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Disabling DPRK Nuclear Facilities

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ABOUT THIS REPORT

The October 3, 2007 Six-Party Talks accord outlines a roadmap for the disablement of the Democratic People's Republic of Korea's (DPRK) core nuclear facilities. While an agreement on "Second-Phase Actions for the Implementation of the Joint Statement" has been secured, the specific details of the nuclear disablement process are still being developed.

The primary goals of this Working Paper are twofold. First, to establish a definition for the term "disablement" which has only recently achieved widespread usage in the disarmament and nonproliferation community. Second, to outline the types of steps that will or could be taken at key facilities in the DPRK to achieve various disablement objectives.

This Working Paper was commissioned by the Korea Working Group (KWG) at the U.S. Institute of Peace. The KWG brings together the leading North Korea watchers from the government and think tank communities to discuss pressing policy issues in the political, security, social, and economic fields.

The Chair of the KWG is Ambassador Richard Solomon. The Director is John S. Park.

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During the February 2007 Six-Party Talks in Beijing, negotiators reached agreement on a series of actions aimed at starting the process of verifiably dismantling the nuclear weapons program of the Democratic People's Republic of Korea (DPRK). A key part of this agreement stipulated that after the DPRK shuts down its nuclear facilities, it would "disable" them. The February agreement did not state which facilities would be disabled or how they would be disabled, except to imply that these issues would be subject to further negotiations.

International Atomic Energy Agency (IAEA) negotiators traveled to the DPRK in late June 2007 and reached an agreement with Pyongyang to monitor and verify the shutdown of several facilities.[1] The DPRK subsequently shut down four facilities in July at the Yongbyon site, located in the northwestern area of the DPRK, and permitted IAEA monitoring of those facilities.[2]

Negotiations on disablement under the Six-Party Talks framework continued throughout the summer of 2007. A team of technical experts from the United States, China, and Russia visited the DPRK in September as part of an effort to develop an initial disablement agreement.

The six parties reached an important agreement in early October to disable all major nuclear facilities. As a start, they agreed to take temporary disablement steps at three facilities at the Yongbyon site that will be implemented by the end of 2007. These facilities, all part of the DPRK's plutonium program, are the 5 megawatt-electric reactor, the fuel fabrication plant, and the Radiochemical Laboratory. According to officials involved in the negotiations or briefed about them, the DPRK agreed in the Beijing talks to take ten disablement steps at these three facilities. While the six parties agreed on removing the irradiated fuel from the reactor and storing it in an adjacent pond, they did not agree on the nine other specific disablement steps that would be taken, except that three such steps would be taken at each facility. It is unknown if the DPRK agreed not to maintain these facilities for restart, but according to one participant in the discussions, at least one party supports including lack of maintenance as part of disablement. Not maintaining the DPRK facilities would be an important commitment, based on its rapid restart of the reactor and reprocessing plant in 2003. The DPRK is also expected to reveal a set of aluminum tubes imported from Russia, suspected to be part of a gas centrifuge program. It is unknown if those tubes would be subject to disablement or destruction.

According to the agreement, the United States will lead the disablement effort and provide the initial funding for these activities. A disablement team under U.S. leadership visited Yongbyon in mid-October, seeking an agreement on the specific disablement steps to take at each facility and develop operational plans for disablement. The United States hopes to start actual disablement soon after this team reports back.

Follow-on agreements, expected to be negotiated next year, should focus on the DPRK's nuclear weaponization program, its nuclear weapons, and its enrichment program. These negotiations should also establish additional disablement or dismantlement steps at the three Yongbyon facilities.

This report establishes a definition for the term "disablement," which has only recently achieved widespread usage in the disarmament and nonproliferation community. It discusses the types of steps that will or could be taken at key facilities in the DPRK to achieve various disablement objectives. Where appropriate, we note whether these steps achieve short-, medium- or long-term disablement.

Background

Under the 1994 Agreed Framework between the United States and the DPRK, the DPRK maintained the 5 megawatt-electric reactor and the Radiochemical Laboratory at the Yongbyon nuclear site in a manner that allowed for restarting the reactor relatively quickly. Between 1994 and 2003, the IAEA observed maintenance at the two facilities. During this time, the IAEA also noticed that the DPRK did not maintain its fuel fabrication plant. Prior to the onset of the "freeze" mandated by the Agreed Framework, it had produced a relatively large stock of fresh natural uranium fuel for the 5 megawatt and 50 megawatt-electric reactors, then under construction, apparently leading the DPRK to decide not to maintain this complex. Without maintenance, portions of the complex that involved highly corrosive chemicals fell into disrepair after about one year.

