

EXTREME EVENT

Decision Making

Center for Policy Research
Rockefeller College of Public Affairs and Policy
University at Albany

Decision Risk and Management Science Program
National Science Foundation

Workshop Report

Thomas R. Stewart and Ann Bostrom

t.stewart@albany.edu
ann.bostrom@pubpolicy.gatech.edu

June, 2002



<http://www.albany.edu/cpr/xedm/>

Extreme Event Decision Making

Workshop Report

CONTENTS

1. INTRODUCTION AND OVERVIEW.....	1
2. OUTLINE OF MAJOR ISSUES	1
3. BACKGROUND	2
3.1 DEFINITION OF EXTREME EVENT	2
3.2 PROPERTIES OF EXTREME EVENTS	3
3.3 WHY DO EXTREME EVENTS DEMAND OUR ATTENTION NOW?	4
4. WHAT DO WE KNOW?.....	5
5. WHAT DO WE NEED TO KNOW?.....	6
5.1 ORGANIZATIONAL STUDIES.....	6
5.2 RISK COMMUNICATION	7
5.3 TRADEOFFS	7
5.4 PLANNING.....	8
5.5 LEARNING.....	8
5.6 DECISION MAKING BEHAVIOR	8
6. CONCLUSION	9
REFERENCES:	10
APPENDIX A: WHAT DO WE KNOW?.....	11
APPENDIX B: WHAT DO WE NEED TO KNOW?.....	13
APPENDIX C: PARTICIPANT LIST	19
APPENDIX D: BRIEF STATEMENTS BY PARTICIPANTS	23
ATTACHMENT: NSF DESCRIPTION OF EXTREME EVENTS RESEARCH.....	85

This material is based upon work supported by the National Science Foundation under Grant No. SES-0078783. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

1. Introduction and overview

This report is the product of a workshop that explored judgment and decision making concerning extreme events. This workshop brought together a diverse group of researchers, to examine how to advance our understanding of judgment and decision making related to extreme events.

The Extreme Event Decision Making workshop was held at the National Science Foundation Headquarters, Arlington, Virginia, April 29-30, 2001. The purpose of this workshop was: a) to develop 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) to develop a research strategy for extreme events decision research. This meeting followed a workshop held in Boulder in June 2000 that identified decision making as an activity that is central to coping with extreme events. The report of that workshop (Sarewitz and Pielke, 2000) is cited here as XE2000.

Recent developments dramatically improve the potential for multidisciplinary efforts to produce useful integrated assessments of and interventions in extreme events (XE). But such efforts are of little practical value unless they are incorporated into the many decisions that affect extreme event preparation, response, and recovery. Further, the characteristics of extreme events, such as rarity, uncertainty, and severe consequences, present challenges to effective information use and decision making.

The discussion was spirited and wide-ranging. This report summarizes the key issues discussed. Many of these arose from the brief statements provided by many participants prior to the workshop (see Appendix D), and others were raised at the workshop.

The workshop discussion was focused on two preliminary lists which are included in Appendices B and C. One is a list of what we know now about judgment and decision making that can be applied to extreme events. The second is a list of research needs in extreme event decision making needs that can be addressed by projects funded through DRMS, either by itself or jointly with other programs. In the body of the report, we provide a summary based on these lists. The lists are preliminary and are offered here for discussion. They represent the thinking of workshop participants, but not always a consensus.

2. Outline of major issues

The following brief outline provides a guide to the major issues discussed.

1. All XE are not the same. Different types of XE pose different challenges to decision making.
 - a. Rapid vs. creeping (earthquake vs. global warming)
 - b. Geographic scale
2. The challenges and consequences of XE are the joint product of an event, the community that is affected by the event, and the organizations involved in preparation and response.
 - a. Events – Major changes in the natural (earthquake) or built (e.g., power failure) environment
 - b. Vulnerability/resiliency – ability of the affected community to cope with the event

- c. Regulations and institutions are often ill-suited to coping with XE.
3. Different decisions are required before, during, and after the event.
 - a. Before – planning, preparation, training, moving toward resiliency
 - b. During – rapid response, communication
 - c. After – recovery, and return to “before” activities
4. In order to understand the problems that a decision makers face, it is necessary to understand their role.
 - a. government, national, regional, organizational, local, individual
 - b. policy making, command and control, the citizen level
5. XE are characterized by rarity or uniqueness, uncertainty, high consequences, stress, and multiple decision makers. These have important implications for decision making behavior.
 - a. Since there are few opportunities for learning, citizens and policy makers will lack relevant experience so opportunities for learning must be created
 - i. Training
 - ii. Models
 - iii. Simulations
 - b. Since the nature, onset, severity, and duration of XE are difficult to predict, planning and preparation are essential, but flexibility must be incorporated into plans.
 - i. Natural incentives for planning and preparation are missing.
 - ii. Difficulties with decision making under uncertainty may lead to lack of preparation or inappropriate response.
 - c. Stress and emotion will influence decision making.
 - d. Communication will be difficult, particularly with regard to risk.
 - e. Decision aids should be in place before the event, and have a critical role to play in improving decision making.

