North Korea’s “Thermonuclear” Test: The Paradox of Small, developing Nuclear Forces
Anthony H. Cordesman

The reports on North Korea’s latest nuclear test are now more an exercise in uncertainty than a clear demonstration of North Korea’s actual nuclear capabilities. North Korea may or may not have been able to demonstrate its ability to use a fission weapon to produce some form of fusion or thermonuclear yield. It is still equally possible that it has simply lied, tried some form of fission-fusion design and failed, or has some uncertain degree of success in “boosting” a fission weapon and claimed this made it a thermonuclear weapon.

It is also important to understand that North Korea’s success in developing any given nuclear weapon will interact with its missile design reliability, and capability. This, in turn, presents the paradox that small nuclear forces with limited effectiveness can push a given power – particularly one with extreme authoritarian leadership – into nuclear postures that present far more risks than the far larger and more capable nuclear forces of major powers.

Thermonuclear Options: Single Stage

In the worst case, going from its past fission to a real thermonuclear design, the difference could be dramatic. It is possible, however, that North Korea has tested a crude single stage nuclear weapon more to celebrate its erratic leader than achieve major military effects, and it might well be difficult to determine its success in doing so. There are obvious risks in any public discussion of nuclear weapons design, but there are highly public sources that do seem accurate enough to illustrate the issues involved.

Reporting in Wikipedia describes one thermonuclear option for North Korea that would represent some degree of serious design progress, but would have minimal warfighting impact in terms of nuclear effects and potentially be so heavy that a test demonstration on the ground would not indicate North Korea could acquire a meaningful bomb or warhead.

Early thermonuclear weapon designs such as the Joe-4, the Soviet "Layer Cake" ("Слоёка", Russian: Слоїка), used large amounts of fuel to induce fission in the uranium-238 atoms that make up depleted uranium. These weapons had a fissile core surrounded by a layer of lithium-6 deuteride, in turn surrounded by a layer of depleted uranium. Some designs (including the layer cake) had several alternate layers of these materials. The Soviet Layer Cake was similar to the American Alarm Clock design, which was never built, and the British Green Bamboo design, which was built but never tested.

When this type of bomb explodes, the fission of the highly enriched uranium or plutonium core creates neutrons, some of which escape and strike atoms of lithium-6, creating tritium. At the temperature created by fission in the core, tritium and deuterium can undergo thermonuclear fusion without a high level of compression. The fusion of tritium and deuterium produces a neutron with an energy of 14 MeV—a much higher energy than the 1 MeV of the neutron that began the reaction. This creation of high-energy neutrons, rather than energy yield, is the main purpose of fusion in this kind of weapon. This 14 MeV neutron then strikes an atom of uranium-238, causing fission: without this fusion stage, the original 1 MeV neutron hitting an atom of uranium-238 would probably have just been absorbed. This fission then releases energy and also neutrons, which then create more tritium from the remaining lithium-6, and so on, in a continuous cycle. Energy from fission of uranium-238 is useful in weapons: both because depleted uranium is much cheaper than highly enriched uranium and because it cannot go critical and is therefore less likely to be involved in a catastrophic accident.

This kind of thermonuclear weapon can produce up to 20% of its yield from fusion, with the rest coming from fission, and is limited in yield to less than one megaton of TNT (4 PJ) equivalent. Joe-4 yielded 400 kilotons of TNT (1.7 PJ). In comparison, a "true" hydrogen bomb can produce up to 97% of its yield from fusion, and its explosive yield is limited only by device size.

This description does not address the weapon’s weight, the problems in moving to higher yields, cost, technological complexity, and a number of other key issues. It also focuses on a period in the arms race where nuclear powers were seeking massive yield increases. If all North Korea wanted was to demonstrate some form of thermonuclear device, regardless of true military value, it might have chosen to demonstrate a far more limited variation on a single stage thermonuclear weapon.

Thermonuclear Options: Multistage

The second option is a multistage thermonuclear weapon. A true multistage fusion weapon is far harder to design and actually build than the fission weapon used to trigger it. A multistage fusion weapon is also far more difficult to make reliable and miniaturize, and complexity and the number of “stages” does increase with yield.

