DPRK Nuclear Futures Workshop

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Executive Summary

In February 2024, the Verification Research, Training and Information Centre (VERTIC), Open Nuclear Network (ONN) and the James Martin Center for Nonproliferation Studies (CNS) convened a two-day workshop to explore the future of the Democratic People's Republic of Korea's (DPRK) nuclear programme. The goal: to assess potential future scenarios shaping weapons-usable nuclear material production, delivery systems and verification options for any future negotiated deals. Using expert elicitation and forecasting techniques, the workshop generated critical insights into the DPRK's evolving nuclear programme.

Discussions highlighted the unpredictable nature of the DPRK's nuclear objectives, which appear driven less by clear defence priorities and more by leader-centric decisions or post-hoc rationalisations of newly acquired capabilities. Despite this secrecy and changeability, participants identified plausible drivers behind the programme, such as national defence, technological ambition and regime prestige. Key uncertainties – ranging from nuclear accidents and economic challenges to famine, pandemics or diplomatic recognition – emerged as potential influences on the DPRK's trajectory.

Focused forecasting exercises and analysis honed in on five areas requiring ongoing scrutiny and open-source monitoring and analysis:

- The Experimental Light Water Reactor (ELWR) at Yongbyon.
- Advancements in gas-boosted nuclear weapons.
- Possible adoption of multiple independently-targetable reentry vehicles (MIRVs).
- Potential nuclear cooperation with Russia.
- The evolving dynamics of nuclear diplomacy with the United States.

While these factors might impact the DPRK's arsenal composition, they are unlikely to drastically alter its size. The workshop underscored that understanding the drivers and impacts of change – not precise numerical predictions of arsenal size – is the key to shaping effective analysis and policy.

Participants praised the unique workshop structure, which encouraged critical debate, challenged assumptions and broadened perspectives. By fostering collaborative inquiry and exploring potential futures, the workshop equipped experts with new information and methodologies to navigate the complexities of the DPRK's nuclear landscape.

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Introduction and methodology

In February 2024, the Verification Research, Training and Information Centre (VERTIC), Open Nuclear Network (ONN) and the James Martin Center for Nonproliferation Studies (CNS) organised a workshop[1] to craft potential future scenarios for the Democratic People's Republic of Korea's (DPRK) nuclear programme, with a focus on drawing implications for necessary production of weapons-usable nuclear material and delivery systems, and verification options for any future negotiated deal based on these scenarios.[2]

Participants were selected from both technical and policy fields, some with DPRK-specific expertise and others without regional focus, to help cover a wide range of topics, including nuclear doctrine, strategy, domestic and international politics, missiles and nuclear warheads. Further, participants were selected to encourage diversity of opinion, ensuring a balanced view across gender, age and geographical location.

The overall focus of the event was to incorporate new workshop formats and analytical methodologies not typically used in the nuclear community to encourage unique thinking and results. This was manifest in a two-track methodology.

The first track focused on expert elicitation. First, all participants were asked to present on their area of expertise in order to establish a common understanding of the current geopolitical and strategic context surrounding the DPRK's nuclear programme. Following this, an exploration of the programme's objectives was conducted in order to understand why the DPRK is developing its programme in certain ways. After broadly categorising these objectives, the participants were then asked to identify drivers that could prompt change in these objectives, thus causing the DPRK to restructure its nuclear programme. This expert elicitation allowed participants to gain a nuanced understanding of the existing political and technical landscape, and start to develop questions and ideas for areas that could affect the future of the DPRK's nuclear programme.

The second track, forecasting, started with the initial formulation of forecasting questions based on results from track one. The forecasting was facilitated by the Swift Centre, using the Delphi method.[3] A baseline question on the future of the DPRK's nuclear arsenal was posed, then participants engaged in a selection process where they suggested and voted on additional questions to address, thereby prioritising topics deemed most critical. All additional questions were generated through a combination of organiser input and participant inquiries, ensuring a diverse array of perspectives. The emphasis on measurability was paramount, with each question carefully drafted to enable quantifiable assessment of how much the additional question would affect the baseline, which was established by an initial forecast question developed by the hosts and facilitators.

Due to the novelty of the approach, feedback from the participants elicited at the end of workshop was of particular interest. The feedback highlighted the methodology's effectiveness in fostering dialogue and collecting valuable insights from a diverse range of experts, clarifying existing assumptions and filling previously unaddressed knowledge gaps. Overall, the participants who were unfamiliar or only moderately familiar with forecasting left eager to learn how to incorporate it in their future research endeavours.

This report is structured around the methodology, starting with results from the expert elicitation on the current geopolitical and strategic context in which the workshop took place, nuclear programme objectives and potential drivers of change. The forecasting results follow, with implications for verification, future research and overall observations concluding the report.

1. The organisers would like to thank the Vienna Center for Disarmament and Non-Proliferation (VCDNP) for hosting the workshop.

