by isolating the more damaging surge effects to a few well designed and well placed buildings, thus limiting damage to protected buildings to just rising water effects. The main objectives of this study are: 1) to perform field studies to collect perishable data on coastal community performance following the Tohoku earthquake, 2) to develop an understanding of the data landscape in post-earthquake Japan, and 3) to develop a preliminary understanding of the role that urban development patterns played in either mitigating or exacerbating tsunami induced impacts.
	J-RAPID	Koshimura, Shunichi	Yamazaki, Fumio; Matsuoka, Masashi	The Role of Urban Development Patterns in Mitigating the Effects of Tsunami Run-up	This joint research aims to establish a method for quantitative evaluation of tsunami impact on urban structures through the detailed damage mapping on The Great Eastern Japan Earthquake/tsunami and tsunami numerical simulation. In the project, the Japanese team will work on the development of the detailed geo-spatial model and the tsunami propagation and inundation simulation for selected tsunami-affected areas in Japan. On the other hand, the American team will perform visual damage inspection and automated damage extraction of the tsunami damages from the Tohoku earthquake using various remote sensing data, and will compare the results with field observation data to validate the accuracy of the image analyses. This mutually complementary joint research is expected to lead a guideline for proper city-block structure and its buildings' layout against future tsunamis in Japan and the United States, and for reconstruction planning from The Great Eastern Japan Earthquake.

3	Japan	Haley, Mark; Furukawa, Tomonari	Nonami, Kenzo	Robots Designed to Assist During Nuclear Catastrophes - Autonomously Creating 3-D Maps, Collecting Radiation/Other Data at Japan's Fukushima Nuclear Plants	The project advances the state-of-the-art of autonomous Simultaneous Localization and Mapping (SLAM) algorithms, and maximizes the ability to explore under extreme conditions with minimal time using real-time 3D methods in nuclear power plants. The integrated system consists of a hardware system with three LIDAR's, a CPU, a GPU, a battery and a wireless unit.
4	Japan	Kumar, Vijay; Nathan, Michael		Aerial Robots for Remote Autonomous Exploration and Mapping	This RAPID project, developing and deploying a team of autonomous aerial robots that can enter an unstructured, hazardous environment to explore and map a facility, provides information to human operators in safe, remote locations. The work brings together research groups with complementary expertise in robotics to address the challenging problem of acquiring imagery and three-dimensional maps for post-disaster assessment. Autonomous robots will be deployed without a direct communication link enabling access to areas in the Fukushima that are currently inaccessible.
	J-RAPID	Yoshida, Kazuya	Nagatani, Keiji; Tadokoro, Satoshi; Ohno, Kazunori	Aerial Robots for Rapid Response: Remote Autonomous Exploration and Mapping	The goal of the proposed research is to develop the technology necessary to enable extensive exploration of damaged or destroyed buildings by combining ground-based and aerial-flying robots. While ground-based robots cannot traverse steep steps or walls, aerial robots which are more suited to such tasks, have a very short operation time. These problems are investigated in this research by combining the Japanese group's ground-based robot, which can carry a micro aerial vehicle into a building and act as a battery-recharge and communication-relay station, and an American group's micro aerial vehicle capable of short range autonomous exploration.
5	Japan	Andrews, Anneliese; Mahoor, Mohammad		CRAWLER Robot with Dual-Use Limbed Locomotion and Manipulation for Void Inspection	This RAPID project, developing and fabricating a custom robotic tool based on the ongoing work in the CRAWLER robot with reconfigurable attachments, aims to deploy the tool in the areas affected by the 2011 tsunami and nuclear disaster in Fukushima, Japan. The robot, to be donated to International Rescue System Institute at Tohoku University in Sendai, will be based on the recent improvements that would make CRAWLER more resistant to water and more cleanable and maintainable. The system expands on the present robotic systems developed by the team to enable the use of multi-camera, orthogonal vision system for emergency responders that would be attached to the robot for enhanced situational awareness
	J-RAPID	Tadokoro, Satoshi		CRAWLER Robot with Dual-Use Limbed Locomotion and Manipulation for Void Inspection	This research focuses on experiments of a small-size surveillance robot 'CRAWLER' developed by the US team and a serpentine robot 'Active Scope Camera' developed by the Japanese team at simulated/real disaster sites in order to gather data that cannot be obtained out of devastated area. Their evaluation for search and rescue at earthquake disasters will reveal important issues to be improved and researched as well as the problems for real use. The Japanese group will mainly perform testing and evaluation of the Active Scope Camera, and the US team will make experiments of the CRAWLER. The important issues will be discussed together. It is expected that the complementary efforts of the both research teams will result in comprehensive achievement beyond single attempts.