An unclassified description of the difference in Wikipedia notes that,

Only six countries—United States, Russia, United Kingdom, People's Republic of China, France and India—have conducted thermonuclear weapon tests. (Whether India has detonated a "true", multi-staged thermonuclear weapon is controversial.)[12] Thermonuclear weapons are considered much more difficult to successfully design and execute than primitive fission weapons. Almost all of the nuclear weapons deployed today use the thermonuclear design because it is more efficient.

Thermonuclear bombs work by using the energy of a fission bomb to compress and heat fusion fuel. In the Teller-Ulam design, which accounts for all multi-megaton yield hydrogen bombs, this is accomplished by placing a fission bomb and fusion fuel (tritium, deuterium, or lithium deuteride) in proximity within a special, radiation-reflecting container. When the
fission bomb is detonated, gamma rays and X-rays emitted first compress the fusion fuel, then heat it to thermonuclear temperatures. The ensuing fusion reaction creates enormous numbers of high-speed neutrons which can then induce fission in materials not normally prone to it, such as depleted uranium.

Each of these components is known as a "stage", with the fission bomb as the "primary" and the fusion capsule as the "secondary". In large, megaton-range hydrogen bombs, about half of the yield comes from the final fissioning of depleted uranium.

Very few all thermonuclear weapons deployed today use the "two-stage" design described above, but it is possible to add additional fusion stages—each stage igniting a larger amount of fusion fuel in the next stage. This technique can be used to construct thermonuclear weapons of arbitrarily large yield, in contrast to fission bombs, which are limited in their explosive force. The largest nuclear weapon ever detonated—the Tsar Bomba of the USSR, which released an energy equivalent of over 50 million tons (50 megatons) of TNT—was a three-stage weapon. Most thermonuclear weapons are considerably smaller than this, due to practical constraints from missile warhead space and weight requirements.

As Figure One at the end of this report shows, such a weapon would be a real “game changer” in terms of its effects, ability to compensate for problems in delivery system accuracy, and impact on an urban target. It would be far more dangerous than a single stage test.

Gas Boosted Thermonuclear Weapons

There is a third type of thermonuclear weapon that has been broadly deployed by the United States and FSU-Russia, and that offers an attractive alternative to smaller nuclear powers like North Korea. This is a gas boosted design that does involve some elements of fusion. They have attracted curiously little attention in the discussion of the nuclear weapons programs of nations like North Korea, Iran, Pakistan, and India, but they might well be a critical or even dominant pattern of their mature inventory.

Again drawing on the unclassified material in the Wikipedia,

A boosted fission weapon usually refers to a type of nuclear bomb that uses a small amount of fusion fuel to increase the rate, and thus yield, of a fission reaction. The neutrons released by the fusion reactions add to the neutrons released in the fission, as well as inducing the fission reactions to release more neutrons of their own. The rate of fission is increased so much that much more of the fissile material is able to undergo fission before the core explosively disassembles. The fusion process itself adds only a small amount of energy to the process, perhaps but might well be 1%.

In a fission bomb, the fissile fuel is "assembled" quickly by a uniform spherical implosion created with conventional explosives, producing a supercritical mass. In this state, many of the neutrons released by the fissioning of a nucleus will induce fission of other nuclei in the fuel mass, also releasing additional neutrons, leading to a chain reaction. This reaction consumes at most 20% of the fuel before the bomb blows itself apart, or possibly much less if conditions are not ideal: the Little Boy (gun type mechanism) and Fat Man (implosion type mechanism) bombs had efficiencies of 1.38% and 13%, respectively.

Fusion boosting is achieved by introducing tritium and deuterium gas (solid lithium deuteride-tritide has also been used in some cases, but gas allows more flexibility and can be stored externally) into a hollow cavity at the center of the sphere of fission fuel, or into a gap between an outer layer and a "levitated" inner core, sometime before implosion. By the time about 1% of the fission fuel has fissioned, the temperature rises high enough to cause thermonuclear fusion, which produces relatively large numbers of neutrons speeding up the late stages of the chain reaction and approximately doubling its efficiency.

