Winter-Safe Deterrence as a Practical Contribution to Reducing Nuclear Winter Risk: A Reply

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In a recent issue of this journal, I published an article proposing the concept of *winter-safe deterrence*. The article defined winter-safe deterrence as "military force capable of meeting the deterrence goals of today's nuclear weapon states without risking catastrophic nuclear winter".[1] The article and a summary version published in the *Bulletin of the Atomic Scientists*[2] have since stimulated extensive discussion in social media, the *Bulletin*,[3] and now a symposium in this journal. The discussion has been productive for refining certain aspects of winter-safe deterrence and getting an initial sense of how the concept may be received. This is exactly what should happen for a new idea with significant policy implications. As a humble author, I welcome the discussion, including the points of criticism. I likewise thank the participants in this symposium for their contributions, as well as the many others who have commented elsewhere on winter-safe deterrence. In this essay, I reply to the contributions to this symposium as part of a broader discussion of winter-safe deterrence and the discussion it has sparked.

Background on Winter-Safe Deterrence

The starting point for winter-safe deterrence is the observation that a sufficiently large use of nuclear weapons could have global environmental consequences that could be catastrophic for humanity. The term "nuclear winter" was coined to refer to global cooling such that winter-like temperatures occur year-round, but for convenience I use the term to refer to the full set of global environmental consequences, which also include reduced sunlight and precipitation and increased ultraviolet radiation. The environmental science of nuclear winter has an increasingly robust basis, drawing on models developed for the study of global warming. The human impacts of nuclear winter are less studied and less well understood. One notable exception is a study estimating two billion people at risk of starvation from a nuclear winter caused by an India-Pakistan nuclear war involving 100 (50 per side) nuclear weapons of 15 kiloton yield.[4] A crucial and poorly resolved question is how large of a nuclear winter it could take to cause permanent catastrophic harm to human civilization.[5] Other effects of nuclear weapons can also cause significant harm, but only on a much smaller scale. And so nuclear winter is not just another of the "vast array of inhumane impacts of the use of nuclear weapons", as Patricia Lewis writes; it is by far the most important.[6]

The possibility of nuclear winter suggests that humanity would be safer if it did not have so many nuclear weapons. Indeed, since nuclear winter research first appeared in the 1980s, nuclear winter has motivated calls for nuclear disarmament. This link continues today, for example, in the ongoing initiative on the humanitarian impacts of nuclear weapons, which cites nuclear winter as one basis for accelerating nuclear disarmament. However, nuclear-armed states have replied by arguing that the severe humanitarian impacts are why nuclear weapons are such effective deterrents, even if there is some possibility that nuclear deterrence could fail.[7] As Jean Pascal Zanders writes, "nuclear weapons still occupy a central position in the military doctrine of several nations and… as a consequence, their removal from military arsenals is not a given".[8]

There would seem to be a tradeoff between deterrence and disarmament. Either nuclear weapons are disarmed, in which case their contribution to deterrence is lost, or they are retained, in which case the possibility of their humanitarian impacts remains. This apparent tradeoff structures much of contemporary international nuclear weapons politics: some favor deterrence; others favor disarmament. For my part, to the extent that a choice must be made, I favor disarmament, because the risk of nuclear winter appears to significantly outweigh any possible benefits to deterrence that the possession of nuclear weapons might bring.

But perhaps the tradeoff can be avoided, or at least lessened. Perhaps it is possible to retain some significant deterrence capability while reducing the harms associated with deterrence failure. In particular, perhaps satisfactory deterrence can be achieved with other weapons while avoiding catastrophic global harms such as nuclear winter. This suggests the outlines of a political deal: the current nuclear-armed states get to keep their deterrence, and the rest of the world gets to be safe from deterrence failure. This is the essential idea of winter-safe deterrence.