3. Background

a. Definition of extreme event

We adopt the following definition, quoted from the “NSF Description of Extreme Events Research.”¹

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.

¹ This description is a short white paper written by Drs. Priscilla Nelson, Ann Bostrom and Rachele Hollander at NSF in 1999-2000.

- 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.

Examples of actual or possible extreme events, according to this definition, include Chernobyl, hurricane Andrew, major earthquakes, zebra mussel invasion, global climate change, extreme stock market fluctuations, destructive and widespread computer viruses, major failure of the internet due to terrorism or system failure, major energy or food shortages, regional armed conflicts, infectious disease epidemics, and collapse of local and regional ecosystems.

The obvious variety of the events included in this list gives rise to a critical question: Is the concept of "extreme event" a useful tool for defining and structuring research and for organizing a research funding initiative? Is it really useful to group such diverse events as earthquakes, climate change, and internet terrorism into a single class?

The extreme event concept is useful if these events share properties that create similar problems and solutions. Recognizing the similarities among these events will facilitate comparisons and generalizations. We now turn to the important properties of extreme events, with particular emphasis on those properties that are relevant to decision making.

b. Properties of extreme events

Table 1 summarizes the important properties of XE that are particularly relevant for decision making. An additional feature that distinguishes among XE is their temporal extension, which from a human perspective may either entail rapid onset or creeping change. The implications for decision making may differ markedly for XE with rapid onset (acute) from those that bring creeping change (chronic).

Table 1. Summary of Properties of Extreme Events

Properties	Implications for decision making
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 (XE2000)
High consequence	Attention will be focused 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, particularly when coupled with high consequences.
Disruptive	Normal activities may cease. Loss of constancy (Hammond, 1999). 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.

c. Why do extreme events demand our attention now?

Three trends suggest that now is the time to address XE: increased vulnerability to XE, the increased threat of XE, and an increasing technical capacity to address XE. Coupled with these trends is a rise in public awareness and demand for mitigation.

As the complexity and interdependence of society increases, so does its vulnerability to extreme events. Factors such as high population densities, globalization, and increased reliance

on interconnected systems (communication, transportation, and other infrastructure systems) increase the potential for events with disastrous consequences.

At the same time, there is an increased threat of extreme events. Although workshop participants did not agree that the number of extreme events is increasing, there are clearly alarming trends such as the rise of terrorism, incidence of new diseases, rapid growth in number of computer viruses, environmental degradation, and the potential for new types of extreme events arising from system complexities and interconnectedness.

Fortunately the technical capacity to address XE is also increasing. Our knowledge and understanding of the processes that lead to XE, of appropriate mitigation strategies and responses, is steadily increasing. The tools for predicting XE (knowledge, databases, and models), while still inadequate in many cases (see, Sarewitz, Pielke, and Byerly, 2000) are improving. Our capacity to respond to extreme events is increasing.

4. What do we know?

A major focus of discussion was the question “What do we know now about judgment and decision making that can be applied to XE?” The list of items discussed appears in Appendix A. Below is a summary based on that list. There are virtually no universal findings or “laws” in this list. Findings are situation dependent. Each deserves a full literature review specifying the conditions under which it has been tested and when it has been found. Such reviews are beyond the scope of this report.

Some of what we know and don't know about judgment and decision making reflects the typical emphasis of judgment and decision research on low consequence rather than high consequences decisions and on individual decision makers rather than groups and organizations. As a result, we know more about low consequence, single decision maker behavior than we do about high consequence decisions in groups or organizations.

With regard to the use of probabilities in decision making under uncertainty, we know that people generally don't do a good job of processing information on probabilities, especially low probabilities, and that people don't attend to probabilities unless they are specifically cued to do so. We also know that the framing of a problem has a big influence on the final outcome of a decision.

We know something about how people combine information. In some situations, people use very few pieces of information, although this is clearly not a universal finding. People seem to combine pieces of information as if they were using an additive model, even when they shouldn't be. For example, people may use an additive model rather than a multiplicative model to incorporate probability terms into their judgments. But it is important to remember that information use is highly influenced by context.

We know a lot about rules and biases in simple, static, low-emotional decision tasks. From research on emotion, stress, and time pressure, we are beginning to know something about the role of emotions in decision making, but the role of emotion in distributed decision making, in dynamic, high consequence situations is not well understood.

Studies of the use of decision aids have shown that people are reluctant to use them. For laypersons, perhaps because they don't understand or relate to models. But this explanation does not apply to experts. They understand the problem.

From research on risk communication we know that predictions about how effectively something will work in communication are often wrong. So pretesting is essential. Experts may think they know what should be communicated, but they are often wrong.

