Stanton Nuclear Security Fellows Seminar

PANEL 3: Selected Nuclear Policy Issues

1. Travis Carless, RAND

Estimating the Nuclear Fuel Cycle Trade-offs and Proliferation Risks Associated with the Export of HTR-PM SMRs

1. On what issue are you working on and why is it important?
I am working on nuclear safety and proliferation risks associated with the export of Chinese Generation IV[1] Small Modular Reactors (SMR). Generally, SMRs are compact nuclear power plants that consist of factory-fabricated modules and components that can be shipped and assembled on site, have an installed capacity of up to 300 MW_e, and have passive safety features. Despite no SMRs bring in commercial operation today, their promise can create opportunities for their deployment in new and emerging markets. Developing nations are exploring SMRs to supply their growing energy needs because they can be constructed and operated in remote locations. Proponents view SMR deployment, specifically Generation III+ integrated Pressurized Water Reactor (iPWR) SMRs, as a strategy to improve overall safety, control the high capital costs and reduce construction times. In addition, Generation IV SMRs provide the benefits of higher fuel burnup rates and higher thermal efficiency rates. However, the near-term deployment of commercial iPWR SMRs are more likely than the Generation IV designs within the US.

   China's Tsinghua University is constructing the first commercial Generation IV high-temperature gas-cooled pebble-bed (HTR-PM) SMR. With an estimated grid connection date in 2018, the design requires High-assay low-enriched uranium (HALEU)[2] fuel enriched to 8.5% to operate. HALEU is mostly used within research reactors and implementing HALEU as fuel would be considered a departure from the norm in the commercial nuclear industry. In comparison, commercial light water reactors utilize low-enriched uranium (LEU). The widespread use of HALEU can lead to increased proliferation risks. Prasad et al. (2015) finds higher enrichment levels and increased deployment of SMRs as are the most challenging issues related to nuclear proliferation related to SMRs. With respect to enrichment, about 73% of the effort required to

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[1] Generation I reactors are non-commercial, early prototype or research reactors. Generation II reactors are current nuclear power plants in commercial operation built between 1965-1996. Generation III+ reactors are evolutionary improvements in standardization, fuel technology, thermal efficiency, and passive safety systems over Generation II plants. Generation IV reactors are designs generally not expected to achieve commercial maturity until 2030.

[2] Low-enriched uranium (LEU) is fuel for light water reactors where U-235 is enriched to 3-5%. High-assay low-enriched uranium (HALEU) is fuel typically used in research reactors or some advanced reactors where U-235 is enriched to 5-19.75%. Highly enriched uranium (HEU) is fuel is comprised of U-235 enriched above 20%. Typically, when HEU is enriched to about 85% or above it is considered weapons-grade.

enrich one tonne of uranium to 90% (weapons grade) is achieved when the uranium is enriched to 5% (LEU level) compared to 82% of the effort for uranium enriched to 8.5% (HALEU level).

The importance of this project is two-fold. First, more than 30 nations in Southeast Asia, Africa, South America, the Middle East, and eastern Europe are interested in establishing or expanding nuclear power generation. An influx of new nuclear power plants in nations with limited commercial, regulatory, and nuclear safety experience can create new proliferation and safety risks. Second, as a geopolitical rival of the US, China is moving forward with the commercialization of Generation IV SMRs. As their commercialization efforts continue, they will have greater influence on the rules, guidelines, and best practices that are established by the International Atomic Energy Agency (IAEA).

2. What is the big question that you are seeking to answer about that issue?

   Given the perceived loss in US competitiveness in the commercial nuclear sector and performance benefits of the HTR-PM SMRs, what are the proliferation and safety risks associated with China exporting HTR-PM SMRs to nations seeking to expand their nuclear capacity?

3. How are you going to answer your question? What methods will you use and what evidence or cases will you explore?
   To answer this research question, Break-even analysis[3], Expert elicitation[4], and Bayesian analysis[5] will be used iteratively to quantify the proliferation risks associated with the export of an HTR-PM SMR. The study will utilize experts from academia, national labs, private industry, government, and think tanks. First, Expert elicitation will be used to quantify the proliferation risk associated with nations seeking to expand or establish a nuclear fleet with the HTR-PM SMR. Prior to the elicitation, the experts will be given a packet detailing the known specifications and features of the HTR-PM SMR. The expert panel will then be asked to assess the increased or decreased likelihood of a country's proliferation and safety risk after obtaining an HTR-PM SMR. As a follow-on, the expert panel would be asked to assess these risks if an iPWR SMR was obtained instead. A series of questions ranging from US competitiveness to political and economic stability of the host country will be asked (e.g. What is the increased proliferation risk of Pakistan obtaining an HTR-PM SMR? How would you assess the risk political instability in Pakistan?). Second, a break-even analysis will be performed to determine if the performance benefits of a HTR-PM would outweigh the economic drawbacks. The information from the break-even analysis, literature containing details of the political stability of each host country, and institutional proliferation resilience[6] from international agencies will be provided