Deuterium-tritium fusion neutrons are extremely energetic, seven times more energetic than an average fission neutron, which makes them much more likely to be captured in the fissile material and lead to fission. This is due to several reasons:

1. Their high velocity creates the opposite of time absorption: time magnification.
2. When these energetic neutrons strike a fissile nucleus, a much larger number of secondary neutrons are released by the fission (e.g. 4.6 vs 2.9 for Pu-239).
3. The fission cross section is larger both in absolute terms, and in proportion to the scattering and capture cross sections.

Taking these factors into account, the maximum alpha value for D-T fusion neutrons in plutonium (density 19.8 g/cm³) is some 8 times higher than for an average fission neutron (2.5×10⁶ vs 3×10⁸).

A sense of the potential contribution of fusion boosting can be gained by observing that the complete fusion of one mole of tritium (3 grams) and one mole of deuterium (2 grams) would produce one mole of neutrons (1 gram), which, neglecting escape losses and scattering for the moment, could fission one mole (239 grams) of plutonium directly, producing 4.6 moles of secondary neutrons, which can in turn fission another 4.6 moles of plutonium (1,099 g). The fission of this 1,338 g of plutonium in the first two generations would release 23 kilotons of TNT equivalent (97 TJ) of energy, and would by itself result in a 29.7% efficiency for a bomb containing 4.5 kg of plutonium (a typical small
Fission trigger). The energy released by the fusion of the 5 g of fusion fuel itself is only 1.73% of the energy released by the fission of 1,338 g of plutonium. Larger total yields and higher efficiency are possible, since the chain reaction can continue beyond the second generation after fusion boosting.[5]

Fusion-boosted fission bombs can also be made immune to neutron radiation from nearby nuclear explosions, which can cause other designs to predetonate, blowing themselves apart without achieving a high yield. The combination of reduced weight in relation to yield and immunity to radiation has ensured that most modern nuclear weapons are fusion-boosted.

The fusion reaction rate typically becomes significant at 20 to 30 megakelvins. This temperature is reached at very low efficiencies, when less than 1% of the fissile material has fissioned (corresponding to a yield in the range of hundreds of tons of TNT). Since implosion weapons can be designed that will achieve yields in this range even if neutrons are present at the moment of criticality, fusion boosting allows the manufacture of efficient weapons that are immune to predetonation. Elimination of this hazard is a very important advantage in using boosting. It appears that every weapon now in the U.S. arsenal is a boosted design.[4]

According to one weapons designer, boosting is mainly responsible for the remarkable 100-fold increase in the efficiency of fission weapons since 1945.[3]

Without getting into any detailed aspect of design, “boosting” would allow North Korea to obtain far higher yields and damage effects, scaling up yields to 100 kilotons and beyond. Such efforts might well involve designs that would be far less lethal than full multistage thermonuclear weapons, but be highly attractive to North Korea both in terms of the regional threat it could pose and the risk that even a limited ICBM could pose to the United States. It seems virtually certain that North Korea and every proliferator and would-be proliferator has made – or will make – boosted weapons a key part of their weapons research and design efforts.

**Measuring Nuclear Weapons Effects**

Nuclear weapons have a wide range of effects. These include blast, heat or thermal, nuclear radiation, ionizing radiation, electromagnetic pulse, radar blackouts, and fallout. These effects vary with weapons design as well as type. For example, fusion per se does not create fission products, and anything like the level of nuclear fallout than fission reactions. However, thermonuclear weapons contain at least one fission stage, and many high-yield thermonuclear devices have a final fission stage. As a result, thermonuclear weapons can generate as much or more nuclear fallout as fission-only weapons – depending on height of burst.

**Blast effects**

Almost all of the summary description of nuclear weapons effects focuses on blast measured in kilotons or megatons of high explosive – the more conventional impact of the weapon, even though this may well not be the dominant effect of most thermonuclear weapons strikes, and all of the above effects interact to some degree in every nuclear strike.

