**PANEL #2**

THE HUMANITARIAN IMPACT OF NUCLEAR WEAPONS: WHAT HAPPENS IF THE BOMB IS USED?

***Climate Effects of Large Scale Nuclear War***

by

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**ROBOCK:** So if you haven't had enough doom and gloom yet, let me describe the effects of a large scale nuclear war between the U.S. and Russia. It would be much worse than I've described already, this is a trident nuclear submarine. It has 100 nuclear weapons and they're much bigger than the ones that were dropped on Hiroshima and Nagasaki. So each trident has the explosive power of about 1,000 Hiroshimas and we have 14 of them. That's only about half of our nuclear arsenal so that makes 28,000 Hiroshimas total. And Russia has about the same size so that makes 50,000 Hiroshimas worth of explosive power in our current nuclear arsenals between the U.S. and Russia.

We decided to then calculate the effects on climate of using the entire arsenal. We did a calculation of 150 million tons of smoke, not 5 million, but a 150 million, 150 teragrams of smoke. How could you get that much smoke? That was a standard nuclear winter scenario that we did 30 years ago. We took a third of each of the U.S. and Russian arsenals and used them in a war.

But it turns out you can still get that much smoke today, and we're trying to figure out why. As we looked at the targeting that they did, they would bomb every possible target in the U.S. and Russia, then they saw this huge pile of weapons. It turned out they're putting nine bombs on every possible target.

So now that was how much overkill we had and that was using only a third of the arsenal. So we can still produce that much smoke with the 4,000 weapons which is what the new START Treaty has committed us to. So here is another movie where the smoke would go from being dropped on the U.S. and Russia, it would be much thicker smoke and blocking out more sunlight.

And if we look at how the temperature would change, one year later, this is in degrees Celsius, temperatures would be 20 to 40 degrees colder than now. So it would be very cold over the middle of the continent, 50 to 80 degrees Fahrenheit.

So let's take a point in Ukraine and see how the temperature would change. This black line is the normal daily minimum temperature without nuclear war and in the summer time, it would get to 20 degrees, that's 70 degrees Fahrenheit. The red line is the temperature once the smoke goes into the atmosphere. The temperatures would rapidly plummet below freezing -- and that's the black line, zero degree Celsius -- and stay below freezing for at least two years.

So obviously, you could do no agricultural work in this situation -- nuclear winter, it's really nuclear winter. And we calculate how the global

temperature would change. The 5 million tons that I showed you before -- I had to redo the scale. It’s now 150 million tons, temperatures colder than during the Ice Age.

And if you put it on the global warming curve, again, I have to rescale it, temperatures colder than Old Ice Age. If you use one-third of that -- 50 teragrams -- you get about half the climate change; that's what you would get if the U.S. attacked Russia in a first strike and Russia didn't do anything. Temperatures would still get so cold; we'd all die from starvation. That means we would be acting as a suicide bomber.

So what's new, a nuclear war between any nuclear state using much less than 1 percent of the current nuclear arsenal will produce climate change unprecedented in human history. Such a so-called small nuclear war would reduce food production by 20 percent to 40 percent for a decade. Nuclear winter theory was correct. The current arsenal can still produce nuclear winter and the effects would last for more than a decade. Do you believe me?

That's good because all I've talked to you about so far is theory, is climate model calculations. I haven't shown you any observations to prove it and so as a scientist, the way I'd like to test my theories is with observations, but I don't really want to do this experiment in the real world. And so, the way we tested is we looked at analogs. We looked at parts of the theory to see if we could find things that behave that way, that can inform us, and tell us whether to believe those parts of the theory.

So, some of the analogs we look at are the seasonal cycles. We know it gets cold in the winter, that's what gave us our name, nuclear winter. The daily cycle we know -- it gets cold at night. So you just have a feel for, if you turn off the sun, how cold it gets. Unfortunately, we also have examples of cities that burned both from natural causes, accidents, from conventional bombs, and nuclear bombs -- I don't like the term conventional, it makes it sound like it's OK. And then we can investigate -- Do particles get transported around the world like our model says? Does it get cold when they put particles in the atmosphere? So I'll show you a few examples of that.

This was Dresden which was burned by fire-bombing just near the end of World War II, Kurt Vonnegut was a Prisoner of War there and wrote *Slaughterhouse Five* based on his experiences. It's an amazing description of what it looks like. This is a drawing of the U.S. B-29s dropping incendiary bombs on Yokohama.

Now did you know that the last two cities that were burned by the U.S. during World War II were Hiroshima and Nagasaki? Does anybody know how many total cities in Japan were bombed by the U.S. with incendiary bombs, genocidal incendiary bombs killing civilians during the summer of 1945? Yes.

(UNKNOWN): Every major city.

ROBOCK: Every major city. And how many cities all together? It was 69 cities. The total area burned in Hiroshima, Nagasaki was less than 3 percent of the total area burned in Japan.