Obstacles to and resources for risk-reducing actions, along with the degree of threat posed by a risk, influence not only whether people will listen to risk communication but whether they will act on what is communicated. Research on whether people believe they can control events and research on timing of what is communicated suggests that, if people have a sense of efficacy, then they will listen to risk communication messages and take action. It is also clear that the credibility of the messenger makes difference.

We know about a number of barriers to the effectiveness of risk communication. We know it is very hard to change routine behavior and habits. It is possible that long-range events are of low salience and that this affects effectiveness of risk communication. Information overload is a problem for experts as well as laypeople. Sometimes people don't know where to find good information. Reception of risk communication varies according to social location, previous experience, or predisposition. Condescension and dissembling will likely generate distrust. Confirmation bias may affect risk communication if people are more likely to accept information they already believe is true.

5. What do we need to know?

This list of potential research topics suggested at the workshop appears in Appendix B. Below is a summary of the major items discussed.

a. Organizational studies

A number of research topics relating to organizations were discussed. These topics were grouped into categories of resiliency, risk management, communication, and learning.

Organizational and societal resiliency is essential for coping with XE. The negative impacts of XE can be reduced if organizations at all levels can absorb such events and continue to function. Specific research questions included the role of technology in promoting or impeding resiliency, the tradeoffs between and other social objectives such as efficiency, and ways to promote investments in resiliency be promoted, even when it may be in no one's private benefit to do so.

Topics in managing risks and XE included studies of how and why organizations create XE and whether some tend to create XE repeatedly. The use of market mechanisms to manage XE should be studied. When does orientation to profit (for-profit, not-for-profit) matter for anticipating and responding to extreme events?

Alternative management strategies and their role in producing and deal with spill-over effects deserves study. What are the advantages and disadvantages of strategic risk management vs operational risk management applied before XE or during an XE?

Organizational communication is an important area of study. What variables influence what and how organizations communicate with regard to XE? What are the effects on communication about XE of conflicts of interest and vision among organizations, different ways of coordinating communication between organizations, and flows of information within organizations about XE?

Further studies are needed on how organizations involved in XE communicate with each other. How and when and how does information go up the chain of command? Communication is inhibited if organizations are not willing to disclose critical information. What determines what they will disclose?

Organizational learning is critical for success in XE decision making. Studies of organizational design for learning from XE are needed. Furthermore, we need to study how organizations can better remember and continue to act on lessons learned.

Some organizations are good at planning for extreme events. How do we transfer that learning to other organizations? We also need to study how organizations learn about local values, culture, and social structure so that they can function effectively and appropriately in various contexts.

b. Risk communication

Naturally, studies in risk communication are important and were discussed extensively at the workshop. There is a need to develop improved methods for identifying, characterizing, analyzing and communicating uncertainty (given cognitive, modeling, and analytical capabilities and limitations). There is an extensive literature on risk communication, but we need to identify how it can be best used to help, and what critical gaps need to be addressed.

Effective risk communication requires learning more about how people think about risk. Do people believe that risks are not real if the government has not intervened? We need to learn more about how people think about causes and consequences. We need to know how risk communication is received by different stakeholders. What do different stakeholders believe about their own vulnerability? Under what conditions do stakeholders come to believe that risk is controllable? What kinds of communications influence attributions of responsibility among stakeholders? What importance do people give to various (objective and subjective) dimensions of risk (beyond what we know from psychometric studies to date)?

The problem of false alarms cut across the discussion of risk communication and the discussion of tradeoffs (see below). What are the implications of false alarms? Can framing influence the impact of false alarms? When do people accept false alarms as an important part of training? Early detection of extreme events can sometimes be achieved by weak intelligence information that is somewhat unreliable. The cost of false alarms based on this information may be high, but the loss for missing a chance to prevent an XE event is by definition catastrophic. How can we combine these probabilities and costs to determine the criterion for setting off alarms to extreme events?

c. Tradeoffs

XE decision making requires difficult tradeoffs. Preparing for XE often involves costs in the near term that are weighed against uncertain benefits in the future. Such costs may be more or less tangible, such as restrictions on civil liberties. We need to develop decision models that incorporate and trade costs off against other attributes.

There was discussion of research on the “precautionary principle” as a way of addressing tradeoffs. The precautionary principle suggests that we should be willing to take protective action to protect the environment or human health even when a lot about the risk is still unknown, and that scientific uncertainty should not be used as a rationale for postponing action. Is this a sensible way to think about XE problems? What influences whether people think in this

way or not? How does it stack up with alternative approaches? The precautionary principle could be evaluated in terms of the accuracy-effort tradeoff. When does the precautionary principle lead to the same or different outcomes? The benefit-cost implications of the precautionary principle deserve further analysis.

d. Planning

In the discussion of planning for XE, a common theme emerged: The need for adaptivity, flexibility and deviation from plans. Plans should be designed to be adaptable. Sometimes it is important to adhere strictly to plans, but other times it is important to be flexible. When should strategic plans build in flexibility? When will the flexibility lead to worse outcomes? Do people who are more experienced deviate more from strategic plans? Can we predict the occasions when people deviate from strategic plans?