The differences in blast effects between pure fission and the three forms of thermonuclear weapon – as well as the differences between any given early design and a fully mature and effective design of a given type – can be tremendous. A true fission-only weapon, without boosting, will generally have a blast equivalent of no more than 20–25 kilotons of high explosive compared to 100 kilotons up beyond 20 megatons. In the real world, however, much depends on the height of burst and mix of other effects.

One of the paradoxes of fissile weapons is that they are most effective at comparatively low altitudes that emphasize their blast effects because of the maximum air pressure at low altitudes and the resulting impact on structures and exposed soft targets. The impact of the blast, however, comes both from the initial shock wave and the winds that follow, and the desired height of burst is a function of yield.

Again drawing on unclassified material in Wikipedia,

For each goal overpressure there is a certain optimum burst height at which the blast range is maximized over ground targets. In a typical air burst, where the blast range is maximized to produce the greatest range of severe damage, i.e. the greatest range that ~10 psi (69 kPa) of pressure is extended over, is a GR/ground range of 0.4 km for 1 kiloton (kt) of TNT yield; 1.9 km for 100 kt; and 8.6 km for 10 megatons (Mt) of TNT. The optimum height of burst to maximize this desired severe ground range destruction for a 1 kt bomb is 0.22 km; for 100 kt, 1 km; and for 10 Mt, 4.7 km.

Two distinct, simultaneous phenomena are associated with the blast wave in air:

- **Static overpressure**, i.e., the sharp increase in pressure exerted by the shock wave. The overpressure at any given point is directly proportional to the density of the air in the wave.

- **Dynamic pressures**, i.e., drag exerted by the blast winds required to form the blast wave. These winds push, tumble and tear objects.

Most of the material damage caused by a nuclear air burst is caused by a combination of the high static overpressures and the blast winds. The long compression of the blast wave weakens structures, which are then torn apart by the blast winds. The
compression, vacuum and drag phases together may last several seconds or longer, and exert forces many times greater than the strongest hurricane.

One needs to be careful about such data because they focus on high blasts of pressure that can produce the actual destruction of major structures and near-certain kills. Blast will cover much wider areas at lower pressures, although it will also be contained by major structures in dense urban areas. Exposed individuals will be vulnerable over much wider areas, as well as anyone caught up in a serious wind, near a window in the wrong area, or affected by the vector and containment of blast in ways that focus its impact on a selected area.

What is striking about all estimates of blast effects, however, is that any power that must rely on fission weapons – and that is seeking to destroy the core of a city or any hard military or infrastructure target – has a strong incentive to detonate them at the low altitudes that maximize fall out, and that even relatively low yield thermonuclear weapons have maximum blast impact at relatively low altitudes. From a practical viewpoint, the ideal height of burst for maximizing blast from a one kiloton weapon is only about 220 meters and is still only 1,745 meters for even a 500 kiloton weapon.

The need to maximize effects is also a function of the fact that an actual nuclear weapon must be part of an overall weapons system that includes the delivery system. While the blast impact of a nuclear weapon is vastly greater than that of any conventional high explosive, it is important to note that any small power with limited ability to carry out tests of both its nuclear weapons and its missiles – like North Korea, India, Pakistan, and Iran – has a strong incentive to use its weapons at such altitudes against area targets like cities.

The cumulative error budget of the entire nuclear weapon-missile design in terms of yield and accuracy is also a function of both the inherent reliability of every aspect of the entire weapons system from rocket motor to weapons yield, and the real world accuracy of the entire system. This means a sane nuclear power cannot rely on the accuracy or yield of any one weapons delivery, or use engineering data like the theoretical accuracy of the guidance platform – particularly in largely meaningless terms like CEP, which define accuracy in terms of only 50 percent of the missiles fired with no risk assessment of what happens to the other missiles fired.

This effort to maximize blast damage and deal with these problems does not preclude a smaller country from carrying some form of high altitude demonstration or attempt to use an explosion as an electromagnetic pulse weapon against the electronic capabilities of the target state. It could also deliberately fire against an unpopulated area as a demonstrative or “intimidation” strike.