6	Japan	Murphy, Robin	Steimle, Eric; Rodocker, Jeese; Dreger, Karen; Smith, Richard; Slaughter, Brian	Sendai Earthquake and Tsunami-Remote Assessment Using Land, Sea and Aerial Unmanned Systems	This RAPID project proposal, consisting of participatory research with land, sea, and aerial unmanned systems for remote assessment and situation awareness for critical life saving and recovery operations in the aftermath of the Sendai earthquake and tsunami, will capture and analyze valuable data on the effectiveness of various robots for recovery and inspection as well as user interface paradigms.
	J-RAPID	Matsuno, Fumitoshi	Kimura, Tetsuya; Makabe, Kenichi; Takokoro, Satoshi; Hiro, Nobutoshi; Hasumi, Yudai	Recovery Activities Using Underwater Robots in Tsunami-devastated Areas	A joint team of Prof. Matsuno and Prof. Murphy will inspect some ports in Minami-Sanriku, Miyagi to collect exact location and image data of underwater debris especially sunk cars and ships at ports by using GPS (Global Positioning System), sonar sensors and cameras. They are an obstacle for sailing ships; they should be removed as soon as possible. And if sunk cars and ship have gas, it is very serious problem for fisheries. They are an obstacle to renew fish nets to breed sermon or other hatchery fishes and to catch sardine for food of big fishes.
7	Japan	Tsugawa, Mauricio; Fortes, Jose; Figueiredo, Renato		IT Virtualization for Disaster Mitigation and Recovery	This RAPID project, aiding the process of recovering Information Technology (IT) infrastructure damaged by catastrophic events, conducts research on the use of virtualization technologies to provide such aid. The work includes IT infrastructure needed to recover damages to non-IT infrastructures and human beings. Machine virtualization offers key mechanisms to move applications from one location (e.g., a data center) potentially affected by a disaster to another safe location.
	J-RAPID	Hirofuchi, Takahiro	Nakada, Hidemoto; Takano, Ryousei	IT Virtualization for Disaster Mitigation and Recovery	This research collaboration aims to analyze the damages of IT infrastructure caused by The Great East Japan Earthquake and discuss the designs of reliable IT infrastructure. The research group in Japan surveys the damages of data centers faced with the earthquake and discusses requirements for reliable IT infrastructure. Both the research groups in Japan and US study reliable IT infrastructure that is sustainable under serious disasters like the earthquake.

OCEANOGRAPHY

#	Rapid Grant for:	Principal Investigator(s)	Collaborator(s)	RAPID**	Summary
1	Japan	Baker, Victor; Pelletier, Jon	Mcguire, Luke	Flow Dynamics/Morphological Impacts of March 11 Tohoku Tsunami, Japan	The unusual, very high-energy conditions achieved by the March 11, 2011, Tohoku Tsunami afford a unique opportunity to greatly advance our understanding of the geological effects of tsunamis in coastal areas. While much of the immediate post-tsunami research is focused on damage assessment, this particular project aims to understand the dynamics of tsunami waves and their impacts on natural landscapes. Prompt access to the field areas is crucial for this effort in order to obtain evidence of the tsunami wave effects. Current disaster response reconstruction efforts are quickly erasing the traces of the event in developed areas. Natural, undeveloped areas of interest in this project will also quickly lose evidence of high-water indicators and subtle sediment layers because of rainstorms, human disturbance, and other post-tsunami processes. This project will integrate numerical modeling with field measurements and remote sensing.
	J-RAPID	Oguchi, Takashi	Hayakawa, Yuichi S.; Saito, Hitoshi; Kobayashi, Akitoshi	Flow Dynamics/Morphological Impacts of The 2011 off the Pacific coast of Tohoku Earthquake Tsunami, Japan	This research investigates topographic changes along the Sanriku Coast due to the tsunami of The 2011 off the Pacific coast of Tohoku Earthquake and applies mathematical models to simulate the changes. The main purpose of this research is to understand the mechanism of topographic changes by large-scale water flow.
2	Japan	Fritz, Hermann; Yeh, Harry; Synolakis, Costas	Phillips, David. A	Reconnaissance of the 11 March 2011 Tohoku, Japan Tsunami	The 11 March 2011 magnitude 9.0 earthquake off Tohoku in Japan triggered a transpacific tsunami that had basin-wide impact of varying severity. Both the earthquake and tsunami magnitudes are unprecedented in Japan's long historical records of over 1,000 years. This award supports a reconnaissance survey team to investigate the effects of this tsunami along coastlines in Japan, the Pacific Islands, and the western United States. The 2011 event in Japan presents a unique research opportunity since there are now three historic tsunamis with significant impact on the same Sanriku coastline, which may allow differentiating between tectonic and potentially superimposed landslide tsunami sources. The primary project deliverable will be a comprehensive multi-scale, geo-referenced database of tsunami damage and flood zone characteristics combined with numerical model results.
