Catastrophe Risk Management in the Public Sector

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Congratulations to Professor Haresh Shah and Professor T. C. Pan on the establishment of the ICRM. It promises to be an important institution in an important field. I am honored to be a part of this week's inaugural symposium.

It's especially fitting that Singapore is the home for the ICRM. Like many others around the world, I have long been fascinated by this country and have enjoyed my visits.

It isn't easy to define globalization for someone, but I notice that many illustrations of the phenomenon begin with the words, "Take Singapore, for instance."

That is pretty apt, considering that it occupies half the territory of my hometown, Los Angeles, and has just 5 million residents. On the other hand, it is served by 80 airlines, and Singapore's port is the busiest in the world for containerized transshipment traffic. Its foreign exchange trading center is the fifth largest in the world.

This degree of interconnectedness with the rest of the world has helped make Singapore so prosperous that it is no surprise that the rest of the world is moving swiftly in that same direction. Of course, interconnectedness can also work in reverse, which is why imprudent home-mortgage practices by banks in the United States could cause distress even here in Singapore, nearly 9,000 miles away.

I mention this at the outset because the proliferation of interconnections—among economies, regions, industries, and everything else—is what makes catastrophe risk and risk management a growing challenge and a worthy subject for this new Institute.

This observation would almost certainly come as a surprise to many public sector decisionmakers. After all, networks of interconnections are often recommended as a way of increasing reliability, robustness, and resiliency. But, if a network contains connections that are unknown or underappreciated, the interconnectedness will propagate failures more quickly and more widely—as we saw in 2008 and 2009 when problems with specialized financial instruments in one country led to a collapse of the international credit market, failure of banks in other countries, and then, in shockingly short order, a worldwide economic recession.

A catastrophe is defined in part by the enormity of its negative consequences. The proliferation of interconnections in the modern world make it more and more likely that events, which might have been small and contained problems in earlier eras, will today and in the

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[1] I am indebted to several people who contributed ideas to this speech, including Robert Reville, Henry Willis, Robert Lempert, Debra Knopman, James Dertouzos, William Rich, and Brian Dille.

[2] For the full program of the conference, see http://www3.ntu.edu.sg/CEE/ICRM/pdf/Brochure_22Dec09.pdf.

future cascade, reverberate, and expand into colossal tragedies in economic, human, environmental, and other terms. I'll come back to this theme again and again.

It's a tribute to the symposium organizers' insight that they devoted a session to the implications of risk for public policy. RAND has more than 60 years of experience helping policymakers in the public sector deal with risk, and I'll draw on some of that experience this morning.

It is well accepted that the first duty of government is to protect its people—to ensure that they are safe. But "safe" means protected from negative consequences. We all know that no government can achieve that, so what is a responsible government to do?

It must have a rational, sophisticated, adaptive, and flexible system for managing risk. That is quite a challenge for any government. In the public sector,

- Rational analysis is usually just one of many inputs to a decisionmaker,
- Sophisticated approaches are often discarded in favor of expedient solutions, and
- Adaptability and flexibility are qualities that are rarely associated with policies produced by bureaucracies constrained by statutes and budgets.

But, managing risks is an unavoidable challenge given the primacy of public safety among a government's duties.

Obviously, ensuring safety in the face of natural disasters is a burden for every government, but this morning I am going to concentrate on two other kinds of catastrophes that governments must also contend with, especially in the future. And, because governments will have to contend with them, so will ICRM. Those involve risks in the international security environment and risks of large-scale harm that may arise from the introduction of new products and substances.

I believe these kinds of risks are at the frontier of catastrophe risk management, and I will say a little about how innovative risk analysis can help governments meet their prime duty to public safety.

I am going to start with the international security environment. It is an area in which the RAND Corporation has conducted a great deal of research over the years. I will then talk about major product-based public health problems. This is where RAND is currently engaged in significant research along with Risk Management Solutions, Inc. (RMS). I will then discuss the difficult problem of the reliance on models and how catastrophe risk management needs to advance both the models as well as the science of using models.

Peter Bernstein has a great passage at the beginning of his book, *Against the Gods*. He wrote that thinkers such as Blaise Pascal and others,

> by defining a rational process of risk-taking, . . . provided the missing ingredient that has propelled science and enterprise into the world of speed, power, instant communication, and sophisticated finance that marks our own age. . . . The ability to define what may happen in the future and to choose among alternatives lies at the heart of contemporary societies.[3]

[3] Peter L. Bernstein, *Against the Gods: The Remarkable Story of Risk*. New York: Wiley & Sons. 1996, p. 2.