2. The workshop hosts provided their views and feedback on the event via video interviews. See: *Grant Christopher/VERTIC on Forecasting DPRK's Nuclear Futures*, 2024, https://www.youtube.com/watch?v=MN91Qu4VAjo; *Marcy R. Fowler/ONN on Forecasting DPRK's Nuclear Futures*, 2024, https://www.youtube.com/watch?v=8XmE29iqPeM; *Michael Story/Swift Centre on Forecasting DPRK's Nuclear Futures*, 2024, https://www.youtube.com/watch?v=P_Zvy9Rktj8; *Finn Hambly/Swift Centre on Forecasting DPRK's Nuclear Futures*, 2024, https://www.youtube.com/watch?v=GXseoBdJteo.

3. The Delphi method allows participants to provide forecasts, then encourages structured discussion of assumptions and thought processes for each result, before finally having participants update their forecasts based on the discussion. The theory is that a group of people can arrive at an answer better than an individual, especially after an informed discussion.

Part I: Expert elicitation

Current context

Despite perceptions of the DPRK's shift towards tactical pursuits since 2014, its nuclear capabilities have been continuously evolving rather than distinctly shifting. Initially, the DPRK's nuclear posture was characterised by reliance on short-range delivery systems due to the absence of long-range systems at the beginning of its programme. Of notable significance was the observation of the DPRK's gradual lowering of the nuclear use threshold over time (via policy changes and greater emphasis on tactical weapons), suggesting that the country is more conducive to nuclear use than ever before, particularly in alignment with global trends. The inclusion of a "dead hand clause"[4] in DPRK planning underscores the country's commitment to conflict readiness and hair-trigger nuclear use.

A shift in DPRK terminology from intercontinental ballistic missile (ICBM) "testing" to "launching drill" in December 2023 indicates that a potential transition may be evolving from mere technical testing to operational deployment and readiness demonstration.[5] There was discussion on how the frequency of future launches might change (and how the frequency could affect the DPRK's nuclear programme), with considerations of production challenges and potential consultation with Russia affecting testing schedules, indicating the geopolitical significance of potential DPRK–Russian cooperation in missile technology.

Nuclear programme objectives

Following the broad discussion of the current context, an extensive list of potential objectives of the DPRK nuclear programme, targeting both domestic and international audiences, was developed to generate discussion and challenge assumptions. This was done through a brainstorming session and subsequent categorisation exercise.

Through the workshop, it became evident that the DPRK's nuclear programme is adaptive, pursuing various capabilities, which may be integrated without an over-arching pre-planned mission. Not only does the programme have many objectives, but they are often competing and changeable, likely heavily influenced by leadership personality.

Defence needs

It was concluded that the DPRK's nuclear programme is fundamentally defensive, rooted in security concerns and the regime's pursuit of survival, peace and strategic autonomy. The country's informational isolation may amplify paranoia among its scientists and political elite, who struggle to assess the credibility of external threats and thus continue to bolster the nuclear arsenal. Beyond defence, nuclear weapons also enable the DPRK to engage in geopolitical manoeuvres, leveraging its deterrent to extract economic or political gains while maintaining confidence in its ability to prevent invasion.

4. The Dead Hand system enables nuclear retaliation even if the leaders with the authority to initiate nuclear launch are deceased or incapacitated. See: Ildo Hwang, 'DPRK's Law on the Nuclear Forces Policy: Mission and Command&Control', IFANS Focus (Institute of Foreign Affairs and National Security, 14 September 2022), http://www.ifans.go.kr/knda/ifans/eng/pblct/PblctView.do?pblctDtaSn=14058&clCode=P11&koreanEngSe=ENG.

5. Vann H. Van Diepen, 'Third Successful Launch of North Korea's Hwasong-18 Solid ICBM Probably Marks Operational Deployment', *38 North*, 21 December 2023, https://www.38north.org/2023/12/third-successful-launch-of-north-koreas- hwasong-18-solid-icbm-probably-marks-operational-deployment/.

While primarily defensive, the DPRK's arsenal is designed to achieve victory in war, not merely endure damage. Tactical nuclear weapons complicate the Republic of Korea's (ROK) missile defences and deter both pre-emptive strikes and retaliatory actions. The DPRK's growing emphasis on force mobility and subtle shifts in doctrinal language hint at the potential for pre-emptive nuclear use. By amplifying external threats and invoking war readiness rhetoric, the regime legitimises its heavy investment in the military-industrial complex. Interestingly, this narrative parallels similar justifications for military buildups on the Korean Peninsula by the ROK and the United States (US).

Technical development

However, as with other nuclear programmes, the DPRK's nuclear weapons development may not solely be driven by defensive or war-fighting needs but also by such factors as pressure from the domestic defence industry, scientific competition, internal momentum, technical ambitions and global power identity. So, the development of diverse weapon systems (tactical and strategic) is not only about enhanced deterrence and flexibility in potential use scenarios, but about capability development/demonstration and desire for parity – a "full set" to mirror other nuclear-armed states.[6]

Therefore, the DPRK's strategy may be evolving in the style of gaining a new capability first and then developing a mission for it. The question persists as to why in such an environment the DPRK does not develop an airleg for its nuclear forces as there are many reasons for and against development of such a capability; however, due to time constraints, this was tabled for future research.

Bargaining chip or national pride?