	J-RAPID	Sato, Shinji	Liu, Tajima H.; Takagawa, T.; Okayasu, A.; Shimozone, T.	Tsunami Reconnaissance of The 2011 off the Pacific coast of Tohoku Earthquake in Japan and Pacific Islands	Effective countermeasures against tsunami will be investigated on the basis of the survey of the performance of seawalls and tsunami breakwaters as well as the numerical simulation of the nearshore behavior of the 2011 Tohoku Tsunami. After a comprehensive reconnaissance survey made by all the members from US and Japan sides, the Japan side mainly focuses on the survey of tsunami inundation heights and topography change due to the tsunami. The data will be characterized on the basis of types of coastal topography, that is, ria coast group in Iwate Prefecture, flat plain group in Ishinomaki district and concave sandy beach group in Sendai district. On the other hand, the US team estimates the destructive force of the tsunami on the basis of the video clip analysis combined with the numerical simulation of the tsunami flooding. High resolution simulation will be conducted both spatially and temporally in order to discuss the coastal trapping of tsunami energy and partial destruction of seawalls. The main target of the simulation will be Otsuchi and Rikuzen-Takata in Iwate Prefecture, where preliminary survey had been conducted by members of this project.

3	Japan	Beardsley, Robert	Lin, Jian; Ji, Rubao	Collaborative Research: The Japan March 11 Earthquake, Tsunami Inundation, and Initial Spread of Fukushima Dai-ichi Radionuclides into the Pacific Ocean: Model Assessment	This project is a comprehensive interdisciplinary study of the March 11 initial M=9 and M=7.9 earthquakes, the resulting tsunami wave generation, propagation and coastal inundation along northern Honshu Island, and the initial pathways and changes in Cs-237 concentrations as it enters the coastal waters at the Fukushima Daiichi nuclear facility and spreads across the shelf to deeper water.
4	Japan	Chen, Changsheng	Lai, Zhigang; Lin, Huichan	Collaborative Research: The Japan March 11 Earthquake, Tsunami Inundation, and Initial Spread of Fukushima Dai-ichi Radionuclides into the Pacific Ocean: Model Assessment	This project is a comprehensive interdisciplinary study of the March 11 initial M=9 and M=7.9 earthquakes, the resulting tsunami wave generation, propagation and coastal inundation along northern Honshu Island, and the initial pathways and changes in Cs-237 concentrations as it enters the coastal waters at the Fukushima Daiichi nuclear facility and spreads across the shelf to deeper water.
	J-RAPID	Sasaki, Jun		The Great Eastern Japan Earthquake, Tsunami Inundation, and Initial Spread of Fukushima Dai-ichi Radionuclides into the Pacific Ocean: Model Assessment	The objectives of the research are to develop a new prediction system using an unstructured finite volume coastal ocean model FVCOM, to assess urgently the effects of The 2011 off the Pacific coast of Tohoku Earthquake tsunami and radionuclides from Fukushima Daiichi Nuclear Power Plant, and to establish a practical tool useful for reducing future tsunami and nuclear power plant associated disasters.
5	Japan	Cormier, Marie-Helene	Seebar, Leonardo; McHugh, Cecilia; Fujiwara, Toshiya; Hirata, Kenji	Collaborative Research - Offshore impacts of the Tohoku-Oki earthquake: Seafloor deformation, sedimentation, erosion, tsunamigenesis	Great megathrust earthquakes and the tsunamis they generate are among the greatest threats to populated coastlines worldwide, such as Chile, Sumatra, Alaska, and Cascadia (the regions extending from southern British Columbia into northern California). The risk of catastrophic consequences and the acute need for improved understanding of these events are underscored by the devastation caused by the 11 March 2011 Tohoku-Oki earthquake off northern Japan. While the destruction from these events is acute, they also offer important opportunities to gain new insights into the processes that spawn them. In the wake of the earthquake in Japan, the proponents of this project have been invited to collaborate with Japanese scientists at JAMSTEC (Japan Agency for Marine Earth-science and Technology) to investigate and document the effects of the earthquake offshore.

6	Japan	German, Chris	Manganini, S.; Buesseler, K.	Time Series Sampling for Radionuclide and Biogeochemical Fluxes at F1 Time-series Station, Offshore Fukushima Dai-ichi Nuclear Power Facility	With funding through this Grant for Rapid Response Research (RAPID), a research team at the Woods Hole Oceanographic Institution will participate in a JAMSTEC-led cruise in June-July 2011, and deploy a time-series sediment trap mooring at a station 80km off the coast of Japan. The specific goal will be to collect settling particulate radionuclide matter over the coming weeks and months through to an already-scheduled cruise to recover the moorings in May, 2012. By deploying traps at 500m and 1000m, the team will intercept particle-attached radionuclide settling out of the upper ocean and assess their fluxes into the deep ocean interior. They will collect fresh samples approximately every 2 weeks at each depth throughout the sampling period to complement snap-shot sampling that will be conducted aboard the JAMSTEC cruise at the start and end of the deployment period.