And so, at its core, winter-safe deterrence is intended as a practical policy option, in consideration of ongoing nuclear weapons politics. Indeed, some aspects of winter-safe deterrence are already policy. At least one state, the United States, is already using advanced conventional weapons to shift its deterrence burden away from nuclear weapons.[9] To my knowledge, the US shift is not motivated specifically by concern for nuclear winter. However, the net result is to shift US military forces in a winter-safe direction. Thus winter-safe deterrence is not strictly a thought experiment, though it certainly is that too, as Brett Edwards notes,[10] and it is not stuck in the "snow globe" (or ivory tower), as Lewis claims.[11]

I wholeheartedly support Lewis's call for academics to step down from the ivory tower and engage with actual political processes. Indeed, I have participated in these processes myself, including the initiative on the humanitarian impacts of nuclear weapons, which Lewis appears to support.[12] However, Lewis's essay seems to equate practical politics with the humanitarian initiative. This is a mistake. Perhaps the humanitarian initiative will be successful in achieving rapid and complete nuclear disarmament, as many in the initiative advocate. In this case, winter-safe deterrence would be unnecessary for reducing nuclear winter risk, though it could still be useful for reducing the probability of war. But the humanitarian initiative might not achieve rapid and complete nuclear disarmament, for example due to concerns about diminished deterrence. In that case, winter-safe deterrence could offer a way forward. It is appropriate for academics to think a few steps ahead on such matters. A bit of ivory tower can be, in practical terms, quite useful.

As an important aside, we should recognize that there are many ways to reduce nuclear winter risk and other nuclear weapons risks. The humanitarian initiative and winter-safe deterrence are just two of them. In a separate paper, I survey options for reducing nuclear winter risk, including by reducing the probability of nuclear war (such as by improving relations between nuclear-armed states), by reducing the severity of nuclear winter if nuclear war occurs (such as by implementing no-cities targeting), and by increasing humanity's resilience to nuclear winter (such as by stockpiling food and other resources).[13] So while the focus here is on winter-safe deterrence, it is very much not the only game in town. Readers who, for whatever reason, dislike winter-safe deterrence may find other options more attractive.

The Merits of Deterrence

Before getting into the details of winter-safe deterrence, I should comment on the general merits of deterrence, including nuclear deterrence. Christian Enemark and Patricia Lewis both argue against policies of nuclear deterrence and therefore against winter-safe deterrence: If states should not have nuclear deterrence in the first place, then there is no sense in replacing nuclear deterrence with some other comparable deterrence.[14] They raise important issues that are worth addressing in turn.

The first issue is how well nuclear weapons deter. Lewis claims that "there is no proof that nuclear deterrence works". Enemark similarly remarks that deterrence "is an anti-phenomenon, merely guessed at, rather than something that is observed or observable". However, it would be a mistake to reject some policy measure just because it cannot be empirically "proven" the same way that something like gravity or electricity can be. Furthermore, just because deterrence is ultimately psychological does not mean it is unobservable. This holds for international nuclear deterrence as well as for local efforts to deter crime and other deviant behavior. Instead of dismissing deterrence outright because it *often* cannot *easily* be observed, we should make the most of what evidence is available to formulate sensible estimates for how effective deterrence is in particular circumstances.

For starters, the probability of nuclear deterrence failure is not zero. Enemark and Lewis both emphasize the possibility of deterrence failure, including through accident or inadvertent use, a possibility I am very well aware of.[15] It is because deterrence can fail, and nuclear weapons can be used, that nuclear winter and other impacts of nuclear weapons merit attention. But deterrence without nuclear weapons can also fail. The key parameter is not the probability of nuclear deterrence failure; it is the change in the probability of deterrence failure that comes from possessing nuclear weapons.

The best analysis of empirical evidence that I am currently aware of finds a lower probability of war between two nuclear-armed states and a higher probability of war between one nuclear-armed state and one non-nuclear-armed state. The study further finds a higher probability of smaller conflicts between two nuclear-armed states, in line with the stability-instability paradox.[16] As Lewis notes, the evidence surrounding deterrence is limited and contestable, but we must make the most of what we have. The above finding suggests that unless other deterrents are developed, nuclear disarmament could increase the probability of war between current nuclear-armed states. Noting that the current nuclear-armed states include many of the world's largest states and alliances, war between them could be disastrous. So nuclear deterrence would appear to have some merit. I personally would prefer it if the evidence indicated no merit to nuclear deterrence, as this would support my preferred position of rapid nuclear disarmament. But we should give the evidence an honest read.

