EE190/390: Nuclear Weapons, Risk and Hope

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Reading for next class

Read this handout and the *Newsweek* essay (10 minutes) quoted below for a succinct summary of the nuclear optimist's perspective. While I question Tepperman's optimism, he presents some very real barriers to nuclear disarmament that warrant serious attention.

Read *Soaring, Cryptography and Nuclear Weapons* (10 minutes). That article presents the risk analysis framework for nuclear deterrence in non-technical language. The next handout will have some material to augment that article by better illuminating the connection between nuclear terrorism, nuclear proliferation and nuclear war. The more technically inclined among you may also want to read my paper paper *Risk Analysis of Nuclear Deterrence*, but that is optional reading.

Background

How much risk do we incur by relying on nuclear weapons for our security and, if that risk is unacceptable, what hope is there of reducing the risk to an acceptable level? Those are the two questions that need to be answered for society to respond, and they are the questions that this seminar will address.

Clearly some risk is associated with nuclear weapons. Some believe that the risk is minimal, with "nuclear optimists" maintaining that nuclear weapons make us safer. Others believe that the risk is highly unacceptable and that the whole concept of national security needs to be completely rethought if humanity is to survive.

While I am in the latter camp, I welcome creative input from those who think differently. If I am right that a serious threat is being overlooked, I need to better understand the barriers that keep people from seeing that. Since I need to learn from those who think differently from me, having such students in the seminar would be a plus. For the same reasons, I encourage seminar participants to seek out the best arguments supporting the nuclear *status quo,* and bring them to my attention.

I am also working on a Stanford-based project with a more activist goal. That project is distinct from this seminar and people can participate in one, or the other, or both.

Nuclear Optimism

Given the public's strong support for nuclear weapons, most people are, at least implicitly, nuclear optimists. A recent *Newsweek* essay, *Why Obama Should Learn to Love the Bomb,* summarizes the viewpoint of nuclear optimists as follows:

> A growing and compelling body of research suggests that nuclear weapons may not, in fact, make the world more dangerous, as Obama and most people assume. The bomb may actually make us safer. … As Kenneth Waltz, the leading "nuclear optimist" and a professor emeritus of political science at UC Berkeley puts it, "We now have 64 years of experience since Hiroshima. It's striking and against all historical precedent that for that substantial period, there has not been any war among nuclear states.

Risk Analysis and Time Horizon

A key parameter that is missing from such optimistic assessments is the time horizon until nuclear deterrence fails. Given that most participants in this seminar have around 60 years additional expected life span, 64 years of nuclear non-use can be shown to be inadequate evidence for optimism. Thinking of those 64 years as 64 tosses of a weighted coin that landed Tails every time, what does that tell us about the chances of the coin showing Heads? Heads corresponds to a nuclear war occurring in a particular year and Tails corresponds to a nuclear war not occurring that year.

Flipping a coin 64 times and having it land Tails every time tells us that the coin is unlikely to show Heads very often, but statistically speaking, if we want 95% confidence in our predictions, we cannot predict that the coin will show Tails for more than approximately the next 20 tosses – and if 95% confidence is considered inadequate given the high stakes involved, that would reduce the time horizon below 20 years.

Viewing the data as 64 years of nuclear non-use is inadequate to distinguish whether deterrence will work long enough (a good question in itself – how long is "long enough"?), but risk analysis can provide a more informed answer by viewing the data differently. Roughly speaking, risk analysis looks at whether, and how often, the coin teetered on its edge, leaning first one way and then the other, before finally landing Tails. In the case of nuclear deterrence, this relates to whether there were any near misses, how serious they were, and how often they occurred. The 1962 Cuban Missile Crisis is the most infamous example of the nuclear coin almost landing Heads, and there are many others as well, some of which we'll discuss in later class meetings.

The first step in bringing risk analysis to bear on nuclear deterrence is to determine an acceptable level of risk. When studying systems such as nuclear power plants, where a catastrophic failure destroys the system, engineers use Mean Time To Failure (MTTF) as a measure of risk. If, as is often the case, such MTTF's are only known approximately, we often use "order of magnitude" estimates, in which all quantities are rounded to the nearest power of 10.

For mathematical reasons beyond the scope of this class, MTTF is not the correct term for the length of time before nuclear deterrence is expected to fail. (For the more mathematically inclined, footnote 3 of my paper *Risk Analysis of Nuclear Deterrence*, discusses that issue.) I therefore use the term *time horizon* in place of MTTF. Loosely

speaking, if the time horizon for a failure of deterrence is 1,000 years, then there is one chance in a thousand of deterrence failing in the next year. That might sound small but, unless the risk is reduced, it builds up to about an 8% fatality rate over the 80 year expected lifetime of a child born today. To avoid giving an impression of greater accuracy than is warranted, that 8% is rounded to 10%. Equivalently, the 80 year life expectancy is rounded to 100 years, the nearest power of ten (the nearest order of magnitude in geek speak).

What time horizon is acceptable for a failure of deterrence?

The table below puts the risk for various time horizons into perspective. The second column is the probability that a child born today will die as a result of our reliance on nuclear weapons causing the end of civilization. (Because that death would be part of a much larger catastrophe, it is much more serious than an individual death.) The third column is the number of nuclear power plants that would have to surround your home town to produce an equivalent level of risk. The last column is how often you would have to skydive from an airplane to produce an equivalent level of risk, except it is not just you in the harness. The whole world is there with you.

Time Horizon (years)	Pr(child dies)	# of nuclear plants	Skydiving
10	Almost 100%	100,000	30 times per day
100	50%	10,000	3 times per day
1,000	10%	1,000	Twice a week
10,000	1%	100	Once a month
100,000	0.1%	10	Once a year

Questions to think about:

1. Where in the above table do you think the time horizon for a partial failure of nuclear deterrence lies? (A partial failure means that at least one nuclear weapon has been used in anger, whether by terrorists or a nation state.)
2. Where in the above table do you think the time horizon for a complete failure of nuclear deterrence lies? (A complete failure means full-scale nuclear war.)
3. Where in the above table do you think an acceptable level of risk lies?