Effective communication links between planners and actors are critical. How do we get feedback back to the planning process? What kind of communication is necessary at the start of the process to reduce the discrepancy between plans and actions. We need to study why different decision strategies can be adaptive, within the specific decision ecology

Other planning research needs include studies of cultural responses to emergency planning, studies of how attribution of responsibility affect planning, and studies on how one decides when it is appropriate to break the chain of command.

e. Learning

Research is needed on ways to learn how to make better decisions before, during, and after XE. One method that deserves more study is simulation. Can simulations be used at the policy making level? Can simulations be used to learn about the effectiveness of different strategies for coping with XE?

More research on training is also needed. What are the most effective training methods? What is the best role for simulation in training? Can training exercises be used to study response to XE. For example, could observations and videos of training exercises be used to study the validity of verbal reports following an actual event?

Data and models also have an important role to play in learning. Support for quick response teams and more critical assessment of data and modeling needs would improve our ability to cope with XE.

Feedback is necessary for learning. What kinds of feedback help people learn best? When does the environment provide feedback for learning? How can the environment be structured for learning?

f. Decision making behavior

Decision making behavior was divided into three phases: before the event, during the event, and after the event.

Important research topics related to decision making before the event include studies of the determinants of taking or not taking prevention or mitigation measures, what makes people more likely to be proactive in terms of protection vs. resignation, and how we develop early warning systems for XE.

Research on decision making during the event should include determining the advantages and disadvantages of using a diversity of approaches and responses to the problem, and studies of how people decide to act or wait and collect more information. How do people make a tradeoff between being too impulsive versus overly cautious?

A number of decision making studies apply to all phases of XE. For example, framing studies should address how categorization of the event affects the perception of controllability. Sensitivity analyses of the effects of frames outcomes are needed. Can people be trained to recognize when framing will affect outcomes and to recognize that different frames will lead predictably to different outcomes/analyses?

There was some discussion and dissent about the role of linear models in decision making, and the implications for XE. An hypothesis is that people typically use linear models to think about the world (when there are multiple, fallible indicators). If they need to use non-linear models, they need to be educated. The dissenting view is that there is a great body of research in categorization literature showing that people are quite capable of learning non-linear categorization schemes (e.g., the XOR problem). Utility theories of decision making also currently emphasize non-linear utility models such as the rank dependent model.

Additional research topics included how people understand the social and organizational factors that influence decisions and behaviors and how different stakeholder goals influence behavior before, during, and after XE.

Understanding the effects of emotion, stress, and time pressure on decision making is obviously critical for XE decision-making studies. We need to better understand the relationships between notions of rational and emotional decision making. How is information about risk processed under conditions of stress? Do more emotional people experience greater dynamic inconsistency?

Two specific hypotheses were proposed for testing. One is that decision makers who rely on linear models won't be much affected by time pressure, because such decision making is rapid, but more analytic methods are slowed substantially by time pressure. Another related hypothesis is that the effectiveness of bootstrapping may increase under time pressure.

Another important research area is on aids for improving XE decision making. Representative topics would include a) the evaluation of decision analytic techniques versus alternative methods in the domain of low-probability/high-consequence events and b) examining when decision aids can be helpful, and when they will make no difference.

6. Conclusion

The workshop identified a wide variety of research topics related to extreme event decision making. These topics are presented here in a general outline. Most need further development and a more specific focus before they can be evaluated and prioritized for funding. We offer this report as a first step in identifying important and potentially useful topics in extreme event decision making research. The next step, and the final research topic we propose is a meta-research project aimed at explicating, evaluating, and prioritizing topics in XEDM, beginning with the topics described here. An informative comparison might be made between the results of such an analysis and prioritization with the budget ramifications of 9-11 and the anthrax attacks later that fall in the U.S.

References:

- Glantz, M.H. (Ed.). (1994). *Creeping Environmental Phenomena and Societal Responses to Them*. Proceedings of Workshop held 7-10 February 1994 in Boulder, Colorado. Boulder, Colorado: NCAR/ESIG, 274 pp.
- Hammond, K.R. (1999). *Judgments Under Stress*. Oxford University Press.
- 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.
- Sarewitz, D., R.A. Pielke Jr., and R.A. Byerly Jr. (Eds.) (2000). *Prediction: Decision-Making and the Future of Nature*. Island Press: Washington, DC.

Appendix A: What do we know?

Following is a list of items discussed by the various breakout groups at the workshop in response to the question “What do we know now about judgment and decision making that can be applied to XE?”