This raises the second issue, which is whether nuclear deterrence should be policy. This is ultimately an ethical question, but one tightly linked to the empirical evidence. Nuclear deterrence may have some merit, but it also comes with major risks. If nuclear deterrence fails, massive harm will result. Enemark finds this harm to be "the moral flaw in nuclear deterrence theory", sufficient to render nuclear deterrence wrong.[17] I would instead argue that the harms of nuclear deterrence failure should be weighed against the benefits of nuclear deterrence. If nuclear weapons did not improve deterrence, then the argument for nuclear disarmament would be clear. However, if, as it appears, nuclear weapons do (imperfectly) improve deterrence, then we face a difficult tradeoff between the probability and severity of war. Possessing nuclear weapons could mean a lower probability of nuclear war but a larger severity.

This is where the ethics of global catastrophic risk is relevant. A sufficiently large global catastrophe could kill billions around the world and permanently harm human civilization. The permanent harm falls on countless members of future generations, which is an extremely large severity. Because of nuclear winter, a war is much more likely to cause permanent global catastrophe if the war involves a large nuclear arsenal. Thus, the possession of large nuclear arsenals drastically increases the severity of war, so much as to dwarf any potential reductions in the probability of war. This is why I favor rapid nuclear disarmament, despite the evidence pointing to nuclear deterrence reducing the probability of war between nuclear-armed states.

Zanders questions my discussion of global catastrophic risk, suggesting that it uses too long of a time horizon for future generations. In my winter-safe deterrence paper, I stated that "barring catastrophe, humanity could survive for millions or even billions of years into the future".[18] In other work, I have called for longer time horizons, all the way up to infinity.[19] Zanders favors time horizons in the range of one to ten million years, corresponding to the lifetimes of typical mammalian species.

Other scholars have made similar reference to typical species lifetimes in this context.[20] The problem with this reasoning is that *homo sapiens sapiens* is not a typical species. Humans are unique in our conquering of the globe, our culture, and our technology, among other things. If we can manage to avoid destroying ourselves, then we have the capacity to live into the distant future, perhaps even beyond the billion-or-so years that Earth will remain habitable. Yes, we will genetically evolve along the way, but presumably our descendants will remain worth caring about. That said, the practical conclusions remain even if we restrict our attention to "only" millions of years into the future. The practical conclusion here is to go to great length to avoid catastrophic nuclear winter.

Finally, there is a practical issue regarding deterrence. Even if it is morally wrong for states to have policies of nuclear deterrence, some states still have these policies. Perhaps their minds can be changed through moral argument. This is worth a try. But, perhaps it would be more effective to meet them partway by finding other, safer means of deterrence. Winter-safe deterrence is morality for a world in which not everyone follows the same morals.[21]

The 50 Weapon Winter-Safe Limit

The ethics of global catastrophic risk leads directly to the proposal in my winter-safe deterrence paper for a global limit of 50 total nuclear weapons. Zanders quite reasonably notes that "How [I] arrive at that number is unclear".[22] This is quite reasonable because there simply is no great clarity to offer. The size of a nuclear war that could cause catastrophic harm to humanity depends on how effectively humanity can cope with nuclear winter, but this is a thoroughly murky topic. One issue is that little research has been conducted on this, which is why I argue that the winter-safe limit could be adjusted pending further research. However, another issue is that this is an inherently difficult topic to study. Extrapolating from climate studies, as Zanders suggests, does not yield the necessary information, which is ultimately about humanity's resilience, not about climate. Zanders also complains that I do not provide any detailed risk analysis, but such analysis is better suited for a dedicated paper on the topic; my objective was to move quickly to policy implications.

In the face of such uncertainty, and with the impacts being so potentially severe, prudent risk management suggests erring on the safe side. This is why my number of 50 is significantly lower than prior nuclear winter studies, which have proposed limits of a few hundred per nuclear-armed state[23]: The prior studies are, I believe, not adequately accounting for the uncertainty in how bad nuclear winter would be for humanity. Furthermore, given the murky nature of the topic, the number 50 should not be interpreted with any precision. If someone was to instead say 40 or 60, I would not complain. In practical terms, the most important part is that the number is greater than zero (though zero nuclear weapons would of course also be winter-safe), it is much less than the status quo of thousands, and it is also significantly less than the hundreds per state commonly associated with minimum deterrence.

