Background

Extreme Event Decision Making Workshop

Convene: 8 am, April 29. 2001
Adjourn: noon, April 30, 2001

The purpose of this workshop is to develop a) recommendations for research topics in extreme event decision making that are suitable for funding by the Program on Decision Risk and Management Science (DRMS), and b) a research strategy for extreme events decision research. As further background, the original proposal for this workshop and the description of the NSF effort on Extreme Events have been placed at the end of this document.

The following topics will be discussed:

1. **What are the properties of extreme events and what are the implications of those properties for decision making? In this discussion, specific examples of extreme events will be used to both focus and bound the discussion.**
2. **What is the role of decision making in extreme events? The Sarewitz and Pielke (2000, hereafter XE2000, available at www.esig.ucar.edu/extremes/summ.html) report, based on a workshop held in Boulder in June, 2000, gave decision making a central role in coping with extreme events. Can we be more specific about what that role is and how research on judgment and decision making is relevant? Specific examples of decisions that are demanded by extreme events will be used to focus discussion.**
3. **What contextual factors that characterize extreme events are important in decision making? This discussion will be organized to ensure that we pay sufficient attention to the importance of the decision making environment.**
4. **What are the decision making needs in extreme events? Here we need to address what is needed to improve extreme event decision making, and how to achieve that improvement through research and application of research results.**

The product of this workshop will be a report in two parts. The first will address the application of judgment and decision research to extreme events. What do we know now that can be applied now? The second part will discuss extreme event research decision making needs that can be addressed by projects funded through DRMS, either by itself or jointly with other programs.

The brief outline below builds on the XE2000 report and will provide an initial structure for the workshop. During the workshop the outline will be completed and fleshed out. The resulting document will be circulated to participants after the workshop for comment.

1. Properties of extreme events

Properties	**Implications for decision making**
Rapid onset vs. "creeping change"	The decision making implications may be quite different for different events.
Rare	Little opportunity for learning Relevant experience may be lacking May or may not be a factor in evolutionary psychology Rare events may control system evolution (7/28/2000 report)
High consequence	Attention will be focussed on event Decisions matter
High uncertainty	Generally, extreme events are difficult to predict. They often occur with insufficient warning. Some extreme events may be predicted months or years in advance (meteor strike, Y2K) but that may still not provide sufficient time, or motivation for action.
Time pressure	Limited time for analysis Stress producing
Disruptive	Normal activities may cease. Loss of constancy (Hammond). Stress producing
Pose complex, ill-structured problems (XE2000)	This lack of structure may encourage intuitive mode of responding when analytic mode is more appropriate.
Potential to create long-term change (XE2000)	In the aftermath of an extreme event, decision makers may face a new environment. Again, loss of constancy and stress are likely.
Affect large numbers of people and/or large ecosystems	Group decision, leadership, government action, trust, and cooperation/communication among stakeholders are important for implementation of effective decisions.
Under-represented and disenfranchised groups tend to be disproportionately vulnerable.	Equity should be explicitly considered in decision making

2. Examples of extreme events

2.1 Chernobyl

2.2 Hurricane Andrew

2.3 Earthquakes in Turkey

2.4 Other potential examples of extreme events

2.4.1 Zebra mussel

2.4.2 West Nile virus

2.4.3 Climate change

2.4.4 Extreme stock market fluctuations

2.4.5 Computer viruses/ terrorism on the internet

2.4.6 Energy or food shortages

2.4.7 Regional armed conflicts

2.4.8 Infectious disease epidemics

2.4.9 Computer network failures

2.4.10 The collapse of local and regional ecosystems

2.4.11 Algal blooms

3. Role of decision making

3.1 Reduce vulnerability by prediction and mitigation (before)

3.2 Effective response (during)

3.3 Rapid recovery and adaptation (after)

3.4 Examples of decisions (depends on type of event)

4. Contextual influences on decision making

"Decisions may also increase vulnerability. People often make choices that neglect to account for extreme events, such as building houses in a flood plain, a beach, or a fire-prone forest. Politicians, land managers, and other decision makers may get more credit for responding to disasters than preventing them. Companies make decisions that favor short-term profitability over long term safety. Such decisions may be overt or unconscious. Computer networks are permeable to viruses and prone to failure because no one anticipated the kind and scale of use they now support." (XE2000)