While it is possible the nuclear arsenal could serve as a bargaining chip, negotiations between the DPRK and the US often falter because the US seemingly cannot compromise on topics such as human rights, while the DPRK refuses to discuss this topic. Further, while the US has insisted on denuclearisation as a goal for any negotiations, the 2023 DPRK constitutional amendment, codifying the permanence of its nuclear policy and demonstrating that the programme has become an inseparable part of the state's defence, seemingly takes denuclearisation off of the negotiating table.

The nuclear programme plays a significant role in the country's identity, symbolising statehood and global prestige, and evoking national pride. It is used domestically to mask economic deficiencies by showcasing success in the nuclear sphere. Since the DPRK cannot demonstrate economic superiority over Japan, the ROK and other rivals, it turns to nuclear superiority.

Potential drivers of change

The workshop also examined potential events or circumstances that could reshape the DPRK's nuclear objectives and prompt a restructuring of its programme. Four drivers emerged as discussion points: nuclear accidents, famine or pandemics, economic shifts and international recognition as a nuclear state. Other potential influences, including leadership changes, regime collapse, conventional military advancements and shifting alliances, were noted but not deeply explored due to time constraints.

Nuclear accidents

The impact of a potential DPRK nuclear accident on its weapons programme remains debated. While some argued that an accident could delay or even halt progress due to the practical complications of fissile material production, it was largely agreed this would only significantly alter the programme's trajectory if it directly affected Kim Jong Un's family or the political elite. Even then, the complete cessation of the nuclear programme seems questionable.

A large-scale accident would be hard to conceal domestically, making it difficult to deflect blame onto other countries. While casualties might be framed as "sacrifices for the greater good," such an incident could strain the regime's justification of its nuclear ambitions, challenging the "social contract" with its population. Internationally, any fallout impacting China, Japan, the ROK or Russia would provoke strong reactions.

[6] However, the evolving landscape of nuclear strategies and differing perceptions among states suggest a fluid understanding of what constitutes the "full set."

Only accidents causing mass casualties or widespread contamination were deemed likely to force significant changes, such as prolonged development delays or even programme shutdowns. However, two exceptions were noted: targeted attacks on the nuclear fuel cycle (NFC) or the loss of key nuclear scientists could cripple the programme, even if the accidents themselves were localised.

Famine or pandemic

Famine or pandemic would likely have a negligible effect beyond perhaps a brief pause in NFC activity as workers starve or fall ill. NFC activity did not seem to be greatly affected by the severe famine in the 1990s or the COVID-19 pandemic, although in future an exception could occur if Kim Jong Un (or future leader) were significantly endangered or if the disaster exceeded a level of damage or hardship that could be tolerated by the population.

Economics

Influencing the DPRK's nuclear programme through economic means is challenging since the country operates outside the international trade and financial systems. Furthermore, sanctions have become significantly less effective over time as the DPRK has been able to replace previously legally imported goods with domestic production or illicit trade, further assisted by the expanding cooperation between the DPRK and Russia.

Nevertheless, if the US and the greater international community acquire the technical capability to shut down more of the DPRK's revenue sources, for example in its illicitly gained cryptocurrency holdings, it could affect the DPRK's nuclear programme. Trends in the global market (including the black market) might also influence the types of delivery vehicles the DPRK focuses on, as some technologies may be difficult to acquire.

Recognition as a nuclear state

It was noted that any form of official recognition of the DPRK as a nuclear-armed state might prompt Japan or the ROK to pursue nuclear weapons due to the demonstrated lack of consequences and gain of prestige imparted by the international community to a state that illicitly develops a nuclear programme. However, recognition could also lead to more engagement via international conferences, diplomacy or peaceful nuclear cooperation in science and technology, potentially reducing the likelihood of accidents or miscommunication and improving security.

Recognition would probably not substantially affect the DPRK's nuclear programme, with its trajectory more likely to be influenced by the development of other countries' nuclear programmes (due to either fear or competition) than its own recognition. It remains unclear whether the DPRK would seek explicit acknowledgement of its nuclear weapons programme as a de facto nuclear-armed state or even some form of full de jure recognition as a Nuclear Non-Proliferation Treaty "Nuclear-Weapon State" (acknowledging that no precedent for such recognition exists nor has any intention been identified in any potential recognising state).

Part II: Forecasting

Forecast baseline

The workshop's forecasting exercise began with a baseline question and expanded to explore conditionals, causes and consequences. Participants first provided initial forecasts, followed by guided discussions to unpack assumptions and reasoning. While responses were anonymised, individuals could choose to share their forecasts openly. After these discussions, participants were encouraged to revise their predictions based on new insights, with space provided to note disagreements, assumptions or caveats.

The baseline question initially separated "tactical" and "strategic" weapons but was soon simplified due to the ambiguity in defining these categories. Instead, the group focused on the overarching question: "How many nuclear warheads will be in the DPRK's arsenal in February 2029?" Forecasts ranged from 65 to 215 warheads, with a 25th percentile of 84 and a 75th percentile of 174. The goal was not to pinpoint an exact number but to create a foundation for examining how various scenarios might influence the arsenal's size.

Two key insights emerged during the discussions:

- Even with significant fissile material production, the DPRK may choose not to convert its entire stockpile into warheads.
- Current estimates of the DPRK's arsenal might be overly conservative, as they often rely on historical or current production rates. With expanded fissile material capacity, technological advancements and increased weapons manufacturing experience, production is expected to accelerate.