There have been enormous advances in catastrophe risk management over the last half century, but the world has evolved just as fast, *if not faster*.

If the proliferation of interconnections lies at the heart of technological innovation and economic progress around the world and if, as I believe, interconnections also give rise to a wider range of possible catastrophes, then strengthening our understanding and management of catastrophe risks is central to sustaining human progress.

The RAND Corporation was founded 60 years ago on a very simple proposition: Rigorous, unbiased analysis produces better decisions. I believe that that proposition holds for decisions about catastrophe risk.

What is needed to make sound decisions about catastrophe risk? The first ingredient is a model for thinking about the future. And this model should be *systemic* to avoid neglecting critical interconnections that might lead to failure from unexpected quarters.

Let me give you two examples from RAND's body of research during the Cold War, when the United States was faced with devising a military strategy and an associated basing posture and force structure for deterring the Soviet Union and, if deterrence failed, for defeating it militarily. With nuclear weapons in each arsenal, this involved catastrophe risk in its most literal and existential form.

In the first example, a RAND mathematician I came to know well in the last decade of his life, Albert Wohlstetter, was asked to evaluate the Strategic Air Command's collection of strategic-bomber bases in Europe.[4] When he began working on the issue in 1951, Wohlstetter brought an outsider's perspective to the problem. He hadn't served in the military, and, before coming to RAND, he had had no interest in military strategy. This lack of familiarity proved to be very useful.

Wohlstetter found that the basing system, as it existed, did not withstand his imagined "worst-case scenario" of a crippling Soviet attack. His analysis uncovered the possibility that the Soviet Union, while en route to an invasion of Western Europe, could potentially knock out 85 percent of America's bomber fleet in Europe. The crux of the problem, as Wohlstetter saw it, was that locating our overseas bases close to their planned bombing targets in the Soviet Union in turn made the bases just as easily accessible to the enemy's bombers.

Although his study took into account many arcane technical details, and was quantitatively very rigorous, Wohlstetter's basic insight was simple. But it had not previously been seriously considered. He advocated not just planning for what he mockingly referred to as the "Western-preferred Soviet strategy," but to try to think about the unthinkable, to take a phrase from another RAND analyst, Herman Kahn.

In other words, to plan for the truly catastrophic—just as America had failed to do regarding a surprise Japanese attack at Pearl Harbor only ten years prior. In fact, Wohlstetter's thoughts on the bomber bases' vulnerability were influenced by the historical study that his wife, Roberta, was then conducting concerning America's failure to heed signals of Japan's preparations and intention to attack Pearl Harbor.[5]

Instead of commenting on desirable locations in Europe for bomber bases, Wohlstetter and his team urged the Air Force to base the bombers in the United States, where they could be co-located on large bases that would operate more efficiently.

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4 Albert J. Wohlstetter, Fred Hoffman, R. J. Lutz, and Henry S. Rowen, *Selection and Use of Strategic Air Bases*. Santa Monica, CA: RAND Corporation. R-266. 1954.

5 Roberta Wohlstetter, *Pearl Harbor: Warning and Decision*. Palo Alto, CA: Stanford University Press, 1962.

By thinking about the unthinkable, Wohlstetter helped ensure that the United States did not have to learn how to avoid the risk of a preemptive nuclear attack through experiencing one first.

What Herman Kahn called "thinking the unthinkable" is what others might call catastrophe risk modeling.

In fact, what seemed like simple tabletop analysis of vulnerability and risk was actually influenced by a sophisticated development in modeling going on right down the hall at RAND. In addition to the work of his wife, Wohlstetter was also influenced by work at RAND in the relatively new field of game theory—by his RAND colleagues John Nash, Lloyd Shapley, John von Neumann, Tom Schelling, John Williams, and others. In the words of Peter Bernstein, "Game theory [brought] a new meaning to uncertainty. Earlier theories accepted uncertainty as a fact of life and did little to identify its source. Game theory says that *the true source of uncertainty lies in the intentions of others*."[6] The Wohlstetter study is an early example of a new method stimulating a new way to think about risk, which in turned convinced policymakers to do things differently.