When the Agreed Framework broke down in late 2002, the DPRK rapidly restarted the reactor and Radiochemical Laboratory. Based on observations of the steam plume of the reactor's cooling tower, the reactor was operating early in 2003. The operation of the Radiochemical Laboratory was more difficult to discern. The DPRK has stated that it operated the facility in the first half of 2003 and recovered plutonium from about 8,000 fuel rods that had been in storage at the reactor site since 1994. DPRK officials also stated that another 8,000 fuel rods discharged from the 5 megawatt-electric reactor in 2005 were subsequently processed.

After 2002, the DPRK started to refurbish the fuel fabrication plant. Because of extensive damage, some of the processing equipment had to be replaced.

Disablement

Having observed the restart of the DPRK's nuclear weapons effort in 2003, U.S. officials indicated that a new agreement should not allow for a similar restart. They asserted that the notion of freezing a facility was not consistent with the goal of verified, irreversible nuclear disarmament, which would include the eventual dismantlement and decommissioning of the DPRK's nuclear weapons facilities.[3] This led to the development of the concept of "disablement." By 2004, the term was in wide use inside the State Department and starting to be used among other parties of the Six-Party Talks.[4]

During the last few years, the disablement of a facility has come to mean a deliberate, mutually agreed action or set of actions taken to make it relatively more difficult and time-consuming to restart a facility after it is shut down. Disablement actions go beyond simply shutting down, sealing, and monitoring a facility. Although disablement steps can be reversed and the facility restarted, it would take an extended period of time to do so.

Recently, the U.S. government has done considerable work to develop a set of potential disablement steps. In addition, it consulted with other parties of the Six-Party Talks to seek consensus on a definition of disablement or specific steps to undertake.

During the spring and summer of 2007, informal discussions with officials involved in the six-party negotiations revealed significant differences over how long disablement steps should delay restarting a facility. U.S. officials suggested options that are more destructive in nature and would require a longer time to reverse. Some of these were effectively permanent in nature. In private discussions, DPRK officials emphasized temporary, non-destructive disablement. They have said that more permanent disablement steps that involve the actual destruction of equipment is akin to dismantlement and should be addressed in later agreements.

By September, the United States apparently dropped permanent disablement as a short-term goal. Ambassador Christopher Hill, chief U.S. negotiator at the Six-Party Talks, said on September 25, 2007 in Japan that the United States is looking for a set of disablement steps "that takes it to about a year."[5]

In developing concrete disablement steps, negotiators at the Six-Party Talks have tried to ensure that such steps are consistent with a range of other goals in the verified, irreversible denuclearization process. Disablement steps should be consistent with the eventual decommissioning and dismantlement of a nuclear facility; they should not make it more difficult to decommission a facility and be in line with modern environmental, safety, and health (ES&H) criteria. They should also not undermine future verification activities, particularly efforts aimed at verifying the correctness and completeness of DPRK declarations, which are also required under the February agreement. For example, a major issue is accounting for the total amount of plutonium the DPRK produced in the 5 megawatt-electric reactor and subsequently separated at the Radiochemical Laboratory. Verifying a DPRK plutonium declaration might require inspector access to the graphite moderator of the reactor and certain types of filters in the Radiochemical Laboratory. These parts of the facility, then, would need to be preserved during more destructive disablement.

Who conducts the disablement has been an issue. The DPRK could carry out the disablement steps itself under the supervision of the other parties. However, DPRK officials stated privately that if parts are destroyed, they may want the other parties to do the destruction. It is unclear how disablement will be done in practice. U.S. officials have stated that the Unites States will send a team to Yongbyon to participate in the disablement.

According to one participant in the negotiations, the DPRK did not want the IAEA to become involved in the disablement process, and instead wanted the United States to do the disabling. The other parties objected to this essentially bilateral process, wanting their own assurances about disablement. The compromise was that the United States would take the lead on disablement. It is unknown what procedures have been created to ensure that disablement steps remain intact. The IAEA would be able to provide this important assurance, and the parties should assign the IAEA this important step. As mentioned above, it is already monitoring that the facilities remain closed under the February agreement.

What is Disabled?

The facilities subject to active disablement steps in the current agreement are limited to those previously frozen under the Agreed Framework. Those facilities at Yongbyon include the 5 megawatt-electric reactor, the Radiochemical Laboratory, and the fuel fabrication plant, including the associated fresh fuel storage facility. Other facilities, such as the unfinished 50 megawatt-electric reactor at Yongbyon, and the unfinished and largely abandoned 200 megawatt-electric reactor at Taechon, are not explicitly included.