5. Decision making needs: What would be needed to improve decision making in extreme events?

5.1 Scale of decision making

The magnitude of extreme events suggests that decision making must be addressed at all levels (government, national, regional, organizational, local, individual), and the interactions among these levels are extremely important

5.2 Information

Accurate and useful information is needed for policy/planning to reduce vulnerability, for risk assessment, for prediction, for response, for recovery, and for adaptation

5.3 Decision support

Decision support is needed for reducing vulnerability to extreme events, for planning responses to extreme event (creating effective choices for decision makers), for making choices during extreme events (e.g., guidelines/algorithms that allow use of analysis under time constraints). See Fort Collins 911 cards for an example of decision aids designed to be used during extreme weather events (www.ci.fort-collins.co.us/c_safety/oem/overview_ndic.htm).

5.4 Expert/scientific judgment

Some extreme events are poorly understood and poorly predicted. Scientists are required to bridge the gap between available research and the needs of decision makers. How best can they do this?

6. Research needs

6.1 Research objectives

6.2 Research strategy

6.3 Research topics

Reference:

Sarewitz, D. and Pielke, R. (2000) Extreme Events: A Framework for Organizing, Integrating and Ensuring the Public Value of Research. Report of a workshop held in Boulder, Colorado, on June 7-9, 2000. (http://www.esig.ucar.edu/extremes/summ.html)

ATTACHMENT: PROPOSAL FOR A FOCUSED WORKSHOP TO EXPLORE DECISION MAKING CONCERNING EXTREME EVENTS

As is stated in the attached extreme events research description, recent developments dramatically improve the potential for multidisciplinary efforts to produce useful integrated assessments of and interventions in extreme events. But our scientific understanding is still far short of allowing us to predict when environmental science will be noticed at all, interpreted as intended, or treated with confidence. And extreme events are characterized by features that are likely to affect information use and decision making, such as rarity, suddenness, and devastating losses.

We propose a focused workshop to explore judgment and decision making concerning extreme events. This workshop will bring together judgment and decision researchers, and a handful of environmental, social, and physical scientists who study extreme events, to examine how to advance our understanding of judgment and decision making related to extreme events. Approximately 20 people will attend the workshop.

Discussion at the workshop will focus on how the theory and methods of judgment and decision research can be advanced to improve our understanding of decision making about predicting, preparing for, and reacting to extreme events. Topics studied in judgment and decision making research that may have particular relevance to extreme event decision making will provide a focus for the workshop. Some examples:

Low-probability, high-consequence events

Learning, expectations, and surprises

Decision aids

Judgment and stress

Perception and communication of risk

ATTACHMENT: NSF DESCRIPTION OF EXTREME EVENTS RESEARCH

Extreme events

- Are nonlinear responses that limit or upset the 'balance' or normal operation of a system.
- Are rare, severe, and rapidly occurring (but the time constant for the process varies for extreme events initiating in different systems: for earthquakes – seconds to minutes; for storms – days to weeks; for stratospheric ozone depletion – years to decades).
- Can originate in the social, built and natural environments.
- Are major drivers of change in anthropogenic, biologic, ecological and earth systems.
- Create effects that cross subsystems and domains and can result in catastrophic losses.
- Do not always constitute hazards to people (e.g., a fire in a national park), but have the potential to do so on a large scale.

Rising numbers of extreme events have captured the attention of international agencies and developed countries worldwide. The built environment is being extended into increasingly fragile natural environments. Constructed facilities are aging, and the level of service and reliability of performance are decreasing. As a society we are developing dependencies on new kinds of infrastructure, which are also fragile and may age even more rapidly than sewers and roads. Our infrastructure (including human services, financial, information) is both increasingly vulnerable and increasingly critical to our society. Social, economic and environmental disparities are growing between groups (both within the U.S. and between developed and developing countries), with some groups becoming ever more vulnerable to extreme events. Growing populations, economic development, and aging infrastructures contribute to society's susceptibility to extreme events.