	J-RAPID	Honda, Makio	Kawakami, H.; Kitamura, M.	Research of Transportation of Artificial Radioactive Nuclides by Sinking Particles in the Ocean	Purpose of this cooperative research between Japan Agency for Marine-Earth Science and Technology (JAMSTEC, Japan) and Woods Hole Oceanographic Institution (WHOI, USA) is to verify the mechanism of transportation and circulation of artificial radioactive nuclides (ARN) emitted by the Fukushima Daiichi nuclear power plant accident occurred in March 2011 in the ocean.
7	Japan	Gonzalez-McHugh, Cecilia; Seebur, Leonardo		Collaborative Research - Offshore impacts of the Tohoku-Oki earthquake on seafloor deformation, sedimentation, erosion, tsunamigenesis	Great megathrust earthquakes and the tsunamis they generate are among the greatest threats to populated coastlines worldwide, such as Chile, Sumatra, Alaska, and Cascadia (the regions extending from southern British Columbia into northern California). The risk of catastrophic consequences and the acute need for improved understanding of these events are underscored by the devastation caused by the 11 March 2011 Tohoku-Oki earthquake off northern Japan. While the destruction from these events is acute, they also offer important opportunities to gain new insights into the processes that spawn them. In the wake of the earthquake in Japan, the proponents of this project have been invited to collaborate with Japanese scientists at JAMSTEC (Japan Agency for Marine Earth-science and Technology) to investigate and document the effects of the earthquake offshore.
8	Japan	Moore, Gregory	Barnes, J.; Boston, B.	RAPID Response to Tohoku Earthquake: Participation in Marine Geophysical Surveys of the Quake Rupture Zone	We propose to participate in one or two marine geophysical surveys covering the rupture zone of the March 2011 great earthquake off Tohoku, Honshu, Japan during summer, 2011. In response to this great earthquake, the Institute For Research on Earth Evolution (IFREE) of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has undertaken a program of marine geophysical surveys to try to detect seafloor and subsurface structures associated with the quake's rupture.
	J-RAPID	Kodaira, Shuichi	Fujiwara, T.; No, T.; Nakamura, Y.; Kaiho, Y.; Fujie, G.; Takahashi, N.; Kaneda, Y.	Response to The 2011 off the Pacific coast of Tohoku Earthquake: Participation in Marine Geophysical Surveys of the Quake Rupture Zone	An extremely large slip (more than 30m) along a fault of The 2011 off the Pacific coast of Tohoku Earthquake was estimated. This slip is believed to be caused of the large tsunami. However, seafloor and sub-seafloor deformation which generated the tsunami are still unknown. In this study, we propose data processing and analysis of seafloor and sub-seafloor survey made by Jamstec in a quick way under collaboration between Jamstec and Univ. of Hawaii. In addition, results from this study will provide fundamental data for a future scientific drilling planned in the fault zone of the earthquake.

SOCIAL SCIENCE

#	Rapid Grant for:	Principal Investigator(s)	Collaborator(s)	RAPID**	Summary
1	Japan	Davidson, Rachel	Scawthorn, Charles; Waseda, U.; Sekizawa, A.; Hamada, M.;	Post-Earthquake Fires in the March 2011 Japan Earthquake and Tsunami	This Grant for Rapid Response Research (RAPID) award provides funds to study the fire-related aspects of the March 2011 Japan earthquake with the aims to improve understanding of where, when, and how fires ignite; how fires spread through a neighborhood; and how they ignite and are suppressed in industrial facilities. The Tōhoku earthquake and tsunami caused 345 fires more recorded fires than any other earthquake in history. By comparison, there were about 110 recorded in Kobe (1995), 110 in Northridge (1994), 128 in San Fernando (1971), and 36 in Loma Prieta (1989). This project will involve three main steps: (1) collecting data on the fire-related aspects of the event through site visits, interviews with key informants, and secondary data sources; (2) compiling the data into easily usable, comprehensive databases that includes all data on each fire and relevant auxiliary data in a consistent format; and (3) analyzing the data through descriptive statistics, fitting generalized linear statistical models to the ignition data, and comparing observations of spread to that estimated by a new physics-based urban fire spread model.
2	Japan	Holguin-Veras, Jose		Field Investigation on Post-Disaster Humanitarian Logistic Practices under Cascading Disasters and a Persistent Threat: The Tohoku Earthquake Disasters	The Tohoku disaster(s) is an event almost without parallels in disaster history. Four specific features make it a very unique disaster: severity and pervasiveness of the trigger and cascading disasters, geographic coverage, and persistence over time of the nuclear threat. As a result of these factors the disaster and its response offer important lessons of benefit to future relief operations.