Forecast conditionals/causes

The workshop's forecasting exercise combined organiser planning with participant-driven inquiry, fostering a collaborative and dynamic approach. Additional questions influencing the baseline forecast were developed through a mix of organiser input and participant suggestions, then prioritised through participant voting to focus on the most critical topics. Each question was designed to be measurable, allowing for quantifiable predictions alongside detailed commentary for nuanced insights.

Time constraints narrowed the focus to the most pressing issues, leaving some questions unaddressed but offering opportunities for future research or workshops. These untapped topics included (listed in alphabetical order): 5 MW(e) reactor operations, delivery systems, DPRK leadership changes, economic factors, nuclear diplomacy, nuclear warhead designs, shifting alliances/rivalries, tritium production and uranium enrichment.

The following is a summary of the forecasting results, categorised by key areas.

Experimental Light Water Reactor (ELWR)

Fissile material production was a key focus of the workshop, particularly how the NFC shapes weapons development and mission planning. While the DPRK has produced significant amounts of highly enriched uranium (HEU), its strategic focus likely[7] remains on the plutonium pathway, which facilitates the miniaturisation of warheads for intercontinental ballistic missiles (ICBMs) and potential deployment with multiple independently-targetable reentry vehicles (MIRV). Plutonium's lighter weight makes it ideal for long-range systems, though the use of HEU or composite materials remains a possibility. However, engineering challenges – such as missile size and geometry – mean weight is not the only concern, aligning with observed trends of larger DPRK ICBMs.

The DPRK's Experimental Light Water Reactor (ELWR) emerged as a critical factor in sustaining plutonium production, given the ageing 5 MW(e) reactor. The ELWR's potential influence on the DPRK's nuclear weapons production, however, is tied to uncertainties about its capabilities, such as its ability to produce weapons-grade plutonium, the quality of output and its classification as a light water reactor (LWR). Notably, the ELWR features an electric substation, absent in the 5 MW(e) reactor, which could indicate dual use for electricity generation or processing cycle demands.

Postulation also centred on possible reprocessing facility modifications, such as establishing a second production line or utilising a potential spare line at the existing plant. The feasibility of manufacturing a pressure vessel for the reactor was also questioned. Estimates suggest the ELWR could yield approximately 20 kg of plutonium annually – enough for multiple warheads – if NFC resources are entirely allocated to its fuel fabrication and reprocessing. However, dividing resources between the ELWR, 5 MW(e) reactor and HEU production[8] could significantly reduce the ELWR's plutonium output.

Plutonium production appears poised to remain central to the DPRK's strategy, driven by doctrinal and practical considerations.

Future ELWR operation

Given the pivotal but yet unclear role of the ELWR, workshop participants engaged in forecasting exercises to assess the potential impact of the first reactor cycle's success on the DPRK's nuclear arsenal, the likelihood of such success and its intended use. The median effect was a net gain of ~10% of the total baseline forecasted warhead stockpile on 16 February 2029. Further, it was considered likely that (1) the DPRK would have a successful first reactor cycle by 16 February 2026, and (2) the ELWR would produce weapons-grade plutonium in its lifetime.

Regarding question (1), it was suggested that success was feasible if the DPRK was conducting a commissioning cycle and managing sustained operation. However, the possibility of failure and significant commissioning delays could not be discounted. Additionally, the reactor could still be in a testing phase rather than in a commissioning cycle for full operation; a critical indicator of operation would be the observation of thermal signatures sustained over several weeks. Factors such as high political motivation and the abundance of similar LWRs worldwide (with ample open-source, operational information available) were mentioned as additional support for the DPRK's likelihood of success with the ELWR.

The ELWR would be an efficient means to achieve the DPRK's goal of expanding its arsenal. However, the ELWR's primary purpose remains uncertain considering its potential inefficiency as a source of weapons-grade plutonium; the possibility of the reactor serving a dual purpose could not be discounted. One participant expressed scepticism regarding the ELWR's role beyond that of a mere power reactor and questioned its efficiency as a plutonium source, adding: "Even if it was, the produced Pu wouldn't affect their arsenal in such a short time span." Another participant echoed this opinion, suggesting that the DPRK would struggle to extract a significant amount of plutonium within the next five years.

[7] For the purposes of this report, "highly likely" is defined as 87-99%, "likely" 61-86%, "even likelihood" 40-60%, "unlikely" 20-39% and "highly unlikely" 1-19%. See: Sherman Kent, 'Words of Estimative Probability' (US Central Intelligence Agency), accessed 27 November 2024, https://www.cia.gov/readingroom/docs/CIA-RDP93T01132R000100020036- 3.pdf.

[8] The ELWR requires different fuel from the 5 MW(e), which could drive resources away from HEU production or divert HEU from its weapons programme.

Further, one participant questioned why, if the ELWR is intended primarily for energy generation, would the DPRK not be building another graphite-moderated reactor at Yongbyon to replace the ageing 5 MW(e) reactor, as some form of plutonium-production reactor would be needed in the 5 MW(e) reactor's stead. As we do not see another reactor being built, it lends credence to the argument that the ELWR's primary purpose is a replacement plutonium-production reactor.

