Nuclear Weapons Development: From Decision to Delivery

How easy is it to develop a nuclear weapon? What are the necessary raw materials – nuclear materials, high explosives, electronics, etc.? What are the pathways for acquisition of such materials? What is the necessary level of technical knowledge? What manufacturing equipment and facilities are needed? How can such capabilities and expertise be obtained or developed? What are the necessary (likely?) timelines?

What is needed and how long does it take for a state or a nonstate actor to acquire nuclear weapons? These related questions have been at issue in recent debates over the nuclear dangers posed by Iraq and North Korea. They have been at the heart of the urgency surrounding, and consequently the means used to eliminate or manage, these threats. The question is central to the notion of a "cascading" nuclear threat where the rapidity of states' development of nuclear weapons is a critical factor underlying current instability and the prospects of uncontrolled proliferation. The impact of a nonstate actor on the equation is less clear. Acquisition and use of a weapon by terrorists would be part of the cascade scenario, but it would not necessarily drive states to develop nuclear weapons unless there were a clear link to a terrorist sponsoring state.

There is no simple, canonical answer to the question of the capabilities and time required to obtain nuclear weapons. (See Appendix A.) Any answer must take into account such global factors as technology diffusion, the nonproliferation regime, etc.; and specific factors like the motivation, levels of technical development, external assistance, technological choices (material production, design, weaponization, testing, etc.), requirements and roles for nuclear weapons, arsenal size and sophistication, delivery systems, etc., of the proliferant, whether a state or a nonstate actor. Any state or a nonstate actor pursuing nuclear issues or weapons will face a series of challenges –

financial, technical, political, diplomatic and military. The basic technical requirements for building a deliverable weapon follow.

Special Nuclear Materials Production

Although nuclear material production was never the chokepoint envisaged in the 1950s, it has been and remains today the long pole in the tent of nuclear-weapon development.

The production of nuclear-weapon materials, especially through misuse of or diversion from civil nuclear activities, are the focus of the nuclear nonproliferation regime's safeguards and export controls. There have been challenges to the regime, which is being strengthened to address difficult problems such as a state's ability to obtain enrichment and reprocessing capabilities or quantities of spent fuel (containing plutonium) and then leaving the treaty, noncompliance, clandestine facilities, the increasing role of nonstate actors, collaborations among proliferants, etc.

The production of special nuclear material – plutonium (Pu) and highly enriched uranium (HEU) – requires specialized equipment, facilities and expertise. The material production process provides a timeline for nuclear-weapon development that can be characterized, albeit only in abstract terms. One can reasonably estimate construction/operation times for needed production of a quantity of Pu or HEU sufficient for a weapon—the IAEA's figures, labeled "significant quantities," are 8kg of plutonium and 25kg of HEU. On this basis, if one assumes a parallel weaponization track, the estimated time for material production also provides an estimate of the time necessary to develop nuclear weapons.

In real-world cases, however, the amounts of material a state or a nonstate actor would require, the technological starting point and other factors would need to be factored into the equation. Some states with advanced nuclear power programs, especially if they entail a full fuel cycle, have the facilities in place for producing weapon-usable materials, or even large stockpiles of these materials essentially ready to go. On the other hand, the possibility of theft or purchase of illicit material from the former Soviet Union or elsewhere offers one scenario that would significantly alter any generic calculations and give any state or a nonstate actor the possibility of rapidly acquiring the materials for nuclear weapons.

This prospect has been the basis for a 15-year effort pioneered by Senators Nunn and Lugar to address the problem of "loose nukes," "brain drain" and nuclear-material leakage from the former Soviet Union that is being expanded to other states, ideally to all states that possess weapon-usable material with inadequate security. This multi-billion dollar effort involves the Pentagon's Cooperative Threat Reduction program and the Department of Energy's Material Protection, Control and Accounting program, among others.

The growing reality of cooperation among rogue states offers another path for obtaining weapon material or the capability to produce it without the technological, time and other constraints of indigenous development. The WMD and missile cooperation between North Korea, Pakistan and Iran has been examined in the open literature. The question is whether that cooperation was limited to these or a few other states or provides a blueprint for the future. Clearly, there are a growing number of states that now possess or are developing WMD- and missile-related technological capabilities and expertise. Will these capabilities be shared, and under what if any constraints? Will they wind up in black markets? In either case, they will erode export control efforts like the Nuclear Suppliers Group (NSG).