The reason that models of the future must be system-wide is that when addressing one risk it is all too easy to simply trade that risk for another. Consider the novel RAND recommendation to move the strategic bombers to bases in the continental United States. Although this new basing posture made the bombers, themselves, more secure from physical destruction, it gave rise to another previously unrecognized risk. Although the communications system linking the national command authority with the bomber force had never in history been disrupted, RAND researcher Paul Baran realized that losing just one communications node would in essence produce a catastrophic failure because it would sever the link between the President and the nation's bomber force.[7]

This insight about a catastrophe risk in the future led to what is perhaps the most significant technical concept to emerge from RAND during the period of the Cold War.

Baran devised a way of breaking up a message into what he called packets, sending the packages on random paths through a network of connected nodes, and then reassembling the packets at the intended destination. He intentionally designed the system to be robust enough that if one node were destroyed, the packet would reroute itself and still reach its destination via another route.

This technique, known as packet switching, became the cornerstone of the Internet. Once again, RAND analysts thought through what had previously been unthinkable—an attack on the continental U.S. that would cripple our capacity to communicate—and then used the insights to create a way to manage the risk before it could become reality.

During the Cold War, systems analysis and modeling using what at the time were cutting-edge tools like game theory proved essential over and over to managing the risk of a bi-polar competition involving catastrophe risks.

Today's security environment is no longer bi-polar, of course. But the risk of catastrophe is no less. It is generally believed that nine states have detonated and currently possess nuclear weapons. At least three others are strongly suspected of actively pursuing the development of nuclear weapons. We know that more than one terrorist group, most notably al Qaeda, has

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6 Ibid., p. 232. Emphasis in the original.

7 Paul Baran, *On Distributed Communications: Summary Overview*. Santa Monica, CA: RAND Corporation. RM-3767-PR. 1964.

tried to acquire a nuclear weapon, and at least one, Aum Shinrikyo, has tried to build one. In this world, it is more essential than ever to generate and apply cutting-edge methods in systems analysis and modeling to manage these new catastrophe risks.

Because of the interconnections I've alluded to, long distances, intervening continents, and oceans are no longer barriers to groups with grievances or hatred. Therefore, all of us concerned with managing risk in the public sector should devote considerable effort to ensuring that we have theories, models, and decision frameworks that are suitable for this new age of terror.

Let me now shift gears to a different kind of risk, the risk posed by new technologies, toxic materials, and substances. It's a risk as old as the industrial age, but the modern and growing level of interconnections in the world's economies, production processes, and supply chains could elevate a growing number of these risks into the catastrophic category. My message: Governments must include product-based public health disasters in their thinking about catastrophe planning.

One of the earliest paths for dealing with this dilemma came through legal systems. The common law of torts, beginning in the 19th century and in response to the increasing pace of technological change during the Industrial Revolution, recognized a new class of activities, called "ultrahazardous."

Actors engaging in ultrahazardous activities became strictly liable for any harm they caused.[8] Having legislatures allocate the consequences of risks gone bad, or later, judges and juries, by establishing and applying rules fixing civil liability, is one way that the public sector manages risk in a society.

The public sector also manages risk through regulation. But the tort system and often regulation, too, tend to be reactive. As Chauncey Starr, in his groundbreaking study of technological risk versus societal benefit, wrote: "Our society historically has arrived at acceptable balances of technological benefit and social cost empirically—by trial, error, and subsequent corrective steps."[9]

One problem with confronting new risks in this fashion, according to Starr, is that the time between first use of a new technology and its subsequent widespread integration into our society has become so short—diffusion of technology occurs before its social impact can be assessed, "and before any empirical adjustment of the benefit-versus-cost relation is obviously indicated."[10] Put differently, without a systemic model for the future to guide decisionmaking with respect to the public health risks of new technologies and substances, the human catastrophes are followed by financial catastrophes rather than mitigated or avoided altogether.

The exemplar for this kind of risk is asbestos, a silicate mineral that became popular in the late 19th century because of its resistance to heat, electrical, and chemical damage, its sound absorption properties, and its tensile strength.

Asbestos quickly found its way into thousands of products in millions of locations. Unfortunately, long after it was introduced into homes and businesses around the world, it

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[8] See *Rylands v. Fletcher*, 1865 3 H & C 774, 159 English Rep. 737.

[9] Chauncey Starr, "Social Benefits Versus Technological Risk: What Is Our Society Willing to Pay for Safety?" *Science*, Vol. 165, No. 3899, 1969, p. 1233.