Winter-Safe Deterrents

If minimum deterrence with nuclear weapons is not winter-safe, then other weapons may be able to make up the gap. It is understandable that this is the part of the winter-safe deterrence concept that has proven most controversial. It is controversial within my own mind as well. I would quite rather for states to resolve their differences and get on with general and complete disarmament, not just nuclear disarmament. If such resolution can be quickly achieved, then I would gladly abandon the no-longer-relevant idea of winter-safe deterrence. But such resolution might not be quickly achieved, even despite our best efforts. Thus, winter-safe deterrence is worth considering.

My aim for winter-safe deterrence research is to consider the entire landscape of candidate weapons. I regret that the discussion has focused almost exclusively on biological weapons. While I understand the interest in the topic, I hope that other weapons can get some attention. In this

symposium, the closest we come is Lewis's passing claim to be able to "dismantle the paper substitute-weapons-system by substitute-weapons-system" while saying that instead she will cover the general topic of nuclear deterrence.[24] I would have liked to see Lewis's attempted dismantlement; perhaps it could have taught us something about overall prospects for winter-safe deterrence.

At present, the weapon type I believe is most in need of closer consideration is electromagnetic weapons, including nuclear electromagnetic pulse. Electromagnetic weapons have several advantages: they primarily affect infrastructure, causing only indirect harm to human bodies; civil defense may be prohibitively expensive; the weapons are not banned by treaty; and there are no strong norms against them. Nuclear electromagnetic pulse has further advantages: a wide but non-global geographic area can readily be hit; the number of nuclear weapons needed is likely consistent with winter-safe arsenal limits; no proliferation is needed, as the nuclear-armed states already have the weapons; and second-strike capability is readily feasible using existing technology. This is an impressive list of advantages, more than enough to merit closer attention.

Could electromagnetic weapons work as deterrents? The weapons destroy electrical equipment, and so electromagnetic threats are essentially threats to destroy a country's economy. At a minimum, this would send people back to simpler times. That alone could be enough to deter in many situations. The infrastructure disruption could also prevent critical resources from being produced and distributed, which could cause disorder and death. That possibility could add to the deterrence effect.

Could electromagnetic weapons cause a permanent global catastrophe on the same order as nuclear winter? Today's economy is globally interconnected, so major disruption in one area could spread worldwide. This is a critical question for further research to resolve if electromagnetic weapons are to be considered for a significant deterrence role. Answering this question is worthwhile anyway in the contexts of electromagnetic attacks that are not deterrence-related and the threat from geomagnetic storms.

Biological Weapons

While I had not intended to spark so much discussion specifically about biological weapons, I have found the discussion insightful. I hope that similar discussions can be held for other weapon types. The discussion of biological weapons has been critical of my paper's tentative suggestion for a role for non-contagious biological weapons in winter-safe deterrence. I see three types of objections to non-contagious biological weapons playing a role in winter-safe deterrence: moral, political, and psychological. The moral objection is not compelling, the political objection may be resolvable, but the psychological objection makes non-contagious biological weapons seem an unlikely candidate for a significant role in winter-safe deterrence.

The moral objection states that non-contagious biological weapons are inherently immoral weapons and thus cannot be approved for any use. For example, Gigi Kwik Gronvall states that considering biological weapons would be "morally reprehensible".[25] However, our moral objections should ultimately be for the harms caused by weapons, not for the types of weapons causing the harms. Non-contagious biological weapons can cause much harm, but this is much less harm than what can be caused by the status quo large nuclear arsenals. Thus the moral objection is not compelling.

The political objection states that including non-contagious biological weapons in winter-safe deterrence could cause additional weapons proliferation and harm to international treaties and norms. The political objection is frequently made; in this symposium, Edwards is especially vocal, arguing that modifying the Biological Weapons Convention to permit current nuclear-armed states to pursue non-contagious biological weapons "would open the door for other states to pursue such capabilities, and have impacts upon other disarmament treaties".[26] While we are at it, we should also consider impacts on non-disarmament treaties, and international relations more generally.

