EE190: Nuclear Weapons, Risk and Hope

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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.

I am in the latter camp, but this seminar will treat all views respectfully. Aside from the fact that this is a university, open to all reasonable viewpoints, 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 bringing 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. Some key excerpts:

> 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 64 years additional expected life span, 64 years of nuclear non-use is inadequate evidence for optimism, so what other evidence might be brought to bear? (To see why, think of the last 64 years as one round in a game of Russian roulette. The gun has an unknown number of chambers and only one bullet. If all we know is that the gun didn't go off on that first round, would you be willing to risk your remaining roughly 64 years by playing a second round: spinning the cylinder, pointing the gun to your head and pulling the trigger?)

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 the coin will show Tails on more than the next 21 tosses – and even 95% confidence is inadequate given the stakes, reducing the time horizon that we can predict with adequate confidence even below that 21 year figure.

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 nuanced answer by viewing the data differently. Roughly speaking, risk analysis looks at whether, and how often, the coin teetererd 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 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 this 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. (So 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.)
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?

Suggested reading

Scott Sagan and Kenneth Waltz' book, *The Spread of Nuclear Weapons: A Debate Renewed,* presents both the nuclear optimist and nuclear pessimist viewpoints. For a shorter read, to see the viewpoint of nuclear optimists, I'd suggest the *Newsweek* essay that was mentioned earlier.

For the viewpoint on why change is needed, I'd recommend my article *Soaring, Cryptography and Nuclear Weapons*. That article needs improvement on the connection between nuclear terrorism, nuclear proliferation and nuclear war and the next two pages of this handout provide supplemental information to do that. The more technically inclined among you may also want to read my paper paper *Risk Analysis of Nuclear Deterrence*.

Addition to "Soaring Cryptography and Nuclear Weapons"

As noted above in the Suggested Reading section, the article needs improvement in relating nuclear war, nuclear terrorism and nuclear proliferation. This revised introduction to section 2 attempts to do that.

Section 2: Substates

Part of society's difficulty in envisioning the threat of nuclear war can be understood by considering the overly simplified model shown in Figure 2 below:

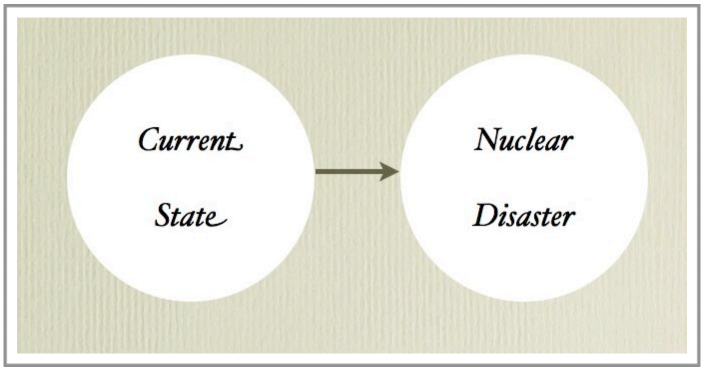

Figure 2. An overly simplified model

The circle on the left represents the current state of the world, while the one on the right represents the state of the world after a full-scale nuclear war. Because that disaster would be a state of no return, no arrow is shown going from it, back to our current state. Even though an arrow is shown to indicate the possibility of moving from our current state to one of global war, that path also seems impossible to most people. How could we possibly transit from the current, relatively peaceful state of the world to one where civilization had been destroyed? The answer lies in recognizing that both states (both conditions of the world) depicted in Figure 2 are, in reality, super-states, each composed of many substates. That more nuanced view is shown in Figure 3 below.

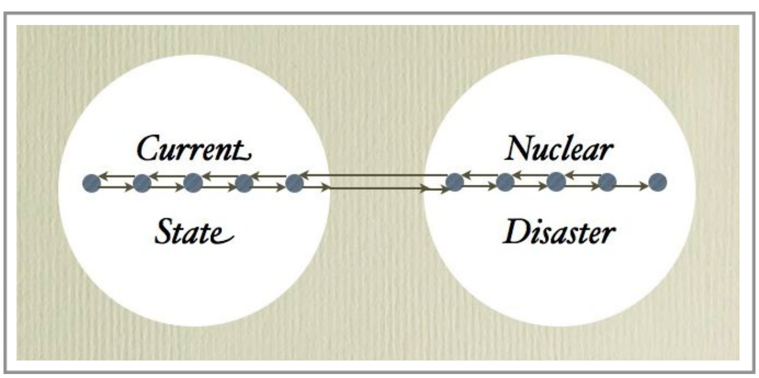

Figure 3. A more accurate model

The circle or super-state labeled "Current State" encompasses all world conditions short of a nuclear weapon being used in anger. It therefore covers a wide range of possibilities, with varying degrees of risk. Society is partly correct in thinking that it is impossible to move from our current state to one where a nuclear weapon has been used in anger because, most of the time, we occupy one of the substates far removed from the nuclear threshold – the region separating the two circles of Figure 3 – and there is little or no chance of a nuclear disaster.

But it is possible to move from our current substate to one slightly closer to the brink, and then to another closer yet. As described in the next section, just such a sequence of steps led to the Cuban Missile Crisis and could lead to a modern day crisis of similar magnitude involving Georgia, Estonia, Cuba, or other some other hot spot where we are ignoring the warning signs.

Similarly, the circle labeled "Nuclear Disaster" also encompasses a number of substates. A nuclear terrorist attack which destroyed New York or Moscow or Tel Aviv would be a nuclear disaster, but not a state of no return. The same is true for a limited nuclear war between the United States and Russia and for a regional nuclear war between India and Pakistan. But once the nuclear threshold is crossed, we are in an entirely new world where the possibility of a full-scale nuclear war becomes much clearer. That state of no return is depicted in Figure 3 as the final substate on the right, with no path back to the preceding substate.

This article is concerned with reducing the risk of a full-scale nuclear war to an acceptable level but, as the preceding discussion shows, doing that will also require reducing the risks of nuclear terrorism and proliferation. The converse is not true. If we only reduce the latter risks, we do not necessarily also reduce the risk of destroying civilization. Studying the risk of full-scale nuclear war, as is done here, provides a system level view that would be lacking in a more limited study of nuclear terrorism or proliferation alone.

<u>Section 2a: Steps That Led To the Cuban Missile Crisis</u>

The Cuban Missile Crisis surprised President Kennedy, his advisors, and most Americans because we viewed events from an American perspective and thereby missed warning signs visible from the Russian perspective….

> You can now pick up reading Section 2 of the original article, starting with the paragraph shown immediately above. I've designated that paragraph as the beginning of a new section because that probably makes sense in the revised paper. I'd appreciate feedback on how you think this addition works.