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We call on governments and funding organizations to bring together these building blocks of data synthesis, training and evaluation to create an evidence clearing house for agriculture. In our view, such a facility would take around three months to set up, with an injection of around \$10 million of funding for a newly established consortium made up of groups that are already contributing evidence to agriculture. Its mandate would be to generate and disseminate such evidence, and it could produce policy-relevant results by the end of this year.

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1. United Nations. *Policy Brief: The Impact of COVID-19 in Africa* (UN, 2020).
2. FAO & African Union. *Declaration on Food Security and Nutrition During the COVID-19 Pandemic* (FAO & African Union, 2020).
3. GSMA. *Connected Women: The Mobile Gender Gap Report 2019* (GSM Association, 2019).
4. United Nations. *Policy Brief: The Impact of COVID-19 on Women* (UN, 2020).
5. Korkoyah, D. T. Jr & Wreh, F. F. *Ebola Impact Revealed: An Assessment of the Differing Impact of the Outbreak on Women and Men in Liberia* (UN Women/Oxfam/Liberian Ministry of Gender, Children and Social Protection & The WASH Consortium, 2015).
6. Teeken, B. et al. *Econ. Bot.* **72**, 263–277 (2018).
7. Luke, D., Masila, G. & Sommer, L. *Informal Traders: A Behavioral Act of Survival* (UN Economic Commission for Africa, African Trade Policy Centre & Eastern Africa Grain Council, 2020).
8. Quisumbing, A. R., Sproule, K., Martinez, E. M. & Malapit, H. J. *Women's Empowerment in Agriculture and Nutritional Outcomes: Evidence From Six Countries in Africa and Asia*. IFPRI Discussion Paper 1930 (International Food Policy Research Institute & CGIAR, 2020).
9. Lobell, D. B. et al. *Am. J. Agric. Econ.* **102**, 202–219 (2020).
10. Tsan, M., Totapally, S., Hailu, M. & Addom, B. K. *The Digitalisation of African Agriculture Report 2018–2019* (CTA, 2019).
11. Deeks, J. J. et al. *Cochrane Database Syst. Rev.* <https://doi.org/10.1002/14651858.CD013652> (2020).
12. Stewart, R., Dayal, H., Langer, L. & van Rooyen, C. *Palgrave Commun.* **5**, 90 (2019).



Ballistic missiles that can carry nuclear warheads go on display at a parade in Beijing.

Nuclear weapons: arms-control efforts need China

Nobumasa Akiyama

As tensions mount and treaties totter, fresh thinking is needed – on deterrence, emerging technologies and key players in east Asia.

It is 75 years since the United States dropped atomic bombs on the Japanese cities of Hiroshima and Nagasaki on 6 and 9 August 1945, killing around 200,000 people. Since then, humanity has had to coexist with the massive destructive power of nuclear weapons. Although such weapons have not been used in wars since, they define the international

order. Nuclear deterrence and pacts to restrict arms between the United States and Russia have assured decades of precarious peace. Meanwhile, the United Nations' adoption of the first-ever Treaty on the Prohibition of Nuclear Weapons (TPNW) in 2017 buoyed hopes of a world free of these catastrophic arms.

Now the skies are darkening. In 2019, the Intermediate-range Nuclear Forces (INF) Treaty between the United States and Russia collapsed, ushering in a new arms race for weapons with a range of 500–5,500 kilometres. China's rise as a superpower is bolstered by a rapidly modernizing arsenal. India and Pakistan are engaging in the worst border scuffles for decades. Iran is re-stoking its nuclear programme, after the United States unravelled the Joint Comprehensive Plan of Action restricting it. North Korea continues to expand its arsenal.



to Prague in 2009, and became the first sitting US president to visit Hiroshima, in 2016. UN secretary-general António Guterres argued that their abolition is crucial “to save humanity” in his 2018 disarmament agenda¹. When Pope Francis visited Nagasaki and Hiroshima in November 2019, he criticized the concept of nuclear deterrence as offering a “false sense of security” sustained by “fear and mistrust”. Peace should be assured instead, he said, through “the arduous yet constant effort to build mutual trust”.