The political objection raises a political challenge: Can non-contagious biological weapons be permitted for current nuclear-armed states while avoiding harms related to proliferation, treaties, and norms? While it may be difficult to predict the outcomes of political negotiations, one can at least sketch out a way that the political challenge might be met. The core is the political deal I mentioned above: The current nuclear-armed states get to keep their deterrence, and the rest of the world gets to be safe from deterrence failure. The Biological Weapons Convention and other relevant treaties would not be scrapped; instead, they would receive only the minimum modifications necessary for current nuclear-armed states to achieve winter-safe deterrence. It would remain illegal for any other states to posses biological weapons. And while other states may become tempted to develop biological weapons, they would need to do so covertly, which, as Sonia Ben Ouagrham-Gormley explains, makes it difficult for biological weapons programs to succeed.[27]

Such a deal is discriminatory, giving special status to current nuclear-armed states. The rest of the world may resent that the deal would further entrench the discrimination already built into the Nuclear Non-Proliferation Treaty (NPT), and may further resent it if the deal also includes the three major nuclear-armed states not recognized by the NPT (India, Israel, and Pakistan; North Korea's arsenal already is winter-safe). That alone might be enough to kill the deal and end the possibility of non-contagious biological weapons in winter-safe deterrence. However, the rest of the world should recognize that it would be getting a massive improvement over the status quo. Because of nuclear winter, under the status quo, deterrence failure among the major nuclear-armed states could result in the rest of the world struggling to stay alive. With winter-safe deterrence, deterrence failure would not significantly harm the rest of the world. If anything, it is the current nuclear-armed states who might be getting a bad deal, if winter-safe deterrence is more expensive (as Edwards suggests[28]) or more failure-prone. But the current nuclear-armed states should remember that they are also threatened by nuclear winter from wars they had nothing to do with. Everyone benefits from winter-safety.

Winter-safe deterrence could also build a norm against causing massive global harm. Such a norm is better than norms against specific types of weapons. A small harm from biological (or chemical or nuclear) weapons is not worse than a large harm from conventional weapons. The international community errs when it acts otherwise, for example in its disproportionate condemnation of the 2013 chemical attack in Ghouta, Syria and relative silence on the numerous conventional weapon attacks across Syria. International support for winter-safe deterrence, whatever the weapons involved, could help shift norms away from weapon types and towards the harms that weapons cause.

The psychological objection states that non-contagious biological weapons do not effectively deter. The psychological objection is also frequently made, though it is typically expressed in technological terms, pointing out various reasons why it may be difficult to cause significant harm in a second-strike attack with non-contagious biological weapons.[29] The technological objections include the potential for civil defense, the difficulty of building delivery systems, the need to test the weapons on humans, and the sensitivity of the effects to local environmental conditions. These factors make it difficult to cause significant harm in a second-strike attack with non-contagious biological weapons. The technological objections raise technological challenges. Judging from points made in the discussions of winter-safe deterrence, I am skeptical about the prospects for resolving these challenges. Even if future technologies could resolve some or all of the challenges, this would slow the availability of non-contagious biological weapons for winter-safe deterrence. Other options for reducing nuclear winter risk likely work faster.

But deterrence is ultimately psychological, not technological. What matters for deterrence is not the harm caused in second-strike but the fear induced through the threat of it. The failure to cause harm in second-strike only weakens deterrence if the adversary is left unafraid. If non-contagious biological weapons could induce sufficient fear despite their technological shortcomings, then they would make rather intriguing deterrents: They would reduce the probability of war, and if deterrence fails, they would not cause significant harm in the war. More generally, one could argue for deterrents that are

perceived to be more harmful than they actually are. Nuclear weapons fail horribly in this regard, as nuclear winter is commonly overlooked, rendering nuclear weapons much more harmful than they are perceived to be. Non-contagious biological weapons may well be the opposite. However, in light of the significant technological issues, it may not be feasible to induce enough misperception for non-contagious biological weapons to be an effective deterrent.

In light of all this, at this time I do not consider non-contagious biological weapons to be a promising candidate for a role in winter-safe deterrence. The technological objections are most important, enough to make it probably not worth attempting to resolve the political objections. Further research might advanced resolutions to the psychological/technological and political objections. However, here Edwards's comment that people's time would be better spent on other matters is helpful,[30] though readers should judge for themselves how to use their time given their particular opportunities. The role of non-contagious biological weapons in winter-safe deterrence has already been discussed at great length. While I would not discourage further discussion, more attention is needed on other types of weapons for winter-safe deterrence and other options for reducing nuclear winter risk.

