Towards an Assessment of North Korea’s Strategic Deterrent

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North Korea’s latest ballistic missile test shows that it is determined to create an effective nuclear deterrent. But what is the likelihood of a single North Korean warhead successfully hitting a target in the US?

North Korea’s latest ballistic missile test has put it back to the top of the international security agenda. Estimates suggest that this significantly upgraded system might have a range of around 13,000 km, if equipped with a relatively light payload. Even US Secretary of Defense Jim Mattis has acknowledged that Pyongyang could reach anywhere in the world with this system.

There is no sign that North Korea is about to let the US strategy of ‘maximum pressure’ deter it from achieving its goal: a nuclear deterrent against a US-led regime change in Pyongyang. This latest waypoint in capability development is concerning, but doesn’t mark a new front in Pyongyang’s nuclear endeavours. It does however increase the challenge for those contemplating policy responses to it – particularly those who have staked political capital on ensuring that this nuclear capability will never emerge.

North Korean missiles are not known for their accuracy

It is worth taking a step back and assessing exactly how much nuclear risk North Korea poses to the continental US, and how much it can pose in future. If its strategic deterrent is founded on an intercontinental ballistic missile (ICBM) fleet with the capability of threatening the decision-making centre of its primary adversary, then we should examine in greater detail just how easily the nominal capability of this latest missile can be translated into practice.

The first factor to consider is the availability of suitable nuclear warheads for the developing ICBM force. North Korean missiles are not known for their accuracy and this is likely to be a particular difficulty at intercontinental ranges. North Korea will likely seek to compensate for this by aiming to maximise the potency of each warhead, such that it can damage its targets even when several kilometres off course; it has shown with its most recent nuclear test that this is the priority for its weapons programme.

But North Korea’s ability to produce missile-deliverable high-yield warheads might be challenged by its limited ability to produce tritium, an isotope of hydrogen that can be used as fuel in thermonuclear fusion. While it is perfectly feasible to produce nuclear warheads without using tritium, it is almost impossible to produce high-yield nuclear weapons that meet the space and mass constraints of ICBMs. Precise requirements are design-dependent (and classified), but authoritative open sources use nominal figures of around 4–5 grams per weapon.

Tritium decays away over time, at a rate of about 5.5% per year, so constant production is required to maintain stocks as well as to expand them. Using that figure, a production rate of around 0.25 grams per year would therefore be required for each tritium-using weapon in the stockpile, just to hold it steady. North Korea’s ageing Soviet-provided IRT-2000 research reactor is one possible source. But its fuel is in short supply; new fuel would require high-enriched uranium, diverted from the weapons programme, and the production rate would be very low.

A more likely source is North Korea’s primary plutonium production reactor, the 5MWe gas-graphite reactor at the Yongbyon nuclear research centre. This reactor might be capable of sustaining production of around 3 grams per year, assuming it operated constantly (which it does not). It could therefore support at most around a dozen high-yield nuclear weapons suitable for delivery by ICBM; it would take around ten years to produce enough material to support the first six, though, and another 25 for the next. In practical terms, if the above assumptions were correct, North Korea’s stockpile of these weapons would be a bare handful.

Without tritium, it is almost impossible to produce high-yield nuclear weapons that meet the space and mass constraints of ICBMs

Pyongyang might instead choose to use some of its uranium enrichment capacity to slightly enrich fuel for this reactor, which would greatly increase tritium output at a cost in plutonium production. If so, then it might aspire to...
the efficiency of the UK’s early tritium-producing reactors at Chapelcross, on which its smaller 5MWe reactor design is based, and which were estimated to be capable of producing up to 200 grams a year if dedicated to tritium production.

We can use the fact that the Chapelcross reactors were approximately ten times more powerful than the Yongbyon reactor to roughly estimate a maximum production of 20 grams per year in these circumstances.

This gives a picture about which we should be much less sanguine: a theoretical stockpile cap of around 80 ‘strategic’ warheads. Again, practical constraints – a more realistic reactor operating profile, extraction losses, and so on – will act to reduce this figure perhaps by half, or more. Even so, a stockpile of tritium capable of supporting 40 weapons is not to be taken lightly.

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But there are two silver linings to this cloud. First, the theoretical worst-case scenario (20 grams of tritium per year) would require production of slightly enriched fuel at a rate sufficient to support a reactor core load of around 50 tons of fuel approximately every two years. This would put a severe dent in North Korea’s uranium enrichment capacity. Assuming a nominal fuel enrichment of 0.95%, around 7,000 Separative Work Units (SWU, the standard measure of isotopic separation performed by an enrichment process) would need to be set aside each year. To put this into context, the Yongbyon uranium enrichment plant is estimated to have a capacity of around 16,000 SWU; this focus on tritium would therefore come at the cost of almost half of North Korea’s known uranium enrichment capacity, and around a quarter of its suspected capacity.

Second, getting to this theoretical maximum would take quite some time. The constant decay of tritium results in spending more energy treadi
water and less making progress as the stockpile expands. In the worst-case scenario above, it would take around five years of constant operation to produce enough tritium for 20 nuclear weapons; in a more plausible scenario, North Korea might have enough for ten weapons over the same period, and enough for 20 after a further seven years.