Indicators of ELWR purpose

When discussing the forecasting results, the issue of indicators one might see if the DPRK were optimising for plutonium production or electricity generation was raised.

The ELWR's fuel would require at least a year of cooling before use, after which the DPRK could extract 3–4 kg of weapons-grade plutonium, assuming a three-month cycle. The operational cycle for energy production would be longer.

Factors that could contribute to delays in operation of the ELWR include the revealing of faults during the commissioning phase (although it was also suggested that the DPRK had likely been testing fuel in an IRT reactor to help with this concern) and the extensive preparatory work required in starting a reactor for the first time.

Concerns persisted regarding the reliability of detecting a heat signature from satellites as an indication of successful full operation, with questions raised about the potential for spoofing or other modes of operation. Although the likelihood of spoofing was discounted, the possibility of intermittent or testing operation (as opposed to commissioning) was considered. Questions remain on: (1) the reliability of heat signatures as a tool to measure operational tempo; (2) how the ELWR heat signatures compare to those of other similar reactors worldwide; and (3) the potential for deception or misinterpretation of heat signatures.

Finally, despite the ELWR having been seemingly operational (or at least producing heat) for an extended period, the DPRK's urgency to put the ELWR into operation has likely increased due to Kim Jong Un's directive at the beginning of 2023 to expand the arsenal significantly.

Notably, since the workshop in February, the ELWR appeared to stop discharging water from mid-March until the end of April, although exact dates are unclear.[9] Further monitoring and analysis continue to be published examining the reason for the potential shutdown and restart and implications for plutonium production.[10]

Gas boosting

The workshop discussion on the nuclear arsenal raised the issue of gas boosting – the use of gaseous tritium/deuterium to boost the efficiency of a nuclear weapon. Considerable uncertainty exists regarding the DPRK's possession of the technology. Therefore, after some initial discussions with participants familiar with the technology, a forecasting question was asked regarding the likelihood of the DPRK incorporating this technology and how it would numerically affect the overall nuclear arsenal.[11] The forecasted effect was a net gain of ~9% of the total forecasted baseline warhead stockpile on 16 February 2029; however, gas boosting was considered unlikely to be incorporated before then.

Gas boosting remains a challenging technology to master, requiring extensive testing and resources. The DPRK's progress in this area is uncertain, as there is no clear evidence it has actively pursued or prioritised the capability. Gas boosting complicates warhead design, testing and maintenance, and its strategic benefits may not justify the effort. As one participant noted: "There is no solid technological reason to have gas boosting just for the sake of having parity with other nuclear states." It would be among the most test-reliant – and thus politically costly – developments in the DPRK's arsenal, raising visibility and risk. While the technology could reduce the amount of fissile material needed for similar yields, the trade-offs require further analysis.

9. Bruce Songhak Chung, 'Satellite Imagery Suggests That North Korea Is Restarting Test Operations in Yongbyon', *Daily NK*, 2 May 2024, https://www.dailynk.com/english/satellite-imagery-suggests-north-korea-restarting-test-operations- yongbyon/.

10. Cecilia Gustavsson et al., 'Modelling Fissile Production in the Experimental Light Water Reactor (ELWR) of DPRK', 2024, https://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-536937; Cecilia Gustavsson et al., 'Modelling fissile production in the Experimental Light Water Reactor (ELWR) of North Korea', *forthcoming*.

11. The question was framed as, "will we believe they can do gas boosting on February 16, 2029?" to enable it to be measured; given the secrecy of the issue, the question could not be "will they be able to," as the external community's belief in their capability is all that can be known for certain.

Still, the DPRK's low missile precision could make higher-yield warheads desirable, potentially increasing interest in gas boosting. A potential tritium handling facility has been identified at Yongbyon, with some external experts believing that tritium production facilities must also be present.[12] The DPRK's potential interest in tritium for initiator purposes was mentioned as a possible explanation for this facility, although alternative neutron initiators could be used instead. Actual lithium production, necessary for the breeding of tritium in nuclear reactors, remains unconfirmed despite exploration by open-source analysts.[13]

Given these hurdles, the DPRK might falsely claim mastery of gas boosting for psychological effect. Such a claim would be difficult to verify with open-source information (e.g. inability to see production inside buildings, inability to assess detailed warhead design information from ground imagery), creating ambiguity that could heighten perceptions of threat among adversaries.

However, pursuing gas boosting could hinder overall arsenal growth. Tritium production would reduce weapons-grade plutonium output, shrinking the fissile material stockpile. Fissile material, human and financial resources would need to shift toward new warhead designs and testing, slowing increases in warhead numbers. These challenges make it unlikely that gas boosting would significantly impact the DPRK's arsenal by 2029, as the timeline for developing and deploying such technology appears too short.

Multiple independently-targetable reentry vehicle (MIRV) capabilities

Workshop participants agreed that development of MIRV capabilities was an important factor that added ambiguity to nuclear weapon predictions; more warheads could be put on missiles, thus increasing the number of warheads that could be assigned to more strategic missions. Therefore, it was decided that MIRV technology should be added to the forecasting exercise, asking if the DPRK were to demonstrate MIRV technology in five years, how would the number of warheads be affected. The median effect was a net gain of ~6% of the total forecasted baseline warhead stockpile on 16 February 2029; however, it was considered unlikely to be demonstrated before that date.