Concluding Remarks

I will conclude with a few remarks about nature of the research that went into the winter-safe deterrence paper. One issue is Zander's concern that the paper's "reasoning collates conclusions by other investigators" instead of providing significant "independent research".[31] Zanders is correct that my paper draws heavily on other studies, but this is an essential feature for this sort of interdisciplinary research. The paper is mainly a synthesis, putting together assorted pieces to see a bigger picture, not an analysis, digging deeper into one specific piece.[32] Synthesis of this sort is underrepresented in contemporary academia, but it is vital for addressing important issues such as nuclear winter.

The core contribution of the paper, as I see it, is to layout the concept of and rationale for winter-safe deterrence, and to provide some initial analysis. This is a lot to do in one paper. Zanders complains that many of the paper's discussions lack depth and nuance, but I was simply up against a word limit. A full discussion could easily fill up a book. I considered writing this as a book, but I judged that it would be more productive to get a shorter version of the idea out in order to enable open discussion. In light of the rich open discussion that has occurred, I am glad that I chose to publish the paper version.

This brings us to another significant issue, which is the tentative nature of the paper's conclusions. Such tentativeness is appropriate when making a first pass at a topic. I do not claim to have any final word on winter-safe deterrence. The winter-safe deterrence topic is highly interdisciplinary; I would not be so bold as to claim deep expertise in all the relevant fields. This is further reason to publish initial analyses—so that other people, with other expertise, can contribute. I have learned much from the discussion of winter-safe deterrence, in particular regarding biological weapons, and I have changed my own thinking as a result of it, in particular to significantly downgrade the prospects for non-contagious biological weapons. I hope that others have learned something as well, and that we can continue the open discussion of winter-safe deterrence and other means of confronting global threats like nuclear winter.

[1] Seth D. Baum, 'Winter-Safe Deterrence: The Risk of Nuclear Winter and its Challenge to Deterrence'. *Contemporary Security Policy*, Vol. 36, No. 1 (April 2015), pp. 123-48, quote at p.123.

[2] Seth Baum, 'Deterrence, Without Nuclear Winter', *Bulletin of the Atomic Scientists*, 9 March 2015.

[3] Gregory D. Koblentz, Gigi Kwik Gronvall, Brett Edwards, Martin Furmanski, Sonia Ben Ouagrham-Gormley, and Seth Baum, 'The Winter-Safe Deterrence Debate', *Bulletin of the Atomic Scientists*, 18 March-2 April 2015.

[4] Ira Helfand, 'Nuclear Famine: Two Billion People at Risk', *International Physicians for the Prevention of Nuclear War* (November 2013).

[5] Christian Enemark has referred to the effort to address nuclear winter as "the greatest material challenge in the history of human civilization"; see Enemark, 'Discontent with Winter-Safe Deterrence', *Contemporary Security Policy* (this issue). While addressing nuclear winter is certainly high on the list challenges for human civilization, it might or might not be at the top. Other candidates include addressing global warming, pandemic disease outbreaks, and accidents involving certain forms of biotechnology or artificial intelligence. The interested reader could consult Nick Bostrom and Milan Ćirković, *Global Catastrophic Risks* (Oxford: Oxford University Press, 2008).

[6] Patricia Lewis, 'Nuclear Winter-Safe and Sound in the Snow Globe', *Contemporary Security Policy* (this issue). A potential exception that has gone largely overlooked in both research literature and policy debate is the possibility that destroying major world cities could cause catastrophic harm to the global economy. But this effect is not unique to nuclear weapons; firebombing and other conventional weapons could also accomplish this.

[7] The nuclear winter vs. deterrence debate in the 1980s is chronicled in Paul Rubinson, 'The Global Effects of Nuclear Winter: Science and Antinuclear Protest in the United States and the Soviet Union During the 1980s', *Cold War History*, Vol. 14, No. 1 (February 2013), pp. 47–69. I have observed similar points made in current debate over the humanitarian impacts of nuclear weapons.

[8] Jean Pascal Zanders, 'Denying Disarmament', *Contemporary Security Policy* (this issue).

[9] United States Department of Defense, 'Nuclear Posture Review Report', (April 2010).

[10] Brett Edwards, 'Escaping the False Dilemma of Strategic Nuclear and Biological Deterrence', *Contemporary Security Policy* (this issue).

[11] Lewis, 'Nuclear Winter-Safe and Sound in the Snow Globe' (note 6).