Pu v. HEU. If a state is starting from the beginning, a plutonium path has long been regarded as requiring less time and technological sophistication than uranium enrichment to develop the material required for a weapon. In addition, although Pu production and reprocessing result in inherently higher radiation signatures than HEU production, a small production reactor and reprocessing facility (which may be only a large hot cell) were more easily hidden than a large gaseous diffusion plant for enriching uranium. Even though it was recognized that the design and production of a plutonium weapon would be more difficult than a gun-type weapon using HEU, this was viewed as secondary to the acquisition of the material. The idea that a nonstate actor could pursue this path was not seen as credible, if considered at all, both in terms of material production or fabricating a weapon.

Today, as reports of foreign assistance to the gas-centrifuge enrichment programs of Iran and North Korea suggest, the spread of technology through lateral proliferation has altered the calculus. The possibility of proliferant states mastering this technology seemed unlikely until recently, when the issue of external assistance came to the fore, and the option of gaseous diffusion enrichment was seen as difficult to conceal due to the size of the facility. However, gas centrifuge enrichment facilities make it very difficult to detect HEU production due to the reduced size of the required facility and the low radiation signatures. This situation has altered the received wisdom of the most likely path to weapons for states. For a nonstate actor, material production, especially HEU production using centrifuges, does not appear as a realistic option, although some argue that if the terrorists received sufficient HEU by purchase or theft they might be able to fabricate a simple gun-type device.

The spreading ability to produce HEU via gas centrifuge technology reduces but does not eliminate the differences between acquisition paths involving HEU and Pu on the basis of time and expertise required. For more advanced states, the differences between the paths are marginal. Even with foreign assistance, some states may confront challenges in pursuing this path to weapon material. Certainly, a nonstate actor would face problems unless it were totally supported by the state on whose territory it could engage in such operations.

In the future, some enrichment technologies now being explored could change the calculus entirely for states and even for nonstate actors at the low end of the technological spectrum.

Other Fissile Materials. Other fissile materials could be used in weapons, including U-233, Neptunium, etc. There are additional technical difficulties in working with such materials. On the other hand, controls, accounting and protection of these materials may be limited.

Procurement of Specialized Equipment and Materials

Specialized, often dual-use equipment including precision milling, electronics, and diagnostic equipment are necessary, as are neutron generators. Nonnuclear materials such as energetic high explosives are required for all paths. Other needed materials include beryllium. For some designs deuterium and tritium may be required.

The problem in dealing with such items is that only small quantities may be required, with limited and ambiguous acquisition signatures. National Technical Means (NTM) are important. The International Atomic Energy Agency's (IAEA's) Additional Protocol (AP), specifically information requirements and complementary accesses, may be useful. (Note that the prospect of successfully using complementary accesses here and in later references within this text is limited at best.) NSG dual- use trigger list is critical.

Weaponization

Weaponization comprises a series of nuclear-weapon development activities, from device design to component engineering to nonnuclear testing that together provide assurance that the nuclear explosive will perform as intended. These activities may be more or less taxing, depending on the type of weapon and the level of development of the state. States with highly developed munitions industries will have many of the needed capabilities in place. For a nonstate actor, any weaponization would be crude, if it is possible at all. The challenges to states and even, to a lesser degree, nonstate actors today no longer involve basic science but primarily engineering. But these engineering challenges can be substantial and should not be dismissed, especially for nonstate actors.

To address this issue, the following tools are available: NTM. IAEA safeguards, if there is a connection to nuclear materials. Visits to suspect sites under IAEA AP complementary accesses. NSG dual-use trigger list.

Although weaponization has its own time requirements, in most cases they will be shorter than material acquisition. Cooperation with other states can reduce the time requirements, but it can be assumed that in most cases they will be undertaken in parallel with material acquisition and will not generally require additional time for the program.

Boosted and Thermonuclear Weapons. In addition to fission devices like the gun- and implosion-types used at the end of the Second World War, a state may also consider boosted or thermonuclear weapons. Boosted weapons use deuterium and tritium to increase the yield of fission devices. Thermonuclear weapons are devices in which a fission explosive (primary) is used to trigger a thermonuclear or fusion reaction in thermonuclear fuel (secondary). These weapons have tremendous power compared to fission weapons.

Both boosted and thermonuclear capabilities pose greater technological and engineering challenges than fission weapons. As a consequence, they are likely to require more time than fission weapons and most likely necessitate a testing campaign as well in order to be certain they will perform, and to perform to specification. States at the higher end of the technological spectrum may be expected to be able to develop these weapons. For states at the low end of the technological spectrum, these weapons may not be a realistic option. For a nonstate actor they are not credible options.