However, these real world limits to yield and predictability may force a nation with very limited stockpiles – or vulnerable nuclear delivery capabilities – to risk what may be a significant part of its early weapons inventory, and invite a form of preemptive retaliation from superior nuclear powers. It also presents the problem that it is far from clear that any such demonstration can accomplish more than negotiation without the demonstration, and that an aggressive power under an authoritarian leader may well extend risk taking to the point of de facto nuclear martyrdom – acting to punish the target state, regardless of the retaliatory consequences.

They could also force a nuclear power with uncertain nuclear strike capabilities to plan to target two to three weapons on a given city: two to ensure a higher probability of an effective strike and a third in reserve. Alternatively, a combination of uncertainty, vulnerability, and limited stockpiles could lead a small nuclear power to use most or all of its nuclear delivery capacity in a first strike – eliminating the risk of strikes on its delivery systems and counting on some or most uses of a single weapon on a single city to be a largely successful strike.

**Radiation Effects**

These calculations do change when radiation and thermal affects are also considered. To begin with radiation, Figure One illustrates the fact that the immediate radiation from a nuclear weapon can have terrible long term effects, and incapacitate large amounts of the exposed population over time, but it is more a “bonus” to blast effects than a dominant effect.

Fallout is a very different story, although even limited sheltering and follow-on evacuation can sharply reduce its effect. The problem is predicting the fallout’s impact, vector, and intensity. In practice, it too is more a “bonus” effect for small powers than a dominant effect for planning actual targeting and use.

These effects vary with weapons design as well as type, but one needs to be careful about distinguishing between fission and thermonuclear weapons. Fusion per se does not create fission products, and anything like the level of nuclear fallout than fission reactions. However, thermonuclear weapons contain at least one fission stage, and many high-yield thermonuclear devices have a final fission stage. As a result, thermonuclear weapons can generate as much or more nuclear fallout as fission-only weapons – depending on height of burst.

There is also an important difference in the real world radioactive impact of strikes by a nuclear force designed to attack area targets like cities and a force designed to strike at sheltered nuclear forces or hard military targets. Large powers – and any other powers planning preemptive strikes – must use ground bursts against hard targets to be certain of hitting a sheltered delivery system or weapons stockpile.

This means maximizing the fallout from a nuclear weapon – even at the cost of cratering that limits broader blast effects, and doing so regardless of where the fallout pattern will actually take place. In practice, this has made claims to counterforce targeting by larger powers something of a polite fiction. Unless all of the target country’s nuclear delivery forces are mobile, airborne, or at sea, the
resulting strikes on sheltered or harden facilities will produce fallout that will have a massive cumulative impact on human life and the economy in the target state.

Thermal Effects

The prompt impact of the thermal effects of a nuclear weapon – particularly an advanced thermonuclear weapon – is also a very different story from blast. In most cases, the thermal impact of an advanced thermonuclear weapon will be substantially greater than its blast impact, and the attacking state would also gain the advantage that a higher altitude of burst would sharply reduce the short through long term effects of fall out and radiation on the ecology.

As Wikipedia notes,

Nuclear weapons emit large amounts of thermal radiation as visible, infrared, and ultraviolet light, to which the atmosphere is largely transparent. This is known as "Flash". The chief hazards are burns and eye injuries. On clear days, these injuries can occur well beyond blast ranges, depending on weapon yield. Fires may also be started by the initial thermal radiation, but the following high winds due to the blast wave may put out almost all such fires, unless the yield is very high, where the range of thermal effects vastly out ranges blast effects, like that observed in the multi-megaton range. This is because the intensity of the blast effects drops off with the third power of distance from the explosion, while the intensity of radiation effects drops off with the second power of distance. This results in the range of thermal effects increasing markedly more than blast range as higher and higher device yields are detonated. Thermal radiation accounts for between 35-45% of the energy released in the explosion, depending on the yield of the device. However, in urban areas, the extinguishing of fires ignited by thermal radiation may matter little, as in a surprise attack fires may also be started by blast-effect-induced electrical shorts, pilot lights, overturned stoves, and other ignition sources, as was the case in the breakfast-time bombing of Hiroshima.[12] Whether or not these secondary fires will in turn themselves be snuffed out as modern noncombustible brick and concrete buildings collapse in on themselves from the same blast wave is uncertain, not least of which, because of the masking effect of modern city landscapes on thermal and blast transmission are continually examined.[13] When combustible frame buildings were blown down in Hiroshima and Nagasaki, they did not burn as rapidly as they would have done had they remained standing. Moreover, the noncombustible debris produced by the blast frequently covered and prevented the burning of combustible material.[14] Fire experts suggest that unlike Hiroshima, due to the nature of modern U.S. city design and construction, a firestorm in modern times is unlikely after a Nuclear detonation.[14] This does not exclude fires from being started, but means that these fires will not form into a firestorm, due largely to the differences between modern building materials and that used in World War II era Hiroshima.