	J-RAPID	Taniguchi, Eiichi		Field Investigation on Humanitarian Logistic Practices under Cascading Disasters and a Persistent Threat: The Great Eastern Japan Earthquake	We will perform interview surveys with the collaboration of US researchers on relief distribution of emergency goods to displaced people (about 440,000 at peak) who have been impacted by The Great Eastern Japan Earthquake including the earthquake, tsunami and nuclear power plant accident. For improving the humanitarian logistics planning in response to future disasters we will collect real data on the relief distribution to refuge centre and perform interviews to those who have been involved in the relief distribution. The purpose of this study is to present recommendations for improving humanitarian logistics based on analysing the success and failure of relief distribution and their causes.
3	Japan & NZ	Lindell, Michael; Prater, Carla	Johnston, David; Becker, Julia; Shiroshita, Hideyuki	Immediate Behavioral Response to Earthquakes in New Zealand and Japan	The proposed project will send questionnaires to 1200 residents in areas stricken by the Christchurch and Tohoku earthquakes. Using our standard mail survey procedures, we expect to get a response rate in the range of 30-50%. This project will extend the American investigators' recent research on the earthquake and tsunami in American Samoa by documenting people's behavioral response during the earthquake shaking and all of the actions they took during the next half hour after the shaking stopped.

4	Japan	McCay, Bonnie; Takahashi, Satsuki		Disasters, Resilience, and Vulnerability of Fishing Communities in Post-Tsunami Japan	The focus of the research will be on how combined natural and human disasters affect community responses. Previous research on the relationships between disasters, vulnerability, and resilience have led in different directions, depending on whether the disasters are understood as caused by human or natural agency. In these accounts, natural disasters encourage communities to work together to develop better systems in the future, while human-made problems, such as air and water pollution, disproportionately affect vulnerable communities and limit their ability to rebuild. Building upon and contributing to social scientific theories on resilience, vulnerability, and nature-culture relationships, this project will investigate the cultural and political outcomes of dual (natural and human-caused) disasters.
5	Japan	Ikegami, Eiko	Shoji, Masahiko; Toyofuku, Shimei; Peake, Adam	Social Networking Services in the Crisis and Immediate Post-Catastrophe Response Processes	This study will analyze the impact of, and draw lessons from, the use of advanced ICTs in the immediate aftermath of the earthquake. We pay particular attention to social networking sites, a type of technology /service that enable users to share information and form communities. This study aims to produce policy recommendations on urgent policies and actions to prepare for future disasters in Japan and other countries.
	J-RAPID	Watanabe, Tomoaki	Shoji, Masahiko; Toyofuku, Shimei; Peake, Adam	Social Networking Services in the Crisis and Immediate Post-Catastrophe Response Processes	This study will analyze the impact of, and draw lessons from, the use of advanced ICTs in the immediate aftermath of the earthquake. We pay particular attention to social networking sites, a type of technology /service that enable users to share information and form communities. This study aims to produce policy recommendations on urgent policies and actions to prepare for future disasters in Japan and other countries.
6	NZ	Berger, Jay		EERI Learning From Earthquakes Program: Targeted Research Questions Emerging from the February 22, 2011 Christchurch Earthquake	This Grant for Rapid Response Research (RAPID) award provides funding to send a small team of researchers to address several focused questions arising from the magnitude 6.3 earthquake which struck Christchurch, New Zealand, at 12:51 p.m. local time on February 22, 2011. This earthquake was an aftershock of the magnitude 7.1 September 3, 2010 (UTC) earthquake, but because of the time of day, the shallow depth of the earthquake and its closer proximity to the city the infrastructure damage, economic impacts and casualties are much greater than from the main shock of September 4, 2010. It is rare for a modern infrastructure inventory to be shaken by two strong and damaging earthquakes -- a major event followed by another at the same place within a six-month period. It is essential to explore this pair of events so that the research aspects of this rare concurrence will not be overlooked. The team will be tasked with addressing specific questions, and keeping an eye open to research opportunities not yet recognized, so that it can report back to the US research community in a timely fashion, thereby facilitating subsequent research as may be proposed by the US research community.