1. We know more about low consequence than high consequence decisions.
2. We know more about single decision maker or group than about organizations.
3. People don't do a good job on processing information on probabilities, especially low probabilities.
 - a. *Decision making under ignorance -- people don't attend to probabilities very much unless they are cued to do so.*
 - b. *We know that there are framing problems. Framing of problem has big influence on final outcome of analysis/decision.*
4. We know that people use very few pieces of information (There was some dissension on this at the workshop.)
5. People seem to combine pieces of information as if they were using an additive model (even when they shouldn't be -- e.g., they use additive model to incorporate probability terms into their judgments, not multiplicative ones).
 - a. *How people use information is highly influenced by context; they often behave as if they are using additive models.*
6. Emotion and stress and time pressure
 - a. *We know a lot about simple rules and biases in simple, static, low-emotional decision tasks. We are beginning to know something about the role of emotions in decision making – but we don't know the role of emotions or communications in distributed decision making, in dynamic, high consequence situations, that are much more extreme, and where communications between different levels of society are much more important.*
7. Decision aids
 - a. *People are reluctant to use decision aids when they have them. Why? For laypersons, perhaps because they can't understand or relate to models. For experts, that's not true -- they understand the problem.*
8. Risk communication
 - a. *There are few empirical studies of risk comparisons. So, one thing we know is that when the experts says we know certain things about risk comparisons they aren't speaking from a position of strength.*

- b. We know that predictions about how effectively something will work in communication are often not right. So pretesting is essential. If you want to communicate something about some risk or possible XE you have to have people read it, do the pretest; you can't make assumptions about the process. We know that we don't know.*
- c. We know that experts think they know what should be communicated, but there's a great deal of overconfidence there.*
- d. There is some research on whether people think they can control events or outcomes. There is also research on timing of what is communicated. If people have a sense of efficacy then they'll listen to risk communication messages and take action.*
- e. Credibility of the messenger makes difference.*
- f. Very hard to change routine behavior; habits, e.g., health, exercise, diet.*
- g. Possible that long events are of low salience and this affects effectiveness of risk communication.*
- h. Information overload is real. More is not necessarily better. This is true for experts as well as so-called non-experts.*
- i. People in some cases don't know where to go for good information.*
- j. Reception of risk communication might vary according to social location, previous experience, or predisposition.*
- k. There is very little research on communication to and between elites and a lot more on one way, top down communication.*
- l. We are reasonably certain that condescension and dissembling will likely generate distrust.*
- m. People are more likely to believe information they already believe is true--confirmation bias.*
- n. We know more about health, safety, financial risks than about environmental risks*

Appendix B: What do we need to know?

This list describes potential research topics suggested at the workshop.

1. Resiliency
 - a. How can technologies promote or impede resiliency?
 - b. What are the tradeoffs between resiliency and other social objectives such as efficiency?
 - c. How can investments in resiliency be promoted when it is in no one's private benefit?
2. Organizations
 - a. Managing XE/risk management
 - i. *How and why do organizations create XE? Do some of them create XE over and over again?*
 - ii. *How do we use market mechanisms (e.g., 3rd parties) to manage XE?*
 - iii. *When does orientation to profit (for-profit, not-for-profit) matter for anticipating and responding to extreme events? They differ on definition and response to XE, incentive structures, cultures, missions.*
 - iv. *How do alternative management strategies produce and deal with spill-over effects?*
 - v. *How to get people to think beyond blaming individuals and to understand the role of the system?*
 - (1) *How do people think about causes and consequences?*
 - vi. *Strategic Risk Management vs Operational Risk Management. Pre XE vs Ongoing XE.*
 - b. Communication
 - i. *What variables influence what and how organizations communicate with regard to XE?*
 - (1) *How do conflicts of interest and vision among organizations affect communication before, during, and after?*
 - (2) *How do different ways of coordinating communication between organizations influence organizational behavior before, during and after XE?*
 - (3) *How does the phase of event in the life cycle affect willingness to assess and communicate efficacy? Some organizations might be more willing to assess or be open about possible deficiencies than others.*
 - ii. *How do organizations involved in XE communicate with each other? How do they share information before, during, and after?*

- iii. *What are the flows of information within organizations about XE and potential XE?*
 - iv. *When and how does information go up the chain of command?*
 - v. *Under what conditions can people in different positions admit to limitations, assess their own efficacy, or communicate same? What information are organizations willing to disclose in pre-event planning? What determines what they'll disclose or feel they can disclose?*
 - vi. *How do stakeholder groups define successful communication before, during and after the XE?*
- c. Learning
- i. *How can organizations be designed to learn from events or near-misses?*
 - ii. *How do we remember and continue to act on the things we have already "learned"?*
 - iii. *How do organizations learn about extreme events? Two perspectives have emerged from theory*
 - (1) *Organizations can learn to avoid extreme events*
 - (2) *The nature of the system is to create extreme events. Humans cannot override*
 - (3) *Some organizations are good at planning for extreme events. How do we learn from those that plan, like the Red Cross?*
 - iv. *How do organizations learn about local values, culture social structure? Can you develop a system for such learning? How does an organization become a learning organization?*

3. Risk communication

- a. What can the full spectrum of the existing risk communication literature do to help? What are the gaps? How do new technologies (e.g. IT; remote sensing) help/inhibit?
- b. Development of improved methods for identifying, characterizing, analyzing & communicating uncertainty (given cognitive, model, analytical capabilities and limitations)
- c. False Alarms. There is some marketing research on what you do when something horrible goes wrong. If you make a false alarm, what are the implications? How do you recover? How does the framing influence the message? False alarms fit neatly into the work on tradeoffs. If there is a good will, people will want to do what makes sense. When do people accept false alarms as an important part of training?
- d. Public education. Do people believe that risks are not real if the government has not intervened? (Research on trust might be relevant, although government is not a homogeneous entity.)