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[3] Equilibrium between total cost and total economic benefit.
[4] The process of capturing and combining the technical judgements from experts to create a probability distribution to support decision-making under uncertainty.
[5] Statistical method that use the prior probabilities of a hypothesis in conjunction with its update probabilities as new information is made available to provide statistical inferences.
[6] The deployment and use reduce the probability of its use in nuclear weapons.

to the experts in a second round of elicitations. Based on the new information that was provided to the experts, their risk judgements will be updated. Finally, Bayesian analysis will be used to integrate each expert's initial and updated judgement to quantify each host nation's final proliferation and safety risk. Ultimately, each host nation will have a proliferation risk from each expert. The results from each expert will be integrated into a distribution for each country, which will allow policy makers to compare the relative proliferation and safety risks between countries.

4. What is your answer to the question you are asking? That is, what is your argument or conclusion even if it is still tentative at this point?
   This study suggests there are increased safety proliferation risks associated with China exporting HTR-PM SMRs to Kenya, Turkey, Zambia, Venezuela, Bangladesh, the Philippines, and nations that are geopolitical rivals of the US. Specifically, risk is driven by concerns related to these countries having access to HALEU, the lack of political stability, nuclear infrastructure and safety oversight, and financial resources. With respect to the trade-offs between performance and economic drawbacks, in certain instances where the cost of enrichment is above $125/SWU, the performance benefits will not outweigh the economic drawbacks of the nuclear fuel cycle.

5. How does your work fit into the existing work on your subject?
   Siegel et al. (2018) used expert elicitation to quantify proliferation resilience based on technical and institutional features for SMRs under different deployment scenarios. My study builds on these efforts and will reduce uncertainty by focusing on the export of an HTR-PM, considering economic factors, and a shifting safety regime that can influence proliferation and safety risks. A similar framework using expert elicitation and Bayesian analysis has been utilized in past studies from Stiber et al. (1999) and Lee et al. (2009) for non-nuclear applications to aid in decision making and to quantify risk. This research utilizes these methods to quantify the safety and nuclear proliferation risks to support decision making.

   a. What alternative arguments or explanations exist and why is your answer superior?
      One alternative argument is that the proliferation and safety risks associated with the export of HTR-PM SMRs are the same as the risk associated with Generation III+ nuclear power plants. Another alternative argument is economic considerations will have no impact on the proliferation and safety risks. My findings will dispel the alternative arguments and my approach would be superior because I will provide each expert with a baseline set of information that calibrates their judgements. Then I will provide additional economic factors to each expert to estimate the impact new economic information will have on their judgements.

   b. How does your work add to or change our understanding of the issue you are studying?
      This work adds to the understanding of issues related to nuclear proliferation and safety by estimating the impact additional information (e.g. economic fuel cycle, political stability, relative SMR performance, and infrastructure) can have on expert judgements.

This will result in more accurate and informed decisions based on a quantitative estimation of nuclear proliferation and safety risks.

c. What do you see as your most important contribution?
This work quantifies the proliferation risks using expert judgements that includes economic and political stability considerations for the export of HTR-PM SMRs.

6. What policy implications flow from your work? What concrete recommendations can you offer policy makers?
This work will provide a risk-informed approach to identifying nations that could pose both nuclear proliferation and safety risks should they receive HTR-PM SMRs from China. Specifically, this work will allow policy-makers within the IAEA, the US State Department, and the US Department of Energy to quantify the role economic, national stability, and a reduced US presence in the commercial nuclear field plays in global nuclear security and safety. From a policy perspective, this study can provide recommendations to mitigate these risks, such as recommending the US State Department provide foreign aid to nations that do not purchase SMRs from China and lobby the IAEA to have more stringent rules and best practices.

7. What do you think is the weakest or most vulnerable aspect of your study and what sort of feedback would be most useful to you?
The most vulnerable aspect of this study is identifying a diverse group of subject matter experts within academia, national labs, private industry, government, and think tanks that can provide a strong expert judgement within a short amount of time.