After forecasting and further discussion, it was determined that MIRV development would likely not determine the arsenal size. Once the DPRK's arsenal increased, the country might be able to use or justify MIRVs. The DPRK could demonstrate various capabilities, potentially including MIRV technology, before 16 February 2029; however, uncertainties persist regarding the operational readiness of such a system and the number of warheads it could accommodate. The likelihood of such a demonstration ultimately hinges on the DPRK's prioritisation and the complex interplay of motivation and technical difficulty.

While MIRV technology was part of a stated goal in the five-year plan (2021–2025), it may not be solely mission-driven but instead aim to demonstrate the capability to produce highly sophisticated technology that few states have mastered.

Plutonium production is a major obstacle to MIRV technology incorporation, as warheads would likely need to be plutonium-based in order to achieve the proper weight reduction necessary to be used in MIRV-based systems. There is also a need for a specific warhead design in order to successfully MIRV nuclear weapons. The success of tests in terms of actual payload delivery remains uncertain. Coupled with unknowns about the material science infrastructure of the DPRK, doubts were raised about the DPRK's ability to demonstrate MIRV technology by 2029. At the same time, concerns about espionage and the deepening relationship with Russia further complicate the assessment.

Nuclear cooperation with Russia

As participants identified nuclear cooperation with Russia as a potential influencing factor in the DPRK's ability to increase its nuclear stockpile over the next five years, a forecasting question on this subject was posed. The median effect, should Russia supply sensitive nuclear weapons technology to the DPRK before 16 February 2026, was a net gain of ~15% of the total forecasted warhead stockpile on 16 February 2029.

12. Siegfried S. Hecker, *Hinge Points: An Inside Look at North Korea's Nuclear Program* (Stanford University Press, 2023).

13. David Albright et al., 'North Korea's Lithium 6 Production for Nuclear Weapons' (Institute for Science and International Security, 17 March 2017), https://isis-online.org/isis-reports/detail/north-koreas-lithium-6-production-for-nuclear-weapons/10; Hugh Chalmers, 'Producing Tritium in North Korea', *Trust & Verify*, no. 152 (March 2016): 1–6.

However, Russia was deemed highly unlikely to directly provide nuclear warhead design information, other sensitive technical state secrets or fissile material unless Russia's geopolitical and economic position were to deteriorate considerably. Russia could, however, offer indirect assistance to the weapons programme by: providing general information or testing data; offering feedback and assisting in troubleshooting problems; or contributing to its nuclear energy programme (e.g. providing assistance with the ELWR). Concerns were also raised about the possibility of Russian individuals (e.g. retired scientists, academics) illicitly aiding the DPRK with nuclear weapon-related technology.

US election and negotiations

Another area of external influence identified as potentially affecting the DPRK's future nuclear arsenal was negotiations with the US. The workshop participants explored this issue further in a series of forecasting questions imagining a future with Trump re-elected in November 2024, versus a future where a non-Trump president is elected, with a general agreement that the DPRK policies of a Democrat-led Administration would be similar and therefore result in similar outcomes.[14]

It was estimated that nuclear negotiations would be unlikely to occur within the next five years under a future Trump Administration, and the overall impact of the US presidential election on the total forecasted DPRK nuclear warhead stockpile was assessed to be small. Under the Trump scenario, only a slight weapons production slowdown was forecasted, resulting in ~4% fewer nuclear warheads than the total forecasted baseline warhead stockpile on 16 February 2029. Under a non-Trump future, it was forecasted that there would be a negligible difference from the baseline.

Despite the outcome of the US election, the DPRK remains unlikely to engage in meaningful negotiations aimed at halting fissile material production, reducing its nuclear arsenal or disarming altogether.

While it was assessed that Kim Jong Un would be reluctant to meaningfully engage with Trump again partly due to political risks – "Trump couldn't deliver before" – there could be a slightly higher potential for talks between Trump and Kim than the non-Trump alternative due to their mutual affinity for high-profile meetings and previous exchanges. While there have been some indications since the workshop that the DPRK may be interested in re-opening nuclear talks with Trump, to include comments from a former high-level diplomat who recently defected to Cuba,[15] such potential discussions were noted by participants as unlikely to yield substantial outcomes, especially considering the significant changes the DPRK has made over the past few years to solidify its nuclear programme.

Overall, significant concessions would be required from the ROK and the US to elicit any willingness to negotiate from the DPRK; even then, the feasibility of achieving agreement on substantial arms control or denuclearisation in the current and worsening geopolitical climate remains doubtful. The maximum concession foreseen could be a cap on warhead numbers or a nuclear test moratorium, which could keep the DPRK from a performing a seventh nuclear test, for which ONN analysts have assessed it could be prepared.[16]

Hence, the outcome of the 2024 US election was assessed as unlikely to change the future of the DPRK nuclear arsenal; if negotiations do occur, they would likely lead to a pause in DPRK activities at most, but not a rollback. The DPRK may even push for recognition as a nuclear power. Moreover, given past negotiations failures, the DPRK was seen as unlikely to agree to cease any activities critical to nuclear weapons production during negotiations, only after such a time that an agreement is reached. Finally, it was noted that the DPRK would only easily give up something it thinks it does not need – any concessions that it would offer without much in return could therefore be understood as of relative unimportance to the nuclear programme.