[12] I have spoken at the 2014 and 2015 Nuclear NPT conferences, the 2014 Vienna Conference on the Humanitarian Impact of Nuclear Weapons, and an experts meeting of the P5 states hosted by the US Mission to the United Nations, and I also attended the 2014 US Strategic Command Deterrence Symposium. I have further advocated for practical efforts to confront nuclear winter and other catastrophic risks in Seth D. Baum. 'The Far Future Argument for Confronting Catastrophic Threats to Humanity: Practical Significance and Alternatives', *Futures*, in press, doi:10.1016/j.futures.2015.03.001.

[13] Seth D. Baum, 'Confronting the Threat of Nuclear Winter', *Futures*, in press, doi:10.1016/j.futures.2015.03.004.

[14] Enemark, 'Discontent with Winter-Safe Deterrence' (note 5); Lewis, 'Nuclear Winter-Safe and Sound in the Snow Globe' (note 6).

[15] Enemark, 'Discontent with Winter-Safe Deterrence' (note 5); Lewis, 'Nuclear Winter-Safe and Sound in the Snow Globe' (note 6). Lewis cites her own study on inadvertent nuclear war, Patricia Lewis, Heather Williams, Sasan Aghlani, Benoît Pelopidas, *Too Close for Comfort: Cases of Near Nuclear Use and Options for Policy* (London; Chatham House, 28 April 2014). I have published one as well; see Anthony M. Barrett, Seth D. Baum, and Kelly R. Hostetler, 'Analyzing and Reducing the Risks of Inadvertent Nuclear War between the United States and Russia', *Science and Global Security,* Vol. 21, No. 2 (28 June 2013), pp. 106–33.

[16] Robert Rauchhaus, 'Evaluating the Nuclear Peace Hypothesis: A Quantitative Approach', *Journal of Conflict Resolution*, Vol. 53, No. 2 (April 2009), pp. 258-77. I thank Caroline Zaw-Mon for drawing this research to my attention.

[17] Enemark, 'Discontent with Winter-Safe Deterrence' (note 5).

[18] Baum, 'Winter-Safe Deterrence' (note 1), p.128.

[19] See for example Seth D. Baum, 'Is Humanity Doomed? Insights from Astrobiology', *Sustainability*, Vol. 2, No. 2 (February 2010), pp. 591-603.

[20] Carl Sagan, 'Nuclear War and Climatic Catastrophe: Some Policy Implications', *Foreign Affairs*, Vol. 62, No. 2 (Winter 1983), pp. 257–92; Jason G. Matheny, 'Reducing the Risk of Human Extinction', *Risk Analysis*, Vol. 27 (2007), 1335–44.

[21] I develop this theme further in Baum, 'The Far Future Argument' (note 12).

[22] Zanders, 'Denying Disarmament' (note 8).

[23] Richard Turco and Carl Sagan, 'Policy Implications of Nuclear Winter', *Ambio*, Vol. 18, No. 7 (1989), pp. 372–6; Alan Robock and Owen Brian Toon, 'Self-Assured Destruction: The Climate Impacts of Nuclear War', *Bulletin of the Atomic Scientists*, Vol. 68, No. 5 (September 2012), pp. 66–74.

[24] Lewis, 'Nuclear Winter-Safe and Sound in the Snow Globe' (note 6).

[25] Gigi Kwik Gronvall, 'The Biological Weapons Ban Increases US Security', *Bulletin of the Atomic Scientists*, 19 March 2015.

[26] Edwards, 'Escaping the False Dilemma' (note 10).

[27] Sonia Ben Ouagrham-Gormley, 'Technological Advance, Proliferation Potential, and the Unsuitability of Bioweapons as a Deterrent, *Bulletin of the Atomic Scientists*, 30 March 2015.
[28] Edwards, 'Escaping the False Dilemma' (note 10).
[29] See in particular the contributions of Gregory Koblentz and Martin Furmanski to Koblentz et al., 'The Winter-Safe Deterrence Debate' (note 3).
[30] Edwards, 'Escaping the False Dilemma' (note 10).
[31] Zanders, 'Denying Disarmament' (note 8).
[32] This synthesis/analysis distinction is from Robert Costanza, 'A Vision of the Future of Science: Reintegrating the Study of Humans and the Rest of Nature.' *Futures*, Vol. 35, No. 6 (August 2003), pp. 651-71.