2. Hyun-Binn Cho, CISAC

Provocation, Brinkmanship, and the Escalation of Nuclear Crises

During the fall of 2017, the "war of words" between U.S. President Donald Trump and North Korean leader Kim Jong-un led to widespread apprehension that verbal provocations might spiral into an unwanted conflict. Concerns about provoking unwanted escalation through heated rhetoric or military actions, however, are a perennial feature of interstate crises. During the Cuban Missile Crisis, U.S. Secretary of Defense Robert McNamara argued that a key advantage of a naval blockade over an airstrike was that "it avoids a sudden military move which might provoke a response from the U.S.S.R. which could result in escalating actions leading to general war."[7]

How do provocative threats and actions affect the escalation of crises between nuclear powers? Despite concerns that insults between Trump and Kim or a "bloody nose" strike on North Korea could lead to nuclear conflict, extant studies on nuclear crises do not explain the dangers of provocative rhetoric and military actions. Indeed, the role of provocation is often dismissed as only marginally important in nuclear crises because launching nuclear war in a fit of anger seems so improbable. Although this scenario is unlikely, however, I argue that provoking anger and honor concerns can increase the risk of nuclear war through other pathways. Building on a new theory of provocation, I outline four such pathways and highlights several of them in a case study of the Sino-Soviet Border Conflict of 1969.

My dissertation develops and tests a new theory of the escalatory logic of provocation.[8] Broadly, a provocation-based mechanism of crisis escalation operates via two mechanisms at the individual level – one typified by the role of anger and the other by honor concerns – and two pathways at the state level.

At the individual level, triggering emotions of anger increase an individual's propensity to take risks, and this heightened risk tolerance increases the individual's resolve to engage in escalatory actions. In contrast, insulting or humiliating actions by a foreign state can heighten honor concerns, and this increases an individual's resolve to escalate a crisis by making backing down appear more dishonorable and escalation as relatively more appealing. In political science, the former type of change can be referred to as a change in *dispositional factors* (i.e. individual propensities) and the latter type as a change in *situational factors* (i.e. features of the strategic environment, specifically, the honor at stake).

These two individual-level mechanisms impact state-level decisions to escalate or back down via two broad pathways: 1) by angering or increasing honor concerns for the individual leader directly, and/or 2) by angering or increasing the honor concerns for the public or political elites, which constrain the leader's political choices between escalating or backing down.

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[7] Minutes of the 505th Meeting of the National Security Council, October 20, 1962, *Foreign Relations of the United States, 1961-63,* Vol. 11: *Cuban Missile Crisis and Aftermath* (Washington D.C.: U.S. Government Printing Office, 1996), Doc. 34.

[8] Hyun-Binn Cho, *Tying the Adversary's Hands: Provocation, Crisis Escalation, and Inadvertent War* (Ph.D. Dissertation, University of Pennsylvania, 2018).

The bottom line is that when one state's actions (i.e. words or deeds) trigger the logic of provocation, it makes the opposing state more willing to take a deliberate decision to escalate – it increases their resolve to stand firm rather than back down. This has two implications, one which accords with our intuition and another which contrasts with conventional wisdom.

On the one hand, the logic of provocation is consistent with the idea that a provoked state becomes more likely to escalate, all else equal – that is, even when the same stake is being disputed, when greater threat perceptions do not arise, and when beliefs about the opponent's military capabilities do not change, etc. Again, this is because anger changes risk preferences and/or because honor, status, or prestige concerns – non-material stakes – increase.

On the other hand, contrary to conventional wisdom, the logic of provocation does not have to lead to impulsive and explosive outcomes to decisively influence the course of crises. Increasing the opponent's resolve means making the opponent more willing to escalate rather than back down, so insults, slights, or humiliations that trigger anger or honor concerns can make a dispute that was once trivial become intractable or can "switch" an opponent that was privately willing to back down at some later stage in the crisis to become resolved to stand firm and put up a fight. The logic of provocation, then, can have dangerous unobserved consequences for crises that heighten the risk of war.

What does this mean for the escalation of nuclear crisis and the dangers of nuclear war? Increasing the opponent's resolve to deliberately escalate a crisis is still unlikely to lead to a deliberate initiation of an all-out nuclear war because the threshold at which such a war becomes preferable to backing down is difficult to reach. Indeed, this is one reason why Thomas Schelling devised the strategy of making a "threat that leaves something to chance:" making a credible threat to deliberately launch an all-out nuclear war is hard because the threshold that must be met to make that decision feasible is so high; yet, states can engage in brinkmanship and threaten to launch a nuclear war accidentally.[9] In other words, for the logic of provocation to trigger a deliberate all-out nuclear war, anger and honor concerns must increase the opponent's resolve to such an extent that it reaches the threshold at which launching a nuclear war becomes more appealing than backing down. This outcome is possible but highly unlikely, and observers may well find that it is "rash" or "irrational."