There are two types of eye injuries from the thermal radiation of a weapon:

Flash blindness is caused by the initial brilliant flash of light produced by the nuclear detonation. More light energy is received on the retina than can be tolerated, but less than is required for irreversible injury. The retina is particularly susceptible to visible and short wavelength infrared light, since this part of the electromagnetic spectrum is focused by the lens on the retina. The result is bleaching of the visual pigments and temporary blindness for up to 40 minutes.

Burns visible on a woman in Hiroshima during the blast. Darker colors of her kimono at the time of detonation correspond to clearly visible burns on the skin which touched parts of the garment exposed to thermal radiation. Since kimonos are not form-fitting attire, some parts not directly touching her skin are visible as breaks in the pattern, and the tighter-fitting areas approaching the waistline have a much more well-defined pattern.

A retinal burn resulting in permanent damage from scarring is also caused by the concentration of direct thermal energy on the retina by the lens. It will occur only when the fireball is actually in the individual's field of vision and would be a relatively uncommon injury. Retinal burns, however, may be sustained at considerable distances from the explosion. The height of burst, and apparent size of the fireball, a function of yield and range will determine the degree and extent of retinal scarring. A scar in the central visual field would be more debilitating. Generally, a limited visual field defect, which will be barely noticeable, is all that is likely to occur.

When thermal radiation strikes an object, part will be reflected, part transmitted, and the rest absorbed. The fraction that is absorbed depends on the nature and color of the material. A thin material may transmit a lot. A light colored object may reflect much of the incident radiation and thus escape damage, like anti-flash white paint. The absorbed thermal radiation raises the temperature of the surface and results in scorching, charring, and burning of wood, paper, fabrics, etc. If the material is a poor thermal conductor, the heat is confined to the surface of the material.

Actual ignition of materials depends on how long the thermal pulse lasts and the thickness and moisture content of the target. Near ground zero where the energy flux exceeds 125 J/cm², what can burn, will. Farther away, only the most easily ignited materials will flame. Incendiary effects are compounded by secondary fires started by the blast wave effects such as from upset stoves and furnaces.

In Hiroshima on August 6, 1945, a tremendous firestorm developed within 20 minutes after detonation and destroyed many more buildings and homes, built out of predominantly 'flimsy' wooden materials.[15] A firestorm has gale force winds blowing in towards the center of the fire from all points of the compass. It is not, however, a phenomenon peculiar to nuclear
explosions, having been observed frequently in large forest fires and following incendiary raids during World War II. Despite regular fires destroying a large area of the city of Nagasaki, notably no true firestorm occurred in the city, even though a higher yielding weapon was used. Many factors explain this seeming contradiction, including a different time of bombing than Hiroshima, terrain, and crucially, a lower fuel loading/fuel density in the city than that of Hiroshima.

_Nagasaki probably did not furnish sufficient fuel for the development of a fire storm as compared to the many buildings on the flat terrain at Hiroshima._[17]

As thermal radiation travels, more or less, in a straight line from the fireball (unless scattered) any opaque object will produce a protective shadow that provides protection from the flash burn. Furthermore, depending on the properties of the underlying surface material, the exposed area outside the protective shadow will be either burnt to a darker color, such as charring wood,[18] or a brighter color, such as asphalt.[19] If such a weather phenomenon as fog or haze is present at the point of the nuclear explosion, it scatters the flash, now reaching burn sensitive substances from all directions, under these conditions, opaque objects are therefore less effective than they would otherwise be without scattering, as they demonstrate maximum shadowing effect in an environment of perfect visibility and therefore zero scattering.