- e. How is risk communication received by different stakeholders in different phases of XE?
 - i. *How do different stakeholders perceive their own vulnerability? How do they construct what they consider a worst case?*
 - ii. *How do stakeholders come to think that an uncertainty or risk is controllable? What do they mean by control?*
- f. What kinds of communications influence attributions of responsibility among stakeholders?
- g. What weights do people give to various dimensions of risk (objective -- e.g., mortality, morbidity -- and subjective)? What attributes do people consider important? (We know even less about how people think about risks to the environment or ecology, vs. risks of mortality or morbidity)

4. Tradeoffs

- a. Develop decision models that incorporate and trade costs off against other attributes.
- b. False alarms. Early detection of extreme events can sometimes be achieved by weak intelligence information that is somewhat unreliable. The cost of false alarms to this information is high in the long run, but the loss for missing a chance to prevent an XE event is catastrophic. These probabilities and costs need to be combined to determine the criterion for setting off alarms to extreme events. How should we set the criterion?
- c. Research on the precautionary principle:
 - i. *Observations*
 - (1) *Likely to be influential when discussing very rare events.*
 - (2) *Trade-offs that people make are not consistent across all substantive domains.*
 - ii. *Is this a sensible way to think about problem? What influences whether people think about the problem in this way or not? How does it stack up with alternative approaches?*
 - iii. *Is the precautionary principle anything more than an application of the mini-max principle?*
 - iv. *Would be very helpful to evaluate the precautionary principle in terms of accuracy-effort tradeoff. When does precautionary principle lead to the same or different outcomes? How much difference does it make?*
 - v. *Does precautionary principle simply imply a very high cost assigned to False Negatives? Answer: Yes, it seems to. For example, in Sweden, many fewer new chemicals.*
 - vi. *There is a need for historical and analytical studies.*
 - vii. *Analyze the benefit-cost implications of the precautionary principle.*

5. Planning

- a. Common theme: Adaptivity, flexibility and deviation from plans. Sometimes it is important to adhere strictly to plans. Other times it is important to be flexible and plans should be designed to be adaptable.
 - i. *When should strategic plans build in flexibility? When will the flexibility lead to worse outcomes? How can the normative framework be built around adaptability?*
 - ii. *Do people who are more experienced deviate more from strategic plans? Are they better?*
 - iii. *Can we predict the occasions when people deviate from strategic plans? What kinds of feedback help people learn best? When does the environment provide feedback for learning? How can the environment be structured for learning?*
 - iv. *Communication links between planners and actors. Get feedback back to the planning process. What kind of communication is necessary at the start of the process to reduce the discrepancy between plans and actions*
 - v. *Need to study why different decision strategies can be adaptive, within the specific decision ecology*
- b. How do we get factors like 'group-think' incorporated in strategic plans?
- c. What do you need to know to write guidelines for XE plans in the first place? Can one piggyback on existing research?
- d. Study cultural responses to emergency planning. To what extent are the strategic plans for emergencies cultural-based or individual-based? People often use the heuristic of doing what your neighbor does.
- e. How does attribution of responsibility affect planning?
- f. How does one decide when it is appropriate to break the chain of command. How does one decide to change or ignore a command from higher levels of the organization on the basis of local information on the scene?

6. Learning

- a. Simulation
 - i. *How can simulations be used at the level of policy?*
 - ii. *How can simulations be used to determine the effectiveness of different strategies for dealing with extreme events. How can simulations be used to estimate the consequences of extreme events or the dynamics of extreme events.*
- b. Training
 - i. *Training: Make videos of training scenarios. Collect after-action reports in the military. Code the emotions*