That said, the logic of provocation may increase the opponent's resolve sufficiently to take additional steps on the escalation ladder short of launching all-out nuclear war. If nuclear states engage in brinkmanship, and hence compete in a "war of nerves," provoking anger and honor concerns could more plausibly increase the opponent's resolve to engage in escalatory actions that raise the risk of the crisis spiraling into nuclear catastrophe. This argument leads to at least four pathways through which the logic of provocation can lead to a nuclear war. I outline these in the order of most likely and least dangerous to least likely but most dangerous.

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[9] Thomas C. Schelling, *The Strategy of Conflict* (New York, N.Y.: Oxford University Press, 1960).

First, insults or military actions that trigger anger and honor concerns can increase the resolve of the opponent to engage and prevail in a game of brinkmanship. For example, the opponent may be more resolved to put its forces on high alert and generate a risk that the crisis spirals out of control.

Second, the logic of provocation may make the opponent more resolved to initiate a conventional conflict that raises the risk of escalating to the nuclear level. There have been two instances in which nuclear powers have fought conventional conflicts: the Sino-Soviet Border Conflict of 1969 and Kargil War between India and Pakistan in 1999. How high the threshold is at which launching a conventional conflict between nuclear states becomes feasible, however, is contested: proponents of brinkmanship argue that the threshold is relatively high, whereas proponents of the stability-instability paradox argue that the threshold is relatively low. The lower this threshold, the more likely that the logic of provocation can influence escalation to a conventional conflict, thus raising the risk of nuclear war.

Third, the logic of provocation may reduce the perceived risks of launching a conventional strike on an opponent's nuclear forces and enabling systems. Barry Posen argues that a conventional war can inadvertently escalate to the nuclear level if a conventional attack sufficiently degrades an opponent's nuclear retaliatory capabilities and incentivizes the opponent to use their remaining weapons before they lose them.[10] Caitlin Talmadge adds perceptual variables to this logic, and also highlights why targeting an opponent's nuclear-related capabilities would be rational; more recently, James Acton argues that "nuclear entanglement" may raise the risk of inadvertent escalation to the nuclear level.[11] From the point of the view of the foreign state which decides whether to risk a nuclear retaliation by launching a conventional strike on the opponent's nuclear forces or enabling systems, however, the logic of provocation may well impinge on that decision to strike rather than back down by changing risk preferences and making backing down in a conventional conflict more dishonorable.

Finally, although less likely, the logic of provocation may also impact decisions to use nuclear weapons short of an all-out nuclear attack. Desmond Ball, for instance, argues that if the nuclear taboo is ever broken, it would be in a maritime theater where demonstrative launches would not directly target civilians or military forces.[12] Launching nuclear weapons short of all-out war, however, not only increase the risks of an all-out nuclear war being launched accidentally, such as by being misunderstood by the opponent as a first strike, but may eliminate any restraining effects of the nuclear taboo. A decision to launch nuclear weapons short of all-out nuclear war will likely occur only in a high-stakes context, such as to arrest an impending defeat in a conventional conflict, but heightened risk tolerance and honor concerns may consciously or unconsciously affect such decisions on the margins.

How plausible are these arguments? Given that, fortunately, there are no positive cases of nuclear war, I examine the Sino-Soviet Border Conflict of 1969 using Chinese sources. Although anger and honor

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[10] Barry R. Posen, *Inadvertent Escalation: Conventional War and Nuclear Risks* (Ithaca, N.Y.: Cornell University Press, 1991).

[11] Caitlin Talmadge, "Would China Go Nuclear? Assessing the Risk of Chinese Nuclear Escalation in a Conventional War with the United States," *International Security*, Vol. 41, No. 4, (Spring 2017) pp. 50-92; and James Acton, "Escalation Through Entanglement: How the Vulnerability of Command-and-Control Systems Raises the Risks of an Inadvertent Nuclear War," *International Security*, Vol. 43, No 1, (Summer 2018) pp. 56-99.

[12] Desmond Ball, "Nuclear War at Sea," *International Security*, Vol. 10, No. 3, (Winter 1985/86) pp. 3-31.

concerns are difficult to measure in a historical context, the case study method is useful for several reasons. For instance, it allows me to examine my theory in a real crisis, and the 1969 case is substantively important because it is a rare case in which nuclear powers fought a conventional conflict.