Summary of impacts

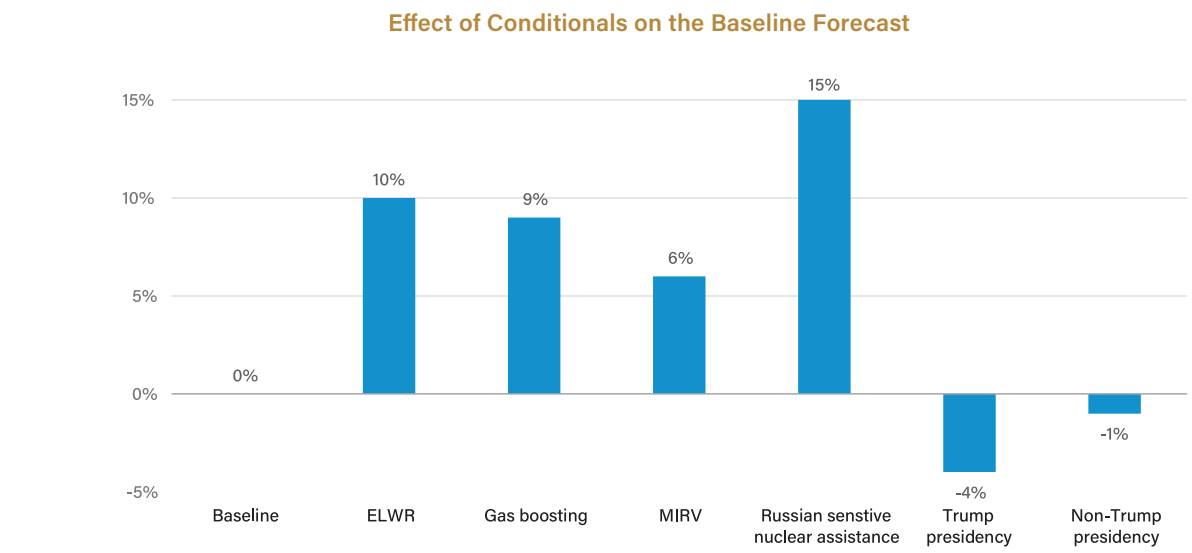
As the focus of this workshop was not to predict an exact number of weapons the DPRK might have in February 2029, a diagram showing how each conditional could affect the baseline forecast is shown in Figure 1 to aid visualisation of the potential impacts of future events or developments.

[14] Since the workshop was held, Donald Trump was re-elected on 5 November in the 2024 US presidential election after spending a term out of office following a loss to President Joe Biden in 2020. Following the election, ONN published a separate piece with excerpts from this section: Sarah Laderman et al., 'US Election Outcome Unlikely to Have Significant Impact on the DPRK's Nuclear Weapons Programme', *Open Nuclear Network*, 12 November 2024, https://platform.opennuclear.org/thoughtroom/quick-takes/us-election-outcome-unlikely-to-have-significant-impact-on-the-dprks-nuclear-weapons-programme.

[15] Hyonhee Shin, 'Exclusive: North Korea Wants to Restart Nuclear Talks If Trump Wins, Says Ex-Diplomat', *Reuters*, 1 August 2024, sec. Asia Pacific, https://www.reuters.com/world/asia-pacific/north-korea-wants-restart-nuclear-talks-if- trump-wins-says-ex-diplomat-2024-07-31/.

[16] Jaewoo Shin et al., 'Strengthening Nuclear Test Ban Monitoring and Verification: The Role of Commercial Satellite Imagery' (Open Nuclear Network, 17 June 2024), https://opennuclear.org/open-nuclear-network/publication/strengthening-nuclear-test-ban-monitoring-and-verification-role.

Figure 1. Percentage effect of each conditional forecast on the baseline forecast (total number of nuclear weapons in the DPRK on 16 February 2029).



Forecast consequences

Future nuclear testing

Discussion surrounding the weapons arsenal and gas boosting shifted to the question of nuclear testing. The DPRK's limited number of tests has likely hindered its ability to diversify designs. However, an increased testing frequency would not necessarily indicate the introduction of new capabilities; failures of the device or suboptimal results (design yield not reached) could also occur that would need correcting via testing. Remarkably, the DPRK seems open to acknowledging test failures, at least in its missile programme.[17] Moreover, increased testing entails greater use of nuclear material, which would more quickly deplete the stockpile of materials available for further weapons production.

Given the workshop discussions and external expert discourse[18] on future DPRK nuclear tests, participants were asked how many nuclear tests would need to take place by 2029 to reach an arsenal of over 125 nuclear warheads at that date. The forecasted range was 1–3.

However, the answer to this forecasting question depends on whether the DPRK seeks to test new warhead designs or has not yet added additional capabilities that warrant testing. The number of tests could also rise if other states resumed nuclear weapon testing, which would serve to remove the norm against nuclear testing, thus encouraging greater testing by the DPRK.