- ii. *What is the role of simulation in training? What is the best feedback from simulation? How can you better train people?*
 - c. Data and models
 - i. *Quick Response Teams are one way of gathering data.*
 - ii. *Promotion of more critical assessment of needed data, models, and analytical approaches, etc.*
- 7. Decision making behavior
 - a. Before
 - i. *What are the determinants of taking or not taking prevention or mitigation measures?*
 - ii. *What makes people more likely to be proactive in terms of protection vs. resignation?*
 - iii. *How do we develop early warning systems or signal detection or alarm systems for warning about extreme events. How do we set the criteria for deciding to set off an alarm? How do we collect and integrate information that goes into such an alarm. How do we form and analyze networks that collect information for early warning systems. How do we do data mining of vast resources of information for early warning systems?*
 - b. During
 - i. *Is there an advantage to a diversity of approaches and responses to the problem? Are there disadvantages to co-ordinate and standardization of actions? Could this reduce robustness or resiliency?*
 - ii. *How does one decide to act or wait and collect more information. How does one make a tradeoff between being too impulsive versus overly cautious?*
 - c. After
 - d. All phases
 - i. *Framing: how does categorization of the event affect the perception of controllability?*
 - ii. *Conduct sensitivity analyses of the effects of frames on analysis and outcomes?*
 - iii. *Can people be trained to recognize when framing will affect outcomes and to recognize that different frames will lead predictably to different outcomes/analyses?*
 - iv. *What are conceptions of locus of responsibility along different phases of event?*
 - v. *How does XE context influence framing of goals and construction of motive?*

- vi. *Hypothesis: People typically use linear models to think about the world (when there are multiple, fallible indicators). If they need to use non-linear models, they need to be educated. Dissenting view: There is a great body of research in categorization literature showing people are very capable of learning non-linear categorization schemes (e.g., the XOR problem). Utility theories of decision making also currently emphasize non linear utility models such as the rank dependent model. It is not wise to make such a general conclusion about linear models based on a narrow segment of research in cognition.*
- vii. *Research question: What do people attend to in a linear model?*
- viii. *How do people understand the social and organizational factors that influence decisions and behaviors?*
- ix. *How do different stakeholder goals influence behavior before, during, and after the XE?*
- e. Emotion, stress, and time pressure
 - i. *Rational vs. emotional decision making*
 - ii. *Hammond's judgment under stress. Under what conditions do people respond in what ways to stimuli? How is information about risk processed under conditions of stress.*
 - iii. *Do emotional people experience greater dynamic inconsistency? Two cells in a design--people Prepare the Plan vs. Don't Prepare the Plan. Dependent variable is whether people use the plans they previously made? (Research on broken leg cues)*
 - iv. *Hypothesis: Linear model DM isn't much affected by time pressure (it's done fast) but more analytic methods are slowed substantially by time pressure.*
 - v. *Hypothesis: Effectiveness of bootstrapping may increase under time pressure.*
- f. Decision aids
 - i. *How would we evaluate decision analytic techniques versus alternatives in the domain of low-probability/high-consequence events?*
 - ii. *Where can decision aids be a helpful or useful component, and where will they make no difference?*

Appendix C: Participant list

Hal Arkes
Department of Psychology
Ohio State University
240N Lazenby Hall
1827 Neil Avenue Mall
Columbus, OH 43210-1222
arkes.1@osu.edu
<http://www.psy.ohio-state.edu/>

Ann Bostrom
Program Director
Decision, Risk & Management Science
National Science Foundation
4201 Wilson Blvd., Room 995N
Arlington, VA 22230
abostrom@nsf.gov

Norman Bradburn
Assistant Director
Directorate for Social, Behavioral &
Economic Sciences
National Science Foundation
4201 Wilson Blvd., Room 905N
Arlington, VA 22230

Jerry Busemeyer
Psychology Department
Indiana University
Bloomington, IN 47405
jbusemey@indiana.edu
<http://php.indiana.edu/~jbusemey/home.html>

William Butz
Director, Division of Social and Economics
Sciences
National Science Foundation
4201 Wilson Blvd., Room 995N
Arlington, VA 22230
wbutz@nsf.gov

Caron Chess
Director, Center for Environmental
Communication
Rutgers University
31 Pine Street
New Brunswick, NJ 08901
chess_c@aesop.rutgers.edu
<http://aesop.rutgers.edu/~cec>
<http://aesop.rutgers.edu/~humeco>

Lee Clarke
Sociology Department
Lucy Stone Hall
Rutgers University
New Brunswick, NJ 08903
lee@leeclarke.com
<http://leeclarke.com>
<http://sociology.rutgers.edu>

Joanne Culbertson
Senior Advisor for Planning and Evaluation
National Science Foundation
4201 Wilson Blvd., Room 505N
Arlington, VA 22230
jculbert@nsf.gov

Michael DeKay
Heinz School of Public Policy
Carnegie Mellon University
4800 Forbes Ave., HbH 2107B
Pittsburgh, PA 15213-3890
dekay@andrew.cmu.edu

Klára Faragó
ELTE Department of Social and Educational
Psychology
Izabella utca 46
1064 Budapest, HUNGARY
farago@izabell.elte.hu

Kenneth Hammond
Center for Research on Judgment and Policy
Campus Box 344
University of Colorado
Boulder, CO 80309
krhammond@earthlink.net

George Hazelrigg
Group Leader, Design & Manufacture
Research Programs
National Science Foundation
4201 Wilson Blvd., Room 508N
Arlington, VA 22230
ghazelri@nsf.gov

Miriam Heller
Program Director, Information Technology
& Infrastructure Systems Program
Engineering Directorate
National Science Foundation
4201 Wilson Blvd., Room 545S
Arlington, VA 22230
mheller@nsf.gov