I find that the first two pathways outlined above played an integral role in the 1969 crisis. First, although a border dispute had been brewing and Sino-Soviet relations had been deteriorating for several years, China's leader Mao Zedong's decision to send the Soviets a signal of resolve by instigating a violent incident on a river island in the border area counterproductively provoked the Soviets to initiate a larger scale military conflict in retaliation. Second, fears that another clash would incentivize their opponent to deliberately initiate a larger reprisal – including a preventive Soviet nuclear strike on China's nascent nuclear capabilities – inhibited both sides and played a crucial role in de-escalating the crisis. That is, contrary to the view that nuclear states will be inhibited by a brinkmanship logic where they fear a clash will accidentally spiral out of control, the Soviets, and particularly the Chinese, worried that a provocative incident will force the hand of their opponent to escalate deliberately. An internal Chinese report, for instance, warns that the Soviets are "conspiring to launch a surprise nuclear attack.''[13] This second finding addresses what Todd Sechser and Matthew Fuhrmann call an "awkward puzzle:" the logic of brinkmanship appears not to have played a major role in why China eventually backed down.[14]

Several policy recommendations follow from this project. Above all, leaders should refrain from unnecessarily provoking an opponent, such as whimsically insulting another leader on Twitter. (In my dissertation, I find that provocations can also signal resolve but only by raising the risk of war.) Second, reassuring an opponent of one's limited intentions or sending stronger signals of resolve are inadequate to avoid the pitfalls of provoking anger and honor concerns. Reassurance reduces perceptions of threat, which differ from provocation; if the opponent is provoked to become resolved to fight, signaling my willingness to stand firm will fail to avert a clash. Instead, if the logic of provocation is inadvertently triggered, policymakers should undo its logic, such as by offering carefully worded apologies to soothe the opponent's ire or by cooperating to devise face-saving formulas for the opponent to back down.

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[13] "Report by the Four Marshals, Chen Yi, Ye Jianying, Nie Rongzhen, and Xu Xiangqian to the Central Committee, 'Our Views about the Current Situation' (Excerpt)." September 17, 1969, History and Public Policy Program Digital Archive, Zhonggong dangshi ziliao, no. 42 (June 1992), pp. 84-86. Translated for CWIHP by Chen Jian with assistance from Li Di.

[14] Todd S. Sechser and Matthew Fuhrmann, *Nuclear Weapons and Coercive Diplomacy*, (Cambridge: Cambridge University Press, 2017) pp. 216-217.

3. Kavita Rathore, Texas A&M

The Effects of the United States, and Possibly European Union, Withdrawing from the Joint Comprehensive Plan of Action

- **On what issue are you working and why is it important?**

  On January 16, 2016 the Joint Comprehensive Plan of Action (JCPOA) was implemented between the Islamic Republic of Iran and the E3/EU+3 (China, France, Germany, the Russian Federation, the United Kingdom and the United States, with the High Representative of the European Union for Foreign Affairs and Security Policy) [1]. The JCPOA aims to ensure that Iran's nuclear program is exclusively peaceful. To achieve this, multiple concessions were applied to the Iranian nuclear program including [1]:

  - Limitations on Iran's uranium enrichment capabilities.
  - Limitations on the Iranian stockpile of enriched uranium, as well as maximum uranium-235 enrichment of 3.67% for stockpiled uranium.
  - A redesign and modification to the Arak IR-40 natural uranium fueled heavy water research reactor. This modification significantly reduces the risk of weapons-grade plutonium production.
  - All spent fuel was shipped out of Iran, to avoid the possibility of reprocessing to obtain plutonium.
  - Iran applied the International Atomic Energy Agency (IAEA) Additional Protocol (INFCIRC/540) to its Comprehensive Safeguards Agreement (INFCIRC/153) with IAEA.
  - Iran allows the IAEA to monitor the implementation of the JCPOA.
  - Iran reaffirms that under no circumstances will Iran seek to develop or acquire any nuclear weapons.

  In return for these concessions, the United States and its partners suspended all United Nations Security Council nuclear-related economic and financial sanctions on Iran [1].

  Many government officials and nuclear experts viewed the JCPOA as an effective tool for limiting the risk of Iranian nuclear proliferation. However, on May 8, 2018, U.S. President Donald Trump announced that the United States would withdraw from the JCPOA. All Iran-related U.S. sanctions will be reinstated by November 4, 2018.[15] These actions raise the possibility that the JCPOA may collapse. This study aims to analyze the effects of the U.S. withdrawal from the JCPOA as well as the effects of a possible EU withdrawal from the JCPOA to determine the influence on Iran's proliferation risk. The analysis of political effects of JCPOA party withdrawals will support us to evaluate a quantitative metric, the nuclear weapons latency of Iran. The nuclear weapons latency of Iran will be calculated as a function of JCPOA withdrawals.