7	Japan	Berger, Jay		<p>EERI Learning from Earthquakes Program - Performance and Resilience Data from the March 2011 Tohoku, Japan Earthquake on Bridges, Buildings, and Government and Community Response</p>	<p>This Rapid Response Research (RAPID) award builds on the Earthquake Engineering Research Institute's (EERI) long-term relationships with Japanese researchers and practicing engineers to organize the rapid collection of perishable data and early field reconnaissance from this 2011 event as a fully collaborative effort. Researchers supported on this award will team directly with respective Japanese colleagues to undertake field investigations followed by jointly authored reports. The primary collaborating organizations are the Architectural Institute of Japan, the Disaster Prevention Research Institute at Kyoto University, and the Japan Association for Earthquake Engineering. Three research themes have been identified for the rapid collection of perishable data: transportation systems, particularly bridges; engineered buildings, including the large inventory of retrofitted structures and use of modern technologies such as base isolation; and government and community response, in the areas of emergency response, social capital, institutional frameworks, and rebuilding, for a disaster of this extraordinary scale and complexity.</p>
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STRUCTURES 1 (New Zealand)					
#	Rapid Grant for:	Principal Investigator(s)	Collaborator(s)	RAPID**	Summary
1	NZ	Gavin, Henri	Nigbor, Bob; Lawson, Wayne; MacRae, Greg; Chase, Geoff; Rodgers, Geoff; Gutschmidt, Stefanie	Performance of the Base-Isolated Christchurch Women's Hospital during the Sequence of Strong Earthquakes and Aftershocks in New Zealand from September 2010 through 2011	The objective of this Rapid Research Response (RAPID) award is to collect perishable data on the seismic response of the base-isolated Christchurch Women's Hospital during the sequence of strong earthquakes and aftershocks in Canterbury, New Zealand from September 2010 through 2011. The relatively high probability of additional strong aftershocks in 2011 presents a unique opportunity to capture high-fidelity data on the performance of a modern seismically-isolated structure.
2	NZ	Kanvinde, Amit	Allington, Chris; Lawson, Wayne	Forensic Analysis of Eccentrically Braced Frame Fracture during the February 2011 Christchurch, New Zealand Earthquake	The principal research objective of this Rapid Response Research (RAPID) award is to identify and understand the conditions that could cause an earthquake-induced fracture in eccentrically braced frame (EBF) steel buildings. For this purpose, multi-scale forensic analysis of the first earthquake failure worldwide of an EBF structure will be conducted.
3	NZ	Leon, Roberto	Ingham, J.; Moon, L.; Schultz, A.; Biggs, D.	Collection of Data on the Performance of Wood Diaphragms in Buildings during the February 2011 Christchurch, New Zealand Earthquake	This Rapid Response Research (RAPID) award will collect data to document the performance of unreinforced masonry (URM) construction during the February 2011 Christchurch, New Zealand earthquake. Specifically, this award will document the ability of originally constructed and retrofitted floor and roof diaphragms to efficiently distribute loads to all walls and other lateral-load resisting elements. NZ URM construction from 1880 to about 1970 typically used timber joists, rafters, and trusses, very similar to U.S. construction from the same era. The project will catalog seismic performance at both the qualitative and quantitative levels. At the qualitative level, the project will identify weak or poor detailing typical in URMs and effective mitigating technologies. At the quantitative level, the project will develop guidelines for the type and detailing of retrofit measures to be used in strengthening projects in the United States.

4	NZ	Restrepo, Jose; Fleischman, Robert	Schoettler, Matthew; Nigbor, Robert; Deutsch, David; Pampanin, Stefano; Tasligedik, Sahin; Akгуzel, Umut; Gallo, Patricio Quintana; Marshall, John; Clarke, Hannah	Mapping of Damage in Precast Concrete Buildings from the February 2011 Christchurch, New Zealand Earthquake	The objective of this Rapid Research Response (RAPID) award is to gather perishable data on the damage to two precast concrete buildings during the February 2011 magnitude 6.3 Christchurch, New Zealand, earthquake. Project team members will travel to Christchurch and catalog earthquake damage (foundation, structural and non-structural) through visual observation. The post-earthquake structural state will be determined by means of collecting ambient vibration and potential aftershock dynamic response. This data will be post-processed for a first-level system identification and characterization of the damaged buildings.
5	NZ	Schultz, Arturo		Data Collection on the Performance of Adhesive Anchor Retrofits in Unreinforced Masonry Buildings during the February 2011 Christchurch, New Zealand Earthquake	The objective of this Rapid Response Research (RAPID) award is to collect perishable data from the February 2011 Christchurch, New Zealand earthquake on the performance of unreinforced masonry (URM) structures that had been retrofitted with adhesive anchors. Such anchors are used to connect floor or roof diaphragms to masonry walls or parapets. Wall-to-diaphragm connection retrofit using these anchors is the most common seismic rehabilitation technique used in both the U.S. and New Zealand. The URM building stocks in the United States and New Zealand, including both unretrofitted and retrofitted buildings, share many similarities. Perishable data will be collected from as many of the 59 retrofitted URM buildings in the Christchurch area, as well as from comparable unretrofitted buildings, as is possible during the 28-day duration of the field work.
6	NZ	Venayagamoorthy, Ganesh	Watson, Neville	Impact of Earthquakes on the Electricity Infrastructure	The objective of this research is to investigate the effects of a series of earthquakes in the South Island of New Zealand (Christchurch) on the electricity infrastructure. Furthermore, this research study will make projections on what the impacts would look like if smart-grid technologies were integrated into the existing power network.