So here are maps of the major cities of Japan, the red is the part that was burned. There was a horrible raid in Tokyo in March 9th and 10th, the first two planes painted an X of fire with napalm in the city. And the others used it as a target, more than 300 bombers came in and over 100,000

people died. More people burned to death in six hours than ever before in the history of our planet. And then Kawasaki, Yokohama, Kobe, Osaka, Nagoya -- all of these cities were burned.

And this is Shizuoka, I've never heard of it either, this is one of the cities that was burned and bombed. And from this book by Martin Caidin, *A Torch to the Enemy*, by the time the atomic bombs had struck -- adding less than 3 percent to the devastated areas, 69 cities were bombed, 178 square miles, making 21 million people homeless or being affected. Cities were being destroyed three or four at a time, two or three every two or three days.

Now, people have asked me, so what about smoke? Do you have any observations that it caused climate change? And I've been thinking about that for a long time, so just in the last month or so, I've done a study to try and calculate how much cooling you would expect and is there any evidence for it. And we just submitted a paper on this last week.

This is a graph of the amount of sunlight -- there were two observatories -- one in Chile and one in California, and the blue is the amount of sunlight reaching the ground. And this is 1945, it's 1944-1945, so the question is: Was this reduction of sunlight caused by the smoke from World War II? We calculated how much reduction you would expect and it was just about right.

Then we looked at the temperature and it turns out that the ocean temperatures are not very good, but if you look at just temperatures over land -- and the black is what climate models say would have happened if there hadn't been any smoke -- indeed you've got this cooling of a couple of tenths of a degree Celsius over land at 1945, and about four-tenths of a degree of Fahrenheit. So I think this is evidence that we actually can see the effect of the smoke on climate from the bombing then.

Now we can also see that effect with dust storms on Mars. This is six to -- four weeks in Mars, a dust storm started here and then the dust was heated by the sun and lofted and end up covering the whole planet. So this whole model I showed you of the dust covering the planet, we observed happening in Mars.

An asteroid killed the dinosaurs, we think most of the effect was the smoke. There were fires started around the world and you find a layer of sediment along with iridium.

This is a fire in Yellowstone Park, I took this picture 19 years after the fire. And I did a study and these are plumes of smoke coming out of Yellowstone and over the Midwest that next day temperatures were 6 degrees Celsius, 10 degrees Fahrenheit colder than normal under the smoke, so we can see you really do get cooling because of smoke. It turns out there's something called Pyrocumulonimbus, if there's a strong enough forest fire, it can produce its own cloud and pumps it up into the stratosphere where we can observe it with satellites.

This is the famous story of the painting, *The Scream*. This sunset is a red and yellow volcanic sunset from what he remembers in the 1883 Krakatoa eruption. And so this reminds me to look at volcanic eruptions. Of course this is how we all feel about nuclear war, the part of the bottom here. But this is the El Chichon volcano before the next 1982 eruption. This is afterwards. And I use satellite pictures to track the fluid of dust and it

went in three weeks around the world being blown by the air in the stratosphere. So it’s another piece of evidence that the particles can be transported around the world.

This is the Laki volcano in 1783. That's the bus we took and these are SUVs just to give you scale. This whole crack opened up for eight months and it caused famine in Africa and Asia. The Tambora volcano in 1815 produced the year without a summer that Ronald Reagan was talking about, it erupted.

And that next summer in 1816, Percy Bysshe Shelley, his wife Mary and their friend Lord Byron were having a vacation on the shores of Lake Geneva, but it was so cold and gloomy because of the climate change. They couldn't go on hiking and boating, so they said, "We're writers so let's have a contest to see who can write the scariest ghost story. And Mary Shelley wrote Frankenstein inspired by the climatic effect of a volcanic eruption and the monsters climbing over the ice at the beginning.

Now Carl Sagan who was a great science communicator and was one of the authors of the first American paper on this, was asked: Well, what about banning nuclear weapons, don't we depend on them for our defense? And he said, "For myself, I would far rather have a world in which the climatic catastrophe cannot happen, independent of the vicissitudes of leaders, institution and machines, this seems to me to be elementary planetary hygiene as well as elementary patriotism."

And I agree with him, I think elementary planetary hygiene demands that we eliminate nuclear weapons much faster than it has been eliminated until now, so that we don't have the chance of them being used by accident or by a crazy leader or on purpose. So the policy implications of what I've told you are immediate American and Russian reductions down to the same arsenals as all the other nuclear nations; 200 weapons would prevent nuclear winter. You would get large climate change but it wouldn't be temperatures below freezing and you wouldn't get global famine. But in order to prevent any of the effects we need to have nuclear abolition to prevent nuclear famine.

So I hope we learned from this to have our planet looking as beautiful as it is for a long time to come. Thanks.

(APPLAUSE)

And we've written many journal articles about this and this PowerPoint and lots of other stuff is available at this web page, if you want more information. http://climate.envsci.rutgers.edu/nuclear/