Similar sentiments among non-nuclear states delivered the TPNW. It was adopted by 122 of the 193 members of the UN, and will enter into force once 50 states ratify it. But, as of this month, only 40 have done so. Signatories agree not to develop, test, produce, acquire, possess, stockpile, use or threaten to use nuclear weapons.

Eradication is unlikely, however. Notable absentees from the treaty include all nuclear-armed countries. They did not vote for the TPNW; they jointly expressed their unwillingness to join. Nor did ‘nuclear umbrella states’ in Europe and Asia, such as the members of the North Atlantic Treaty Organization, Japan and South Korea, whose security from nuclear attack relies on the United States.

A global regime of arms control is still crucial to manage nuclear risks.

Fracturing framework

The United States and Russia together possess 90% of the world’s 14,000 nuclear weapons. Their holdings have been shaped through four bilateral treaties at three levels: strategic nuclear arms, missile defence and sub-strategic nuclear and conventional arms. Negotiations began in 1969 under the Strategic Arms Limitation Talks (SALT).

The SALT I agreement, signed in 1972, restricted systems that were capable of directly delivering nuclear weapons to either country. That agreement was replaced by the 1991 Strategic Arms Reduction Treaty (START I), which capped the numbers of nuclear warheads as well as delivery systems that each nation could hold. President Obama and then Russian president Dmitry Medvedev signed a replacement ‘New START’ treaty in April 2010.

The Anti-Ballistic Missile (ABM) Treaty, signed in 1972, limited competition concerning these offensive weapons that had shaped confrontation between the two countries in a framework of mutual assured destruction.

In 1987, the United States and the Soviet Union agreed to eliminate ground-launched, medium-range missiles under the INF treaty, and signed the Treaty on Conventional Armed Forces in Europe, which set ceilings on key conventional forces in Europe. Russia announced its withdrawal from the treaty in 2015.

Each nation agreed to abide by these rules because they recognized the existential risks: either could wipe out the other. The rules were

formalized and verified. Predictability and transparency increase trust. Scientific teams from both countries conducted on-site inspections of warheads and exchanged data. The number of nuclear weapons held in each country has now fallen to around 6,000, or one-fifth of their peak during the cold war.

But tensions are rising again between the United States and Russia. The United States backed out of the ABM treaty in 2002. And in February 2019, it announced it would withdraw from the INF treaty, citing Russia’s testing of prohibited missiles. After Russia made counter accusations, both sides abandoned the treaty in August 2019.

Enter China

Negotiations have also stalled over a replacement for New START, which expires in February 2021. If the treaty is not renewed or extended, the nuclear arms race will go unchecked. The United States wants to bring in China and expand the scope of weapons covered. Russia wants to stick to the original remit.

China’s rise has transformed the geopolitical landscape. The United States cited that country’s unrestricted build-up of nuclear forces as one reason for its withdrawal from the INF treaty. China has around 320 nuclear warheads, and more than 250 missile launchers capable of carrying them². The majority of its nuclear arsenal is in land-based, medium-range missiles.

For example, the Chinese ballistic missile Dongfeng 26 can travel 4,000 km, roughly the distance from eastern China to Guam, a US territory in Micronesia in the western Pacific Ocean. Dongfeng 21 can reach a target 2,000 km away, enough to hit US aircraft carriers deployed around the South China Sea if launched from central western China. Dongfeng 17 is a manoeuvrable missile that can deliver both nuclear and conventional warheads at a similar range. It could function as boosters for a hypersonic glide vehicle flying at low altitude, which radars would have little time to detect³.

These types of missile are the very assets that the United States and Russia could not possess under the INF treaty. For China, they are key to being able to compete with the United States in the western Pacific Ocean. It is because of these that the United States, keen to protect its superiority in the region, wishes to bring China into the arms-control fold.