Conversely, factors that might cause the DPRK to refrain from testing include production issues, technological unreadiness, knowledge transfer to the DPRK (such as computational testing that might render a physical test unnecessary) and a potential restart of the unilateral test moratorium.

17. For example, on 31 May 2023, DPRK state media acknowledged the failure of a satellite launch. See: 'KCNA Report,' *KCNA*, 31 May 2023, https://kcnawatch.org/newstream/1685496981-427573091/kcna-report/.

18. For a small selection of the discourse, see: Tianran Xu, 'Backgrounder: Previous DPRK Nuclear Tests' (Open Nuclear Network, 17 June 2022), https://platform.opennuclear.org/thoughtroom/quick-takes/backgrounder-previous-dprk- nuclear-tests; Jack Liu, Olli Heinonen, and Peter Makowsky, 'North Korea's Punggye-Ri Nuclear Test Site: No Signs of an Imminent Test - 38 North: Informed Analysis of North Korea,' *38 North*, 11 April 2023, https://www.38north.org/2023/04/north-koreas-punggye-ri-nuclear-test-site-no-signs-of-an-imminent-test-2/; Rachel Minyoung Lee, 'To do or not to do: Pyongyang's Seventh Nuclear Test Calculations,' Bulletin of the Atomic Scientists 80, no. 2 (3 March 2024): 87–93, https://doi.org/10.1080/00963402.2024.2314434.

Potential verification and safeguards

There is a significant increase in available information about the DPRK's nuclear programme (from satellite imagery, open-source analyses, state-supplied images/statements and previous International Atomic Energy Agency inspection details) compared to during previous verification negotiations with the DPRK; however, establishing safeguards would still pose challenges, particularly as the DPRK is unlikely to accept comprehensive safeguards and would be unlikely to allow access to sensitive military sites required to verify the cessation or dismantlement of a nuclear programme.

There is a nuanced understanding of what international inspectors could discern about the DPRK's programme versus what the DPRK would precisely reveal; South Africa serves as a relevant example. Any future verification agreement will encounter technical challenges like accounting for materials in poor condition, limitations of DPRK disclosures and historical knowledge gaps within the DPRK.

With these limitations and concerns about future access, the workshop and forecasting results can help prioritise potential verification and inspection measures should there be an opportunity to enter the country in the future. For example, given the amount of speculation that has surrounded the ELWR, immense importance rests on knowing more about the reactor design and its operation in order to better understand the future of the DPRK's nuclear arsenal. This would then make the ELWR a very high, if not the highest, priority for inspection and verification. Following the discussions mentioned here, understanding any potential tritium production, enrichment operational history and lithium facilities could also be considered high priorities.

Areas of future research

To further understand the DPRK's nuclear programme objectives, the following non-exhaustive list of research areas were proposed: (1) a comparison of the DPRK's nuclear doctrine to the Soviet/Russian doctrine to identify any common areas of motivation or objectives; and (2) an in-depth assessment of the reasoning behind the DPRK's inability to develop an air-leg for its nuclear arsenal.

To assist with greater understanding of how the forecast conditionals could affect the future of the DPRK's nuclear programme, the following research areas were proposed: (1) a comparison of the DPRK's ELWR heat signature to similar reactors elsewhere in order to better establish a baseline of how the ELWR might look on satellite imagery in different operational modes; (2) an assessment of the weight trade-off of gas-boosting technology to determine if MIRV technology is possible with or without gas boosting, how the range could be modified for different missiles and what yield trade-offs would be possible; (3) an assessment of the type of assistance Russia or other parties could offer to the DPRK.

Participants were overwhelmingly positive in their assessment of the workshop and its use of forecasting and were eager for future workshops exploring this topic further and using this methodology on other relevant topics. In any future iterations, participants recommend going into more depth into specific scenarios, focusing on likelihoods of each scenario and impacts beyond numbers for warheads. More time to focus on different issue sets, such as the influence of China, the specific composition of the nuclear arsenal and uranium enrichment capabilities, would also be beneficial, perhaps even running a series of workshops segmented by topic area to allow for more in-depth discussion and use of the forecasting methodology.

Overall observations and conclusions

Throughout the workshop, it was noted that the DPRK's nuclear programme does not always appear to strictly adhere to clear defence objectives. This could be due to the fact that it is dependent on the "whims" of Kim Jong Un or that the DPRK tends to gain a new capability first and then develop a mission for it.

While there are multiple objectives for the arsenal and drivers that affect it, none of these objectives or drivers appear to radically shift the numerical structure of the DPRK's nuclear arsenal; changes tend to happen in the margins or on overall composition of the nuclear arsenal.

The key areas of discussion, and those areas where more information should be sought through continuous monitoring and future open-source analyses, included the ELWR, gas boosting, MIRV technology, cooperation with Russia and nuclear diplomacy with the US.

The process of discussing the key determining factors and understanding their relative impacts on the baseline during the forecasting exercise was found to be more important than the end result of specific numeric predictions, especially as the process allowed all participants to investigate and question their assumptions. Participants appreciated the intensive knowledge exchange and unique workshop format, having acquired new information and methodologies to bring back to their own research.

By thinking about problems from different angles, and questioning assumptions and baseline knowledge, we can better understand different potential futures and their consequences.