- **What is the big question that you are seeking to answer about that issue?**

  Based on the preceding discussion, the questions for this study can be summarized as listed below.

  1) What are the political effects which influence Iran's proliferation risk of the U.S. withdrawal from the JCPOA?

[15] Currently this does not directly affect the suspended European Union (EU) and UN sanctions against Iran. However, the possibility exists for suspended EU sanctions to be reinstated due to pressure from the US.

2) How does the U.S. withdrawal from the JCPOA influence Iran's latent capacity to make nuclear weapons?
3) How would the EU's withdrawal from the JCPOA or the collapse of the agreement altogether influence Iran's nuclear weapons latency value?
4) What broad implications would the collapse of the JCPOA have on peace and stability in the Middle East?

The political effects of each scenario listed above can be significant. By calculating the nuclear weapons latency values, a quantitative metric regarding Iran's nuclear proliferation potential will be assessed.

- **How are you going to answer your question? What methods will you use and what evidence or cases will you explore?**

  The broad political effects of U.S., and possibly EU, withdrawal from the JCPOA will be analyzed, including the influence to nuclear proliferation risks. The Nuclear Weapons Latency Tool developed at Texas A&M University will be used to estimate the nuclear weapons latency values [2]. Nuclear weapons latency is defined as the time needed for a non-nuclear weapons state to develop a conventionally deliverable nuclear weapon, given the decision to proliferate has been made [3]. Assuming that the longer it takes for a state to proliferate, the less likely they are to do so, it is expected that the nuclear weapons latency provides a strong indication of the proliferation potential of a state [3]. The changing economy and nuclear program of Iran as a result of continued implementation of the JCPOA should have effects on Iran's nuclear weapons latency value.

- **What is your answer to the question you are asking? That is, what is your argument or conclusion even if it is still tentative at this point?**

  This study expects to find that the continued implementation of the JCPOA further increases Iran's nuclear weapons latency value as time progresses. The scenarios of the U.S. withdrawal as well as U.S. and EU withdrawal from the JCPOA should have effects on the country profile for Iran and thus nuclear weapons latency values. For instance, party withdrawals from the JCPOA may have an effect on the outside supply of uranium for civilian power reactors, altering the Iranian stockpile of uranium available to non-civilian purposes.

- **How does your work fit into the existing work on your subject?**

  - **What alternative arguments or explanations exist and why is your answer superior?**

    A previous study assessed the value of implementing the JCPOA in terms of Iran's nuclear weapons latency values [3]. Now, more than two and a half years since the agreement went into effect, further assessment is needed to evaluate the ramifications of JCPOA party withdrawals.

  - **How does your work add to or change our understanding of the issue you are studying?**

    Multiple sources study and gauge the wide-ranging consequences the U.S. withdrawal from the JCPOA [4, 5]. This study will build upon those efforts as well as focus on the consequences as they relate to nuclear proliferation risks.

  - **What do you see as your most important contribution?**

Reassessing the current status of Iran's nuclear proliferation risk, part of which being a quantitative metric on their nuclear weapons latency value, as a function of party withdrawal from the JCPOA.

- **What policy implications flow from your work? What concrete recommendations can you offer to policymakers?**
  The status of the JCPOA has implications for nuclear proliferation in the Middle East. This study is aimed at assessing, and estimating a quantitative metric, the nuclear proliferation risks as a result of the U.S., and possibly EU, withdrawal from the JCPOA. Such a study will help inform policymakers considering implications related to the JCPOA. Such considerations may include enforcement of secondary U.S. sanctions on EU entities, or a future U.S. administration considering re-entering into the JCPOA.

- **What do you think is the weakest or most vulnerable aspect of your study and what sort of feedback would be most useful to you?**

  The consequences of the full reinstatement of Iran-related U.S. sanctions on November 4, 2018 have yet to be realized. The JCPOA situation is dynamic in nature and remains uncertain. Consequently, studying the effects of party withdrawal from the JCPOA has the risk of being overtaken by the indefinite future of the JCPOA.

References

[1] U.S. Department of State, *Joint Comprehensive Plan of Action*, 2015. https://www.state.gov/e/eb/tfs/spi/iran/jcpoa/

[2] Sweeny, D.J., *Nuclear Weapons Latency Tool Manual and Operation*, M. Johansen, Editor. 2015.