So, in June this year, the United States invited China to attend its discussions with Russia in Vienna about what will replace New START. China declined. Not keen for the United States to dampen its nuclear ambitions, it would rather wait and see what happens in November’s US presidential election.

But there are good reasons for China to engage. Not least, it could influence the agenda – to raise issues that concern it, such

This environment had made the old rules of strategic stability obsolete even before the COVID-19 pandemic fuelled nationalism and tensions. New ways of thinking about nuclear security and arms control are needed urgently, and for more than two players.

First, researchers and security experts need to find deterrence strategies that are acceptable to three nations. China should join arms-control talks with the United States and Russia, even if these are open-ended. Second, international security discussions need to encompass emerging technologies and conventional weapons, as well as nuclear ones. Third, non-nuclear states, including Japan – my nation – need to be at the table.

In the 75 years since the nuclear cataclysm at the end of the Second World War, scientists have been central to deterrence, detection and verification, capitalizing on global collaborations to build trust, technology and treaties. Researchers’ skills and commitment are needed now more than ever.

Nuclear-arms control is at a crucial juncture. On a positive note, world leaders are increasingly vocal about abolishing these abhorrent weapons. Sadly, current geopolitics means that situation is a long way off.

Former US president Barack Obama called for a world without nuclear weapons on a visit

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as the missile defence systems of the United States and its allies, which include Japan.

Three challenges

Finding a trilateral arms-control strategy will be difficult for three reasons⁴.

First is a problem of game theory. It makes more sense for three players in a non-cooperative dilemma game to defect rather than cooperate⁵. Conventionally, rational players would rather engage in an arms race than agree not to. That view changes when they look ahead. Players place more emphasis on the value they will gain in future – they would rather be guaranteed a smaller payback than risk gaining nothing or losing. Cooperation then becomes possible. That's why the United States and Russia agreed to act in the past. The game repeats endlessly, and the devastating power of nuclear weapons makes the cost of defection high – a nuclear-first strike from the other.

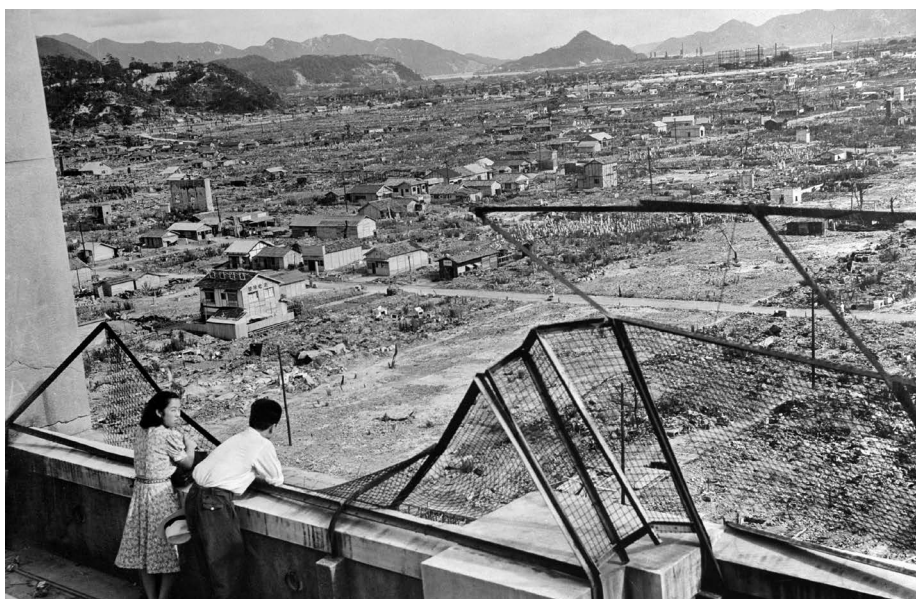
In a three-way game, the outcome might be different. It is harder to find a stable equilibrium in the first place. And it's better for two to form a coalition against the other, even in the long run. Thus, every player fears others teaming up against them. When trust is missing, players prefer to stay in competition rather than reach agreement.