Charles Herrick
Stratus Consulting Inc.
4504 Warren St., NW
Washington, DC 20016
CHerrick@stratusconsulting.com
<http://stratusconsulting.com/Staff/Herrick.htm>

Rachelle Hollander
Program Director/Cluster Coordinator,
Societal Dimensions of Engineering,
Science and Technology
Social, Behavioral & Economic Sciences
National Science Foundation
4201 Wilson Blvd., Room 995N
Arlington, VA 22230
rholland@nsf.gov

Bill Hooke
American Meteorological Society
1200 New York Avenue
NW Suite 410
Washington, DC 20005
hooke@dc.ametsoc.org

Julie Irwin
Marketing Department
University of Texas at Austin
Graduate School of Business
Austin, Texas 78720
jirwin@mail.utexas.edu
<http://www.bus.utexas.edu/faculty/mkt/irwin/home.html>

Alex Kirlik
School of Industrial & Systems Eng.
Georgia Institute of Technology
Atlanta, GA 30332-0205
kirlik@isye.isye.gatech.edu

David Krantz
Department of Psychology
419A Schermerhorn Hall
Columbia University
1190 Amsterdam Avenue, Mail Code 5501
New York City, NY 10027
dhk@columbia.edu
http://www.columbia.edu/cu/psychology/indiv_pages/krantz.html

Howard Kunreuther
Wharton School
University of Pennsylvania
3620 Locust Walk
Philadelphia, PA 19104-6366
kunreuther@wharton.upenn.edu

Barbara Mellers
Department of Psychology
Ohio State University
Columbus, OH 43210
mellers.1@osu.edu

M. Granger Morgan
Professor of Engineering and Public Policy
BH 129H
Carnegie Mellon University
Pittsburgh, PA 15213
gm5d+@andrew.cmu.edu
<http://www.heinz.cmu.edu/researchers/faculty/gm5d.html>

John Mulvey
School of Engineering and Applied Science
Department of Operations Research and
Financial Engineering
Princeton University
26 Prospect Avenue
Princeton NJ 08540-5296
mulvey@Princeton.EDU
<http://www.princeton.edu/pr/pwb/99/0222/risk.htm>

Jeryl Mumpower
Center for Policy Research
University at Albany
135 Western Avenue, Milne 300
Albany, NY 12222
mumpower@csc.albany.edu

Priscilla Nelson
Director, Division of Civil & Mechanical
Systems
Engineering Directorate
National Science Foundation
4201 Wilson Blvd., Room 545S
Arlington, VA 22230
pnelson@nsf.gov

Phil Rubin
Director, Division of Behavioral &
Cognitive Sciences
Social, Behavioral & Economic Sciences
National Science Foundation
4201 Wilson Blvd., Room 995N
Arlington, VA 22230
prubin@nsf.gov

Sandra Schneider
Program Director
Decision, Risk & Management Science
National Science Foundation
4201 Wilson Blvd., Room 995N
Arlington, VA 22230
sandra@chuma.cas.usf.edu

Sandor Schuman
Center for Policy Research
University at Albany
135 Western Avenue, Milne 300
Albany, NY 12222

Thomas Stewart
Center for Policy Research
University at Albany
135 Western Avenue, Milne 300
Albany, NY 12222
t.stewart@albany.edu
<http://www.albany.edu/cpr/stewart/>

Miron Straf
Consultant
Social, Behavioral & Economic Sciences
National Science Foundation
4201 Wilson Blvd., Room 905 N
Arlington, VA 22230
mstraf@nsf.gov

Bonnie Thompson
Program Director, Central and Eastern
Europe
Social, Behavioral & Economic Sciences
National Science Foundation
4201 Wilson Blvd., Room 935N
Arlington, VA 22230
bhthomps@nsf.gov

William A. Wallace
Rensselaer Polytechnic Institute
C11 5117
110 Eighth Street
Troy, NY 12180
wallaw@rpi.edu

Elise Weaver
Center for Policy Research
University at Albany
135 Western Avenue, Milne 300
Albany, NY 12222
eaweaver@csc.albany.edu

Rae Zimmerman
Director
Institute for Civil Infrastructure Systems
411 Lafayette Street, Suite 300
New York, NY 10003-7032
rz1@is2.nyu.edu
<http://www.nyu.edu/icis>
<http://www.nyu.edu/wagner/info-Zimmerman.html>

Appendix D: Brief statements from participants

The following people prepared brief statements that can be read at

<http://www.albany.edu/cpr/xedm/>

Hal Arkes
Jerome Busemeyer
Lee Clarke
Mike DeKay
Klára Faragó
Kenneth Hammond
Charles Herrick
Julie Irwin
Alex Kirlik
David Krantz
Howard Kunreuther
Barbara Mellers
John Mulvey
Jeryl Mumpower
Ola Svenson
Al Wallace
Elise Weaver
Rae Zimmerman

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