[3] Johansen, M., *The Nuclear Weapons Latency Value of the Joint Comprehensive Plan of Action with the Islamic Republic of Iran*, M.S. Thesis, Texas A&M University, 2016. http://hdl.handle.net/1969.1/156989

[4] Council on Foreign Relations, *The Return of U.S. Sanctions on Iran: What to Know*, 2018. https://www.cfr.org/article/return-us-sanctions-iran-what-know

[5] Slavin, B., Atlantic Council, *The Dangerous Consequences of US Withdrawal from the Iran Nuclear Deal*, 2018. http://www.atlanticcouncil.org/blogs/new-atlanticist/the-dangerous-consequences-of-us-withdrawal-from-the-iran-nuclear-deal

4. Benjamin Zala, BCSIA

The Global Spread of Advanced Conventional Weapons and U.S. Nuclear Policy

In recent years a number of scholars and analysts have tracked a fundamental shift in the way we manage nuclear-armed relationships in world politics. The growing body of research examining the shift away from traditional deterrence relationships based on varying degrees of mutual vulnerability has highlighted the important role of advanced conventional weapons (ACW) in helping to drive this trend.

These non-nuclear weapons have been developed with the aim of reducing the vulnerability of the United States to nuclear attack. These technologies take both defensive and offensive forms. They include ballistic missile defense (BMD), anti-satellite (ASAT) and anti-submarine weaponry (ASW), conventional precision strike missile technology, and elements of both cyber and artificial intelligence (AI) capabilities.

While governments, thinks tanks, and scholars have begun to give ACW technologies greater attention, often missed in this analysis is the importance not of their individual, but instead their possible effects on the reliability (and therefore vulnerability) of nuclear arsenals when used in combination. When combined, these technologies may even offer the possibility of a disarming first-strike capability without having to cross the nuclear threshold. The implications for stable deterrence relationships is likely to be profound.

While the United States has led both the technological development of ACW and the associated political push to abandon mutual vulnerability as the cornerstone of nuclear stability, others are now following suit. This project focuses specifically on the spread of ACW beyond the United States.

Question:

The central question this project seeks to address is: *In what ways is the global spread of ACW likely to impact on the United States' nuclear relationships in the years ahead?*

The research is then designed around three subsidiary questions addressing the empirical, theoretical and policy-focused aspects of the topic:

1. Which states are positioning themselves to take advantage of technological breakthroughs in this area (and in which specific weapons/technologies) – including collaborative research and development projects?

2. As these technologies spread to both U.S. adversaries as well as allies and partners, what effects can we anticipate this having on deterrence relationships involving the United States?

3. How can and should Washington best respond to the proliferation of ACW in policy terms to take advantage of opportunities and mitigate risks posed to U.S. national security?

Method:

The first sub-question is a relatively simple empirical one – what is the current global picture in terms of the spread of ACW? Open source secondary literature (mainly scholarly books and journals and think tank reports) will be combined with industry analysis and expert interviews to compile an up to date database across the six technology areas mentioned above. This information will include currently deployed capabilities, active programs in the testing stage and, where possible, planned future projects.

By contrast, the second sub-question is a theoretical one – what is the effect for deterrence and stability? This aspect of the research will rely on qualitative analysis aimed at identifying which aspects of traditional deterrence theory remain compatible with, and relevant to, an age in which most or even all of the nuclear-armed states also develop and deploy various ACW technologies. It will consider how developments in the offence-defense balance might play out as ACW transfers increase and indigenous development becomes more sophisticated outside of the United States. This will include whether the first-mover advantages enjoyed by Washington in the short-term in, for example BMD technology, may be equalized in particular dyads (e.g. US-China) and what the effects of this might be on nuclear stability.

The third sub-question is also a theoretical one, but this time with a distinct policy focus – what are the different policy responses available to Washington as it faces the globalization of ACW technologies? This will include examining options for specific bilateral relationships, the prospects for arms control and non-proliferation measures, and how the global spread of ACW can and should impact upon on the United States' own nuclear and ACW deployments and posture. This will include drawing on the lessons for the United States from comparative analysis of previous strategic technological breakthroughs (the development of ICBMs, MIRV technology etc.).

Tentative conclusions:

From my initial work in this area, a number of tentative conclusions have emerged. The first is that in addition to working on decoys, nuclear modernization and other counter-measures against Washington's recent development of ACW capabilities, developing their own indigenous ACW capabilities has become a key part of the response of nuclear-armed major powers. China, Russia and India appear most important at this stage.