The key to trilateral arms control is to ensure that the isolated party benefits from signing up. It's unclear whether the confidence-building and verification measures associated with existing arms-control treaties are sufficient to do that, and whether the level of transparency that could be required is acceptable for all three.

Second, power balances, strategic goals and arsenals that were evolving fast are now profoundly in flux. The economic power shifts brought about by technology alliances and globalization have been accelerated and amplified by the COVID-19 pandemic. At potentially one of the most profound inflection points for centuries, it is hard to define a stable state of relations among countries that have different (and unpredictable) goals and assets.

From a global perspective (even as the pandemic continues), the United States is still a political and economic heavyweight, as well as a military one. It has been pursuing cooperation with allies in the Indo-Pacific, Europe and the Middle East. Russia's power is declining: its core interests are in Europe and central Asia, and it is seeking to keep its superpower status, even if only nominally. China's global status is rising: it has been extending its influence worldwide by economic and diplomatic means, such as the Belt and Road Initiative, and its military focus has enabled it to gain dominance in the western Pacific.

These three rival powers, with their varying future trajectories, face a major challenge in finding a sustainable way to accommodate all of their strategic interests.



A view of Hiroshima in Japan, about two years after it was hit by a US nuclear bomb.

Third, boundaries are blurring between different types of weapon. Emerging technologies such as hypersonic gliders, precision-guided strike systems, robots and artificial intelligence (AI) make conventional weapons as effective strategically as nuclear ones (go.nature.com/2x46wda). Cyberattacks could cheat nuclear command-and-control systems and confuse decision-making, leading to risky situations. Satellite-imaging technologies enhanced using AI make it easier to identify and target strategic assets such as missile-launch sites and commands.

All of these factors complicate deterrence calculations. Discussion on regulating them has not produced any tangible results, and it will remain difficult.

Steps forward

The United States, China and Russia should immediately begin talks that explore how stable strategic relationships can be built. That would reassure other countries and pave the way for more substantive security agreements. Meanwhile, the United States and Russia need to extend New START to avoid a gap in arms control.

The three powers should discuss ways to identify and reduce the risks associated with nuclear weapons, as well as how to implement transparency measures. Then they should take the following steps. First, agree the definition and scope of the weapons systems covered by an arms-control treaty. Second, reach a mutual understanding regarding the definition of a strategic equilibrium that serves the security of each country. This will involve balancing qualitative values with a quantitative formula. Third, formulate mechanisms for verification and confidence-building that prevent defection without compromising sensitive security information.

Researchers and specialists in security need

to explore new models of deterrence and arms control. Win-win-wins need to be found for a three-player game. And a formula is needed to convert the balance of strategic interests into measurable levels of force, given different goals and military assets. Deterrence strategies that cover nuclear, conventional and cyber capabilities also need to be designed.

Non-nuclear states must participate in arms-control discussions. East Asia could be one focal point for testing new strategies, for three reasons. First, it is caught in the middle of a competition between the United States and China. Second, four nuclear powers, including North Korea and Russia, are involved in the region's instability. And third, non-nuclear allies of the United States – Japan and South Korea – are major strategic and scientific players in the high-tech environment that today shapes the power of states.

This places my country in a difficult but important position. Japan should take the lead in envisaging new forms of arms control, because it would be a way for the nation to commit to its promise: that what happened to the people of Hiroshima and Nagasaki must never happen again.

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1. United Nations. *Securing Our Common Future: An Agenda for Disarmament* (UN, 2018).
2. Stockholm International Peace Research Institute. *SIPRI Yearbook 2020* 354–362 (Oxford Univ. Press, 2020); available at <https://go.nature.com/3f60pjj>
3. Panda, A. *The Diplomat* (28 December 2017).
4. Krepinevich, A. F. Jr *Foreign Affairs* (January/February 2019).
5. Dawes, R. M. in *Human Judgment and Decision Processes* (eds Kaplan, M. F. & Schwartz, S.) 87–107 (Academic, 1975).