STRUCTURES 2 (incl tsunami data collection)					
#	Rapid Grant for:	Principal Investigator(s)	Collaborator(s)	RAPID**	Summary
1	Japan	Naito, Clay	Cox, Dan; Yu, Kent; Riggs, Ron; Kobayashi, Marcelo; Tsujio, Daiki; Mizutani, Norimi	Impact of Debris Generated from the 11 March 2011 Tohoku, Japan Tsunami	Estimation method of tsunami impact to structures is investigated in this joint research project. Japanese team conducts numerical simulation of tsunami wave force acting on building and impact force due to debris, which leads to design method of tsunami evacuation buildings. US team will conduct experimental investigations using full scale collision test and large scale model experiments of behavior of drifting shipping container and its impact on buildings.
2	Japan	Olsen, Michael; Yim, Solomon	Kikitsu, Hitomitsu	Post-Disaster Structural Data Collection Following the 11 March 2011 Tohoku, Japan Tsunami	Careful documentation of flow depth and structural response resulting from this tsunami will provide data that can be used to validate tsunami inundation models and corresponding methodologies for calculating structural response due to the inundation. The primary objective of this Rapid Response Research (RAPID) award is to collect time sensitive impact data in Japan from this March 2011 tsunami that will soon be lost, as buildings and infrastructure in the affected areas are repaired or demolished. The investigation team includes researchers and students from the University of Hawaii and Oregon State University. This study will focus on collecting detailed, localized data in several of the most severely damaged areas of the coastline in the Miyagi and Iwate Prefectures, rather than a general survey of all of the inundation areas, which has been undertaken by other local and international reconnaissance teams.
3	Japan	Robertson, Ian; Cheung, Kwok Fai	Okuda, Yasuo; Kato, Hiroto; Kabeyasawa, Toshikazu	Post-Disaster Structural Data Collection Following the 11 March 2011 Tohoku, Japan Tsunami	Careful documentation of flow depth and structural response resulting from this tsunami will provide data that can be used to validate tsunami inundation models and corresponding methodologies for calculating structural response due to the inundation. The primary objective of this Rapid Response Research (RAPID) award is to collect time sensitive impact data in Japan from this March 2011 tsunami that will soon be lost, as buildings and infrastructure in the affected areas are repaired or demolished. The investigation team includes researchers and students from the University of Hawaii and Oregon State University. This study will focus on collecting detailed, localized data in several of the most severely damaged areas of the coastline in the Miyagi and Iwate Prefectures, rather than a general survey of all of the inundation areas, which has been undertaken by other local and international reconnaissance teams.
4	RAPID	Buckle, Ian	Frost, David; Yen, Wen-huei; Marsh, Lee; Dashti, Shideh	Evaluation of the Seismic Performance of Bridges during The Great Eastern Japan Earthquake	This joint research aims of investigating damage and damage mechanism of bridges which are key structures of road and railways. An emphasis is provided to investigate 1) effectiveness of recent design practice implemented since 1990.
	J-RAPID	Kawashima, Kazuhiko	Unjoh, Shigeki; Hoshikuma, Jun-ichi	Evaluation of the Seismic Performance of Bridges during The Great Eastern Japan Earthquake	This joint research aims of investigating damage and damage mechanism of bridges which are key structures of road and railways. An emphasis is provided to investigate 1) effectiveness of recent design practice implemented since 1990.

5	Japan	Lee, George; Song, Jianwei	Zhou, Yihui	Investigation of Cascading Effects of the 2011 Japan Earthquake to Structural Damages of Bridges	This Rapid Response Research (RAPID) award provides funding to carry out an exploratory study focused on modeling of structural damages of selected bridges subjected to long duration, high intensity earthquakes (including both mainshock alone and mainshock plus aftershocks), and strong earthquake followed by tsunami wave force by using actual input data of the March 11, 2011 Japan earthquake off the Pacific coast of Tohoku. The PIs will work with their Japanese research partners who are collecting ground motion and tsunami wave force records as well as other useful perishable information; and will identify instrumented and damaged bridges that are suitable for preliminary investigations on the correlations between structural damages and long duration earthquake load effects as well those due to cascading hazard effects.