Nuclear Testing

Testing is likely to be of no concern to nonstate actors. For states, it may or may not be required for new nuclear weapons, depending upon the type of weapon chosen, the political and military role envisioned, the risks a state is willing to assume and other factors. In cases where a single, relatively unsophisticated weapon is sought and is envisaged as a means to intimidate adversaries, testing may not be required technically. States such as South Africa that developed gun-style fission weapons using HEU would not appear to have needed to test on technical grounds. However, South Africa was reportedly interested in, and preparing to test at one time. Testing may have been seen as useful politically to prove their capability. For more sophisticated weapons that are to be fully integrated into a modern military, testing is likely to be required. Political considerations may reinforce this need, or at least provide another rationale for testing. The Indian tests in 1974 and 1998 appear to have had political as well as technical drivers. In cases where testing is required technically, it will add to the time required to field the weapon – from months to years.

National Technical Means are the first line of defense, but the International Monitoring System being developed by the Comprehensive Test Ban Treaty Organization has some capability. Visits to suspected test sites via IAEA AP complementary accesses.

Weapon Production

If more than one or two crude nuclear weapons are required, there will be a need for a viable weapon production infrastructure. This might be extensive and costly with a large throughput or relatively small scale operation, but it will require trained personnel, facilities, equipment, etc. The precise requirements depend on the size and sophistication of the arsenal, the availability of nuclear materials and weapon production lines, etc. The time required for the establishment of the production infrastructure is a key consideration and will depend on a variety of factors including domestic environmental and other factors.

Available tools include: NTM. Visits to suspected sites via IAEA AP complementary accesses.

Delivery Means

Delivery system requirements determine the requirements for warheads, and are likely to influence size, sophistication and other considerations. In turn, the time requirements for a nuclear weapon are affected by the means of delivery chosen. The requirements for a nuclear weapon that can be delivered unconventionally by nonstate actors may be less than for one that can be delivered by a commercial airliner, other aircraft or a missile, unless the unconventional delivery requires miniaturization. Terrorists could in theory choose to bring components, high explosives and expertise to a site and assemble a weapon on site. Assuming sufficient time and capability, this option would not have some engineering challenges associated with more conventional delivery requirements. On the other hand, the sophistication and presumably the time required for weapons that are delivered by military air or missiles increases. For the latter, testing becomes a significant issue and may be needed because if there are military requirements such as reduced size and maximized yield, this may raise questions about whether a weapon will work, achieve desired yields, etc.

Available tools include: NTM. Visits to suspected sites via IAEA AP complementary accesses. Active defenses (air and missile) and passive defenses. Deterrence. Assurance.

Appendix A

Despite variations in real-world cases—the record of proliferation in India, Pakistan, Israel, South Africa and North Korea suggests each case is unique—much of the discussion of the capabilities and time required for a nuclear weapon from development to delivery reflects a simplification of the issues. States or nonstate actors either have or do not have nuclear weapons, it is asserted, and the resources/time required for those that desire but do not possess them is seen as a simple function of the laws of physics. The resources/time required to produce nuclear weapon material is seen as the only factors in the calculus. The only variable is the level of technological development, measured primarily by any existing civil or military nuclear program. The actual number and types of weapons being pursued and their means of delivery, along with the nuclear doctrine of a state, are seen as largely irrelevant to the equation.

In actuality, different states have different needs and capabilities, which lead to differing prospects, time frames, etc. Three types of states may be usefully identified. For states with no or minimal nuclear energy activities, indicators include any activity related to nuclear energy beyond the medical and industrial use of isotopes, and any weaponization efforts such as high-explosive testing. Efforts could be expected to take a decade or more, albeit that timeframe could significantly be affected by imports as well as other factors.

For states with some level of nuclear development, key indicators include efforts to develop:

- Large research reactors;
- Sensitive fuel cycle capabilities, including enrichment and reprocessing;
- Weaponization activities; and
- Delivery capabilities (air, missiles, etc.).

Imports and other cooperation could be significant in the timeline, which otherwise may be about 5 years with an aggressive, dedicated program.

For wealthy industrial countries such as Germany or Japan, indicators of a move to nuclear weapons (virtual or actual) may include:

- Deliberate decisions to establish short lead-time capabilities to develop and produce nuclear weapons;
- Possession or development of associated military capabilities to make weapons a strategic threat, the undertaking of military exercises and so on; and
- Development or deployment of active and passive defenses (for strategically vulnerable countries).

These states, with a robust nuclear fuel cycle and a strong industrial base, have some level of virtual capability, which could be turned to weapons in 1-3 years if a priority national decision is taken.

In addition to these three categories of states, nonstate actors must be considered. No terrorist organization has shown the capability to produce material or to develop and produce weapons, but the possibility of purchase or theft cannot be discounted.