[10] Ibid.

was determined that inhalation of asbestos fibers caused such serious illnesses as lung cancer, mesothelioma, and asbestosis.

In terms of lives ended and adversely affected, asbestos has rivaled the most horrific natural disasters and dwarfed the consequences of even the most lethal terrorism attacks we've seen. The result has been an explosion of mass litigation in the United States that continues today. The insured losses attributable to asbestos so far have been roughly double those from the 1994 Northridge, California, earthquake and roughly equal to those from the 9/11 attacks.

Asbestos is an example of a rippling and cascading public health problem, which leads to many thousands of deaths and impairments, billions of dollars of losses, bankruptcies, and other financial strains on the very same institutions and processes that we need to be healthy for natural catastrophes.

Analytically, slow-moving product-driven public health disasters have important similarities to natural catastrophes. For an individual substance or material or process, the chance of a public health disaster is very low, but when one does occur, the costs are generally very high for individuals and businesses. For insurers, if the claims are unexpectedly highly correlated, the effects can be devastating. Because of the economic interconnections I alluded to before, in the future, when substances turn out to be toxic, their negative effects will course through the global streams of commerce at unprecedented speeds.

Indeed, another facet of globalization is that legal practices are becoming more global. U.S. litigation features are spreading to other countries around the world. This means that when global public health disasters occur in the future, the resulting mass litigation may be global as well, with financial consequences that are even more catastrophic.

If we had models for these risks, they could be managed, just as hurricane and earthquake risks are managed. Is this possible? Companies such as RMS have harnessed large bodies of meteorological and seismic data to build models of the future that help manage risk of natural disasters. Can we do the same for products, public health, and the risk of mass litigation?

The problem is different, of course. Historical hurricane patterns do tell us something about future patterns, because laws of nature are at work. But, mass torts of the past are not very useful in identifying which new substances might go down the same path. Is there another body of data we can use to analyze risks? A few years ago, RAND economist Robert Reville noted that academic research exploring possible links between substances and harms precedes litigation by many years, often decades.

With hindsight, we know that that was true for asbestos. Reville realized that scientific research could serve as an early warning system and that, as the scientific literature develops, the risk could be managed. But, there are literally tens of thousands of articles a year involving hundreds of thousands possible substances, compounds, and materials. Is it possible to harness all that textual information and build a risk management system for the health consequences of new technologies and substances?

Just as advances in computing power enabled the development of sophisticated quantitative models of natural-disaster risks to property, Reville and another RAND colleague, Sid Dalal, recognized that advances in "knowledge engineering" now enable us to search the voluminous literature and find accumulations of linkages between a substance and a bodily harm and to track the literatures over time. This new system is called L-CAT, for "liability catastrophe," and it is a joint development by RAND and RMS.

If we are successful, the policy implications would be profound. A better-informed insurance industry could manage its own risks more effectively, and when they do this they would signal to their business customers that they should find ways to avoid harming their workers, their customers, or the environment.

International and domestic public health agencies would also benefit from models of emerging product risks. They could then focus their regulatory activities and prioritize their research agendas where advances in the scientific literature are most likely to pay off. In the best of worlds, the assessment of toxicity or carcinogenicity and the promulgation of rules to govern exposure is a painfully slow-moving process. In the worst of worlds, it is entangled in politics. And, once decisions are made, they are hard to revisit and revise, even when science advances to render them obsolete.

With models of the risk of catastrophic product-based public health disasters, emerging risk could be identified more quickly, and decisionmaking could keep up with the pace of science. Catastrophe risk models in this area could even help inform careful policymaking around the world, as legal systems converge and best practices in one country are adopted in others and the worst practices are avoided. We might be able to avoid the next asbestos, averting the cascade of deaths and injuries to people as well as the blows to the financial services industry that can result.

Before I conclude with the implications of all this for ICRM, I would like to turn to my last theme, namely the use of models. I have suggested that catastrophe risk management requires the use of models, but we have all heard the arguments that over-reliance on models can lead to inappropriate decisions, which is certainly true.

Models are an important source of information and decision aids to policymakers, but, particularly in the realm of catastrophes, their use can come at a price. The European Environmental Agency commissioned a survey by RAND Europe that showed that the more policymakers rely on models, the less they may factor in the prospect of surprising or unexpected events.[11] Therefore, research is needed not only on how to model catastrophes better, but also on how to use the resulting models to expand rather than contract a policymaker's view so that the chances of overlooking or ignoring possible discontinuities or surprises are reduced.