Moreover, similar to a foggy or overcast day, although there are few, if any, shadows produced by the sun on such a day, the solar energy that reaches the ground from the sun's infrared rays is nevertheless considerably diminished, due to it being absorbed by the water of the clouds and the energy also being scattered back into space. Analogously, so too is the intensity at range of burning flash energy attenuated, in units of J/cm², along the slant/horizontal range of a nuclear explosion, during fog or haze conditions. So despite any object that casts a shadow being rendered ineffective as a shield from the flash by fog or haze, due to scattering, the fog nevertheless fills the same protective role, but generally only at the ranges that survival in the open is just a matter of being protected from the explosion's flash energy.[20]

The thermal pulse also is responsible for warming the atmospheric nitrogen close to the bomb, and causing the creation of atmospheric NOx smog components. This, as part of the mushroom cloud, is shot into the stratosphere where it is responsible for dissociating ozone there, in exactly the same way as combustion NOx compounds do. The amount created depends on the yield of the explosion and the blast's environment. Studies done on the total effect of nuclear blasts on the ozone layer have been at least tentatively exonerating after initial discouraging findings.[21]

It should be stressed that this description focuses on the thermal effect of fission weapons, and that the primary effect of thermonuclear weapons is thermal, not blast, particularly at higher altitudes of burst. This is made all too clear in the Figure One below, although it must be stressed that all nuclear effects – including indirect effects – are cumulative. People and structures will normally be directly or indirectly affected by a combination of blast, radiation, and thermal effects.

**Figure One: Key Effects of Nuclear Weapons**

<table>
<thead>
<tr>
<th>Effects</th>
<th>Explosive yield / Height of burst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast—effective ground range GR / km</td>
<td>1 kt / 200 m</td>
</tr>
<tr>
<td>Urban areas completely levelled (20 psi or 140 kPa)</td>
<td>0.2</td>
</tr>
<tr>
<td>Destruction of most civilian buildings (5 psi or 34 kPa)</td>
<td>0.6</td>
</tr>
<tr>
<td>Moderate damage to civilian buildings (1 psi or 6.9 kPa)</td>
<td>1.7</td>
</tr>
<tr>
<td>Railway cars thrown from tracks and crushed (82 kPa; values for other than 20 kt are extrapolated using the cube-root scaling)</td>
<td>≈0.4 ≈4 ≈10 ≈10</td>
</tr>
<tr>
<td>Thermal radiation—effective ground range GR / km</td>
<td></td>
</tr>
<tr>
<td>Conflagration</td>
<td>0.5</td>
</tr>
<tr>
<td>Third degree burns</td>
<td>0.8</td>
</tr>
<tr>
<td>Second degree burns</td>
<td>0.8</td>
</tr>
<tr>
<td>First degree burns</td>
<td>1.1</td>
</tr>
<tr>
<td>Effects of instant nuclear radiation—effective slant range SR / km</td>
<td></td>
</tr>
<tr>
<td>Lethal² total dose (neutrons and gamma rays)</td>
<td>0.8</td>
</tr>
<tr>
<td>Total dose for acute radiation syndrome²</td>
<td>1.2</td>
</tr>
</tbody>
</table>

1 For the direct radiation effects the slant range instead of the ground range is shown here, because some effects are not given even at ground zero for some burst heights. If the effect occurs at ground zero the ground range can simply be derived from slant range and burst altitude (Pythagorean theorem).

2 "Acute radiation syndrome" corresponds here to a total dose of one gray, "lethal" to ten grays. This is only a rough estimate since biological conditions are neglected here.


**Summing Up**
It may be days or weeks before the full nature of North Korea’s recent test becomes public – if reliable data do become available and are released. It is all too clear, however, that the precise level of progress is critical, that weapons types really do matter, and so does progress in delivery system range payload, and real-world accuracy and reliability. It is also brutally clear from the previous data that even one nuclear weapon could have a massive destructive impact when targeted on a population center, and that a successful boost or multistage thermonuclear weapon could effectively destroy and kill the major population center, structure of governance, and economic center of most states.

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