Why should NSF coordinate extreme events research?

Is there a reason to consider "extreme events" as a focus area for research, to include all directorates in interdisciplinary, multi-investigator research?

Much of the past and present research in which NSF and other funding organizations have invested has a strong disciplinary focus and has produced necessarily simplified system models. This is understandable, and often desirable, because of the tremendous complexity in natural, constructed and human systems.

Recent developments have created an opportunity to go beyond disciplinary research and highly simplified models. These include: 1) better understanding of human contributions to extreme events, 2) higher performance computational capabilities (distributed computing, supercomputers, management of large data bases, visualization), 3) new technologies for monitoring and sensing (information acquisition, diversity of information, wireless and distributed sensors, satellite-based data platforms), 4) widespread interest in predictions and infrastructure investments, and 5) publics and decision makers who are more willing to consider risk-based decision making. Along with these developments comes a dramatically improved potential for multidisciplinary efforts to produce useful integrated assessments of and interventions in extreme events.

The opportunity exists now to create increasingly powerful predictive and integrated models of natural, constructed and human systems. Integrated system models that address the biological, physical, social and economic contributions and effects of extreme events need to be developed and validated. Sensing systems need to be developed with the diversity of sensors necessary to do this. Validated models can be used to develop an understanding of system robustness and flexibility, to develop feedback strategies and real-time response planning, and to develop improvements in sensor deployments for efficiency and sensitivity. Such models can also help clarify how system responses to extreme events depend on the diversity and variability in the system(s) affected. Research on moral hazards of extreme events and on collective and distributed responsibility for extreme events is needed as well. "Most environmental issues are interdisciplinary, and their drivers, indicators and effects propagate across extended spatial and temporal scales. Increased resources are needed for interdisciplinary, long-term, large-scale, problem-based research and monitoring efforts. In addition, special mechanisms may be required to facilitate successful interdisciplinary programs (from NSB report 99-133).

What would be the outcomes of such an effort?

Better understanding of

- complex systems
- reversible vs. irreversible processes or system responses

Better prediction of

- event occurrence
- event impacts/damage/losses

Improved possibilities for

- avoidance
- prevention
- mitigation

Better decision making about

- long term impacts and
- effects of investments in all domains (including equity issues)
- priorities for research and spending

Interdisciplinary topics in extreme events (agencies potentially involved):

(1) Natural disaster reduction (DoC – NIST and NOAA, DHHS – CDC and NIH, DOD, DOI - Forest Service and USGS, DOT, EPA, FEMA, NASA, NSF)

The recent NSB Task Force on the Environment Interim Report, *Environmental Science and Engineering for the 21st Century*, recommends (#12) that NSF seek partnerships to encourage an expanded national portfolio of environmental R&D. It suggests that the NSTC, with PCAST advice, identify research gaps and set priorities for this expansion.

The area of natural disaster reduction provides a good conceptual frame with which to foster this goal, and the Subcommittee on Natural Disaster Reduction (SNDR) of the NSTC is interested in developing a case for an area of special emphasis about this in the FY2002 budget. It believes that it is useful to approach the issue as one fertile for interdisciplinary as well as disciplinary research directed at improving our understanding of the relationships between natural disaster losses and social, built, and natural environments.

Hurricanes, earthquakes, floods, droughts, fires, avalanches and other natural disasters can be mitigated through individual preventive actions, organizational redesign, and policy changes, as well as technological innovations. Prevention, intervention and adaptation are all potentially appropriate approaches to risk reduction from natural disasters, each of which may involve the social, built, or natural environments.

(2) Technological failures (DoC, DHHS, DOD, DOE, DOI, DOT, FEMA, NASA, NSF)

Extreme technological failures range from industrial accidents (e.g., Bhopal); catastrophic failures of transportation, power, or drinking water systems (e.g., Chernobyl, Minneapolis cryptosporidiosis outbreak) and computer viruses (Melissa). Such failures are readily attributed to human error or malice.