Thinking systematically about the future, even with the aid of new, sophisticated analytical techniques, is most difficult when there isn't agreement on which key driving forces will shape the future and how; on the magnitude of uncertainty surrounding key variables; or on the appropriate mix of long-term objectives. We call those conditions "deep uncertainty."

Governments confront deep uncertainty when they consider policies to protect the environment; promote, restrict, or regulate new genetic technologies; and counter terrorism and numerous other 21st century challenges. What steps should they take in the near term when the consequences of their decisions may not be known for a generation or more? Are there analytical techniques that can help human decisionmakers make good decisions in the face of deep uncertainty?

My colleagues, led by physicist Robert Lempert, have been developing an approach called robust decisionmaking. It also draws on the recent advances in computing capabilities, as well as the special ability of humans to draw inferences and form hypotheses. Like so many path-breaking analytical efforts, it starts by changing the question.

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[11] European Environmental Agency, *Looking Back on Looking Forward: A Review of Evaluative Scenario Literature*. Copenhagen. EEA Technical Report No. 3/2009, 2009.

Rather than seeking a solution that is optimal for some particular scenario, or the best-estimate set of expectations about the future, the technique seeks a robust approach, one that performs well relative to alternatives across a very wide range of plausible alternative future scenarios. That is, rather than ask "what will the future bring?" robust decisionmaking encourages decisionmakers to ask "what can we do today to shape a potentially surprising future more to our liking?"

When I first started my career, a big policy study for a government client might involve tens of Monte Carlo simulation runs or sensitivity tests of one key assumption at a time. Last month, we concluded a study of future energy use in Israel that examined seven strategies in 1,400 potential future states of the world, generating 9,800 simulated scenarios out to the year 2030.[12] Today we can:

- Generate literally hundreds of thousands of cases,
- Use statistical analysis to group these cases into clusters of key scenarios,
- Analyze these scenarios to test the resilience of alternative courses of action,
- Evaluate tradeoffs among the most promising alternatives, and thereby
- Enable decisionmakers to identify strategies that are robust over a wide range of seemingly low-probability futures.

Let me try to tie together the several threads I've tried to describe. First, the challenges of analyzing and managing risks are increasingly complicated by the growing interconnections among societies, economies, and industries.

Second, that fact means that when it comes to catastrophe risk, the risk management community must devote as much analytical attention to major risks emanating from the international security environment and the introduction of new products and substances as it devotes to the risks of natural disasters.

Third, the challenge is not only to understand analytically the propagation of risk through complex, interdependent systems, but also to understand analytically risk-risk tradeoffs.

Fourth, there are promising new approaches to formulating analytical models for these 21st century challenges, but more work on them is needed.

And, finally, governments in particular need better ways of making sound near-term decisions about risk in the long-term future.

That brings me back to the ICRM, to my own institution, and to the rest of the analytical community. Let me close with four observations in the form of challenges to us all.

First, do not neglect catastrophic risks in the international security environment and in the area of product-based public health disasters.

Second, make sure that all work is guided by a systems view so that interconnections are not neglected. Governments are generally not organized to deal with complex systems. They have even more silos than universities. So, the analytical community can play an especially important role in helping policymakers recognize and take account of interconnections.

Third, recognize that, in a world of complex interconnections, we need a global outlook to effectively manage catastrophic risk. I am using the world "global" in a sense that is even

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[12] Steven W. Popper, Claude Berrebi, James Griffin, Thomas Light, Endy Y. Min, and Keith Crane, *Natural Gas and Israel's Energy Future: Near-Term Decisions from a Strategic Perspective*. Santa Monica, CA: RAND Corporation. MG-927-YSNFF. 2009.

broader than encompassing many different nations. We also need to engage both the public sector and the private sector in defining the systems that are at risk.

Finally, we must continue to explore methodological developments, not only in identifying, sizing, and comparing risks but also in helping decisionmakers expand the range of possible futures they consider and helping them improve their evaluation of courses of action. In other words, we need to strengthen both our models and our use of models.

General Douglas MacArthur once said, "There is no security on this earth. Only opportunity." And with opportunity comes risk, so the ICRM has a great future ahead of it as it seeks to advance and transform the important field we are all discussing this week.

My congratulations again to Professor Shah and Professor Pan for their vision.