6	Japan	Mahin, Stephen		Workshops to Facilitate Engineering Research Related to 2011 Tohoku-Kanto Earthquake and Tsunami	The Tohoku-Kanto earthquake of March 9, 2011 and the tsunami that followed it, though unfortunately devastating, are very unique events of unparalleled scientific and engineering interest. This earthquake has caused extensive damage to the built environment, yet there are examples of structures that have survived the strong shaking. Apparently, Japanese researchers have already collected some information about the damaged and undamaged structures and are willing to share this information with their US counterparts. Much can be learnt from further in-depth analysis of this information to understand the causes of failures and survivals of these structures with the objective of preventing this from happening in future events. This project will support the travel to Japan of a team of researchers to enable them to meet with Japanese engineers and researchers to gather data and information about the damage caused by this earthquake and tsunami that can be shared with US researchers. The team will hold workshops and meetings with Japanese researchers to gather information about what data of research interest is available, and disseminate this information to the wider research community in the US through webcast seminars, Webex-type workshops, and meetings.
7	Japan	Nelson, Tracy	Kokawa, H.; Sato, Y.	RAPID/IUCRC: An International University Collaborative Research Program between the Center for Friction Stir Processing (an NSF I/UCRC) and Tohoku University	This RAPID project, enabling graduate students from the Kokawa Laboratory from Tohoku University in Japan to go to Brigham Young University (BYU) to use the facilities and equipment available within the CFSP (Center for Friction Stir Processing, an NSF ENG I/UCRC) to continue performing essential research for short periods of time (2-6 weeks), responds to the disaster in the labs caused by the March 11 earthquake in Japan. Sensitive Optical and electron microscopy equipment were rendered unusable and are currently not on the priority list for immediate repair.

8	Japan	Pujol, Santiago; Sozen, Mete		Investigation on the Performance of Buildings with Structural Walls in the Tohoku, Japan, Earthquake of 2011	The objective of this Rapid Research Response (RAPID) award is to investigate the performance of buildings with structural walls in the Tohoku, Japan, earthquake of 2011. The goals of this investigation are (1) to collect quantitative data on the seismic performance of buildings with dominant structural walls in the Tohoku region, (2) to compare it with similar information obtained in Chile, (3) to identify the causes of successes and failures observed in the two locations, (4) to test the ability of state-of-the-art simulation tools to reproduce what occurred in the field, and (5) to summarize the findings in brief statements and/or algorithms that can be used to design safer structures. Building standards in Chile, Japan, and the US are comparable. Nevertheless, the Maule, Chile, Earthquake of 2010 caused severe structural failures that demonstrated that there are critical missing links in our technology related to earthquake resistance of mid- to high-rise buildings with structural reinforced concrete walls.
	J-RAPID	Maeda, Masaki		Investigation on the Performance of Buildings with Structural Walls in The Great Eastern Japan Earthquake	Severe structural failures caused by the Maule, Chile, Earthquake of 2010 (Mw = 8.8) have demonstrated that there are critical missing links in our technology related to earthquake resistance of mid- to high-rise buildings with structural reinforced concrete walls. In Concepción, Chile, where the peak ground acceleration did not exceed 0.4g, nearly 7% of the buildings with structural concrete walls and more than 10 stories were evacuated and scheduled for demolition. In contrast, the intensity of the ground motion caused by The Great Eastern Japan Earthquake was larger (with peak ground accelerations exceeding 2g) but the frequency of building damage was lower. The goal of this investigation is to collect perishable, quantitative field information on the seismic performance of buildings with dominant structural walls in the Tohoku region and compare it with similar information obtained in Chile.
9	Japan	Wallace, John	Ghannoum, W.; Moehle, J.; Sause, R.	US-Japan Collaborative Study on Seismic Damage of Buildings and their Mechanism	This research aims at collecting and recording the data of structural damage of engineered buildings and investigating the factor which caused each structural damage. The investigation is carried out jointly by researchers of the US and Japan. The Japanese researchers collect information on location, damage intensity and design documents of damaged buildings and provide them for the US researchers. The US researchers visit the affected area in Japan to confirm the information. The researchers of both countries organize and analyze the information and the results will be published as journal papers on SPECTRA; a journal of EERI. As a result the information will be disseminated in English to the engineering society in the world. The efforts should be dedicated to reduce the damage of the buildings in Japan and the US as well as the countries vulnerable to seismic disaster with high seismic activity.
	J-RAPID	Shiohara, Hitoshi	Nagae, T.; Tahara, T.; Matsumori, T.; Maeda, M.; Midorikawa, M.	US-Japan Collaborative Study on Seismic Damage of Buildings and their Mechanism	This research aims at collecting and recording the data of structural damage of engineered buildings and investigating the factor which caused each structural damage. The investigation is carried out jointly by researchers of the US and Japan. The Japanese researchers collect information on location, damage intensity and design documents of damaged buildings and provide them for the US researchers. The US researchers visit the affected area in Japan to confirm the information. The researchers of both countries organize and analyze the information and the results will be published as journal papers on SPECTRA; a journal of EERI. As a result the information will be disseminated in English to the engineering society in the world. The efforts should be dedicated to reduce the damage of the buildings in Japan and the US as well as the countries vulnerable to seismic disaster with high seismic activity.