The second is that the spread of ACW is already beginning to present create complex policy dilemmas for the United States (see below), but that having been the first mover in this area, Washington faces a unique window of opportunity in the short-term. This window should be used to explore the possibilities for arms limitation agreements as well as using high-level (including military to military) dialogues and other confidence building measures to increase shared understandings across nuclear-armed states about the role of ACW. However, due to the spread of ACW beyond the US, this window (in which Washington would negotiate from an unambiguous position of strength) is rapidly closing.

Existing work:

In general, existing work on ACW and the ways in which it can impact upon nuclear forces has focused on U.S. capabilities. This includes Charles Glaser and Steve Fetter's recent work on whether the US should pursue a 'damage limitation' strategy or not vis-à-vis China, Keir Lieber and Daryl Press' work on improvements in weapons accuracy and remote sensing and their effects on second-strike survivability, and scholarship on the risks of nuclear escalation in the context of conventional conflicts such as that by James Acton, Joshua Rovner, and Caitlin Talmadge. Because of the near-term focus of this literature, the vast majority assumes that the United States will enjoy an asymmetric technological advantage in any potential dyad (U.S.-Russia, US-China, U.S.-DPRK etc.). It also tends to assume that any potential escalation that may involve the use of ACW against nuclear forces would take place in the context of a two-state dyad rather than in a more complex setting in which capabilities can be aggregated (e.g. U.S./NATO v. Russia/China).

Similarly, much of the existing work on ACW has focused on the individual technologies in isolation from each other. This includes the work of both critics and advocates of BMD, studies into cyber vulnerabilities and nuclear weapons, the use of AI in future nuclear warfighting etc. Therefore this project will examine ACW in a more holistic setting by looking at developments across the six technology spaces (include examining the potential of their use in combination) and in a much wider geopolitical setting by focusing on dynamics beyond the United States.

Policy implications:

The implications for policymakers can be thought of in terms of both defense and diplomacy. For the Pentagon it raises issues about whether, as the leading developer of ACW so far, the U.S. can maintain its existing advantage across all of the technology areas or whether a degree of comparative advantage/specialization might be advisable (e.g. BMD and ASAT weapons). In a more reactive sense, the impact of the spread of ACW can already be seen in high-level calls for the U.S. to respond with counter-measures to recent developments. The current Undersecretary of Defense for Policy, John Rood, has already linked the need for space-based BMD interceptors to the development of hypersonic missile technology in China and Russia.

In diplomatic terms, State Department officials face both short and long-term challenges in this area. In the short-term, Washington will need to construct a coherent strategy for responding to burgeoning ACW partnerships. For example, despite attempts to improve US-Indian cooperation on strategic issues, the U.S. has recently threatened to impose economic sanctions on India if it goes ahead with the purchase of Russia's S-400 *Triumf* air defense and theatre BMD system. In time, it may also be necessary to consider whether or not to expand the U.S.'s own existing partnerships (e.g. on BMD with Japan) to other technology areas. Over the longer-term, U.S. officials will need to decide whether facing a completely unregulated ACW environment is still in the U.S. national interest and if not, what kind of arms control agreements might be forged to limit ACW proliferation. More modestly, the role of existing (and new) strategic dialogues will need to be considered between the major actors in this area in order to create greater clarity around capabilities, doctrines and mutual understandings around stability, red lines, escalation etc.

Weaknesses and challenges:

For the empirical work, in some of the technology spaces I have already identified a number of categorization challenges in terms of being able to cleanly separate and identify weapons technologies from each other and even civilian from military programs. For example, there is a degree of overlap between BMD interceptors, ASAT weapons and conventional precision strike missiles.

Similarly, in relation to both cyber and AI capabilities, as both relate to the development of software rather than hardware, the costs are significantly lower compared to the other technology types. Breakthroughs in the civilian sector are likely to have military applications making this a somewhat complicated picture.

An obvious but relatively important challenge will be both accessing reliable information on what, in some circumstances, may be classified research programs as well as accessing material in languages other than English. As well as using my existing contacts at universities and think tanks in China, India and Russia, I intend to seek assistance from those working on the individual technology spaces in the United States who will themselves have useful contacts having faced similar problems in their own work.

A potential weakness of the project as planned is that it is somewhat technologically driven. The data collection is focused on which state is developing what technology which is then the baseline for thinking through the possible challenges this may pose for the United States. This may miss important changes in thinking in these countries around deterrence, the role of conventional versus nuclear weapons, stability etc. This may need to be either incorporated into the theoretical research on sub-question two (on deterrence theory) or simply identified as an important topic for further study in the future but outside the bounds of the substantive work of this project.