Technological failures can be a product of unanticipated or malicious interactions between humans and the technology, or of inherent design defects in the technology itself, or the medium or material in which it is deployed. Even defined narrowly, technological failures have an enormous damage potential. Defined more broadly as short-sited or poor design, technological failures have the potential to affect social structure, impinge on freedom, and incrementally shift fundamental social values as well.

(3) System resilience: sustainable environments (DoC – NIST and NOAA, DOD, DOI - Forest Service and USGS, DOT, EPA, FEMA, NASA, NSF)

Understanding and planning effectively for extreme events and their aftermaths can increase a system’s robustness and resilience. Local “sustainability means that a locale can tolerate – and overcome – damage, diminished productivity and reduced quality of life from an extreme event without significant outside assistance” (Mileti, 1999). This general notion can be extrapolated to social and technological systems. Through robust design, prevention or adaptation, systems can in theory be designed to neither produce extreme events nor be irreversibly damaged by their effects. Assessments of irreversibility can provide not only a basis for determining research and spending priorities, but may enable us to target prevention efforts.

Research to date has shown that how environmental science information is used depends on characteristics of the information, its production and distribution mechanisms, its producers' credibility, and its recipients' background and incentives. Our scientific understanding is still far short of allowing us to predict when environmental science will be noticed at all, interpreted as intended, or treated with confidence. One consequence of this is that we cannot anticipate the response of human systems to environmental changes or extreme events. Nor can we less address the environmental-management challenge of ensuring wise use of the potentially useful forecasts that science and engineering are increasingly able to produce (e.g., of seasonal-to-interannual climate variations, contaminant pulses, disease outbreaks, fish stocks, ecological effects of land use changes). [Baruch Fischhoff]

At the international level, the IPCC has identified human vulnerability as a key factor in defining future impacts of climate change and sea-level rise. It is also true of other types of global change, such as scarcity of clean water and deforestation. The U.S. has an ongoing national assessment of potential future vulnerability to and impacts of climate change. The environmental justice movement is essentially about differential exposure and sensitivity to environmental threats. The gaps in the social science knowledge necessary to support these assessments are quite limiting: we lack an adequate theory of vulnerability. While we have a very eclectic body of fragmented information about vulnerability in different arenas, it is scattered and has not been brought into systematic organization and testing. There is great interest in hot spots, critical areas, and endangered places and regions, but there are no agreed-upon indicators and measures. Comparative research has been rare. In short, a major initiative in the social sciences should address some of our most fundamental needs in research on extreme events, global environmental change, and national environmental policy and protection strategies.

Research Areas

The following research areas, with a few exceptions, cut across the three topics described above

(*NSF directorates potentially involved)*:

Predicting extreme events (CISE, ENG, GEO, MPS, SBE)
Extreme event preparedness (CISE, EHR, ENG, SBE)
Systems design and implementation (BIO, CISE, EHR, ENG, GEO, SBE)
Organizational design (CISE, ENG, SBE)
Sensors, monitoring, data collection and management (BIO, CISE, EHR, ENG, GEO, MPS, SBE)
Modeling impacts on the built environment (CISE, ENG, MPS, SBE)
Intergovernmental influences in extreme events (EHR, SBE)
Environmental decision making (EHR, ENG, SBE)
Ecological response to or recovery from extreme events (BIO, ENG, GEO)
Assessing human variability and vulnerability to extreme events (BIO, SBE, MPS)
Effects of extreme events on infectious diseases and transmission thereof (BIO, ENG, SBE)
Appropriate warnings and response plans (BIO, CISE, EHR, ENG, GEO, SBE)
Communicating uncertainty and risk of extreme events (CISE, EHR, MPS, SBE)
Valuing extreme events (BIO, ENG, GEO, SBE)
Fairness, social justice, and perceptions of responses to extreme events (SBE)
Safety and privacy (CISE, SBE)
Extreme events and moral hazards (SBE)

6-Feb-00