Leaving aside potential warhead constraints, missile performance and reliability is also likely to be a concern for North Korea. It has increased the pace of its missile testing in recent years, but has still conducted relatively few tests of intercontinental systems, and none involving atmospheric re-entry under representative conditions. Without the test ranges available to the US, China and Russia, Pyongyang will never be able to fulfil this last criterion, as it cannot monitor the performance of a test warhead during atmospheric re-entry. This means that it cannot know for sure what proportion of warheads could be expected to survive – and it does not know which of those can be expected to land close enough to their targets to have the desired effect.

The final factor to consider is US missile defence efforts. Theatre missile defence systems cannot currently defeat ICBM targets, due to their rapid acceleration in boost phase and their extreme speed in the terminal, re-entry phase. This leaves the US Ground-Based Midcourse Defense (GMD) system as the country’s only system to claim a capability against these targets, the teeth of which are provided by 44 Ground-Based Interceptors (GBIs).

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President Trump recently cited an implausibly high success rate for this system, at around 97%. This is more likely to be the objective for the system as a whole, in which the concept of operations involves firing four interceptors at every incoming threat. For simplicity’s sake, if we take each interception attempt as an independent event, rather than the correlated events that they are in practice, this corresponds very roughly to each missile having an interception probability of 60%. Still, given the performance record of the system, this is rather high: a more conservative interception probability for each missile would be 25%. If there are sufficient interceptors to maintain the four-shots-per-threat doctrine, this means that any warheads that make it past boost phase will have just under a 70% chance of being intercepted by US GMD. Any warheads that make it past the interceptor shield might well not survive re-entry.

At this stage – re-entry – we have almost no information, with the only public data coming from a Japanese weather camera video of what appears to be a payload breakup on re-entry during North Korea’s ICBM test on
28 July; a US intelligence assessment, on the other hand, reportedly indicates that North Korean re-entry vehicles should survive if launched on more realistic trajectories. But without access to the sources on which this assessment draws it is hard to do anything more than guess. If we were to estimate, with great uncertainty, that around half of these warheads would survive re-entry, then this would be a reasonable starting point until we have more data.

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We can therefore outline a rough estimate of the likelihood of any single warhead successfully making the journey from North Korea to a target in the US. First, what is the likelihood that the warhead will make it out of boost phase? North Korea has a solid recent record, but there haven’t been enough tests of the ICBM-class systems to call them truly reliable; an estimated 90% success rate would perhaps be high but not implausible. Combined with the estimated interception probability of 70% for each of those surviving warheads, and a re-entry survival rate of 50%, this suggests that, in the best-case scenario for Pyongyang, each warhead it fires at the US has only around a one in seven chance of arriving. If the estimates become less favourable – a boost phase success rate of 75% and a re-entry survival rate of 25%, say – then that figure could look more like one in eighteen.

If we set this number against the tritium-limited number of high-yield ICBM-deliverable warheads that North Korea might be able to produce, then we can start to get a sense of the real risk that Pyongyang’s developing strategic deterrent poses to the continental US. At one end of the spectrum, North Korea may be able to sustain a strategic deterrent that could expect at best to threaten a strike with one or two nuclear warheads, and more likely none. At the other end of the spectrum, Pyongyang might, within ten to fifteen years of having begun tritium production at an optimised graphite reactor, be able to overwhelm the current GBI fleet and credibly threaten a strike with around half a dozen nuclear warheads.

Widely varying as these figures might seem, two constants do leap out. First, the failure of the performance of the current US national missile defence system to live up to its ambitions makes a major difference to the potential of North Korea’s deterrent force; second, the limited number of GBIs available at present would be relatively straightforward for North Korea to exhaust, even given the constraints noted above, with any more than eleven targets – which could include decoys – necessitating a reduced number of interceptors per target and therefore significantly reduced effectiveness. Taken together, this has a concrete impact on the effectiveness of North Korea’s strategic deterrent: if the performance of GMD were improved such that it matched Trump’s system effectiveness figure of 97% (an improvement in interceptor effectiveness to 60% from 25%), and assuming sufficient GBIs were available to maintain the four-shot doctrine against all incoming threats, then the result is that a realistically sized North Korean strategic deterrent force cannot reliably hit the continental US at all (although there still remains a concerningly high 10–20% chance, depending on assumptions, that it might).

The failure of the US national missile defence system to live up to its ambitions makes a major difference to the potential of North Korea’s deterrent force

This illustrative analysis cuts a lot of corners, but it does indicate the need for serious consideration of the scale of the strategic threat that North Korea poses in practice. Yes, missile defence is far from perfect – but so too is North Korea’s nascent deterrent force. Its strategic warhead capability might be limited, and the deterrent system is likely to have reliability and accuracy issues that the leadership in Pyongyang cannot completely understand.

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It is therefore at least possible that the level of threat that North Korea poses to the continental US could be kept sufficiently low that even those calling for a military solution might be persuaded to endure the discomfort of that uncertain nuclear threat – and work to mitigate it through more effective defensive measures. Such a path would avoid a preventive war and thus certain catastrophe. At the same time, it may be possible for the leadership in Pyongyang to feel that its strategic rocket forces, while not providing a truly inexorable deterrent capability, hold Washington at sufficient risk that it has the security from external regime change that it seeks. If this were the case – and Pyongyang’s recent announcement that its ‘state nuclear force’ is complete may indicate a bounded ambition of this kind – then it may be possible for equilibrium, if not stability, to be found.

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