In later phases of disarmament, additional facilities and items would be expected to be disabled. Nuclear weapon production facilities, nuclear weapons themselves, and any operating uranium enrichment plants and associated facilities would be expected to be disabled.

Reactor Disablement

The 5 megawatt-electric reactor is a priority for disablement, because it is the DPRK's only source of additional plutonium. Currently, the DPRK has an estimated stock of about 45 to 65 kilograms of plutonium, including the plutonium inside the core of the reactor.[6] A critical purpose of the February agreement is to prevent that stock from growing further.

The most straightforward disablement step is to remove all the fuel from the reactor and transfer it to the adjacent irradiated fuel ponds. DPRK technicians could unload the irradiated fuel in a matter of weeks. Once the irradiated fuel is wet, it cannot—without great difficulty—be reloaded into the reactor. The DPRK does not have enough fresh fuel ready for use in the 5 megawatt-electric reactor. Reportedly, it has only about one-third of the 5 megawatt-electric reactor fuel it needs, and some of that fuel is defective and unusable without extensive processing. The DPRK also has a large stock of fresh fuel for the 50 megawatt-electric reactor, but the fuel rods are too long and thick for use in the 5 megawatt-electric reactor. Retrofitting these fuel rods for use in the 5 megawatt-electric reactor by cutting and thinning them would take a significant period of time. Until the DPRK brings back into operation its fuel fabrication facility, unloading the irradiated fuel from the 5 megawatt-electric reactor would in effect be a form of disablement. The DPRK is estimated to need 6 to 12 months to make enough new fuel for the 5 megawatt-electric reactor to have a full core of fuel. Thus, this option should delay restart by this timeframe.

Another vital disablement step is that the DPRK would agree not to conduct maintenance of the reactor, except those steps necessary for ES&H reasons.[7] Over time, the lack of maintenance will reduce the DPRK's ability to restart the reactor quickly due to the inevitable aging of components and equipment, causing them to malfunction or become less reliable. Independent monitoring may be required to ensure that banned reactor maintenance is not conducted under the pretext of conducting allowed ES&H activities.

Once the fuel is removed, a range of additional steps could be taken that would require varying amounts of time to reverse. Temporary disablement options that have been considered include:

- Destroying or otherwise rendering inoperative the mechanisms that permit the neutron-absorbing control rods to be pulled from the reactor, a step necessary to restart the reactor.[8] The control rods could also be removed from the reactor and stored, destroyed, or moved out of the country.
- The reactor is cooled by blowing carbon dioxide into the reactor core. To stop the ability of the DPRK to cool the reactor, the gas blowers could be removed and destroyed, preventing the primary cooling of the reactor.
- The heat in the carbon dioxide gas is transferred to a secondary cooling circuit that uses water. The heat transfer equipment could be disabled or destroyed, making it impossible for the excess heat to be extracted from the reactor core. Another option is to demolish the single cooling tower near the reactor.
- Prevent new fuel from being loaded into the reactor by removing and rendering inoperative the fuel rod handling machine.
- A neutron-absorbing material, such as cadmium or gadolinium, could be dispersed in powder form in the fuel and control rod channels.
- Concrete or epoxy resin with hard bits could be poured into the fuel channels. The additives would make the repair more time consuming.
- Salty water could be poured in all the control panels of the reactor.
- The reactor core is shielded on top and on its side by several meters of concrete. This concrete shell could be partially destroyed, making it unsafe to restart the reactor without repairs.
- Cut off all instrumentation flush with the surface of the biological shield of the reactor.

All of these temporary disablement options could be implemented within a few months. These options pose little risk of radiation release and are straightforward to plan and implement. After disablement, inspectors could easily observe the continuation of disablement activities, particularly with the options of removing the control rods, cutting or removing portions of the secondary cooling circuit (or destroying the cooling tower), or removing the gas blowers.

All of these options can be reversed, but not quickly. For example, the DPRK could build more control rods, but the process of re-installing them would likely take months, even assuming that new control rods were built in secret while the reactor is under IAEA monitoring. In addition, the replacement, installation, and bringing into operation of new gas blowers would be expected to take many months. Applying more than one disablement step is likely to be more effective and could lengthen the time needed for restart. In all cases, however, repairs would not be expected to require more than about 6 to 12 months.

A disablement option that would be expected to require more than a year to reverse would be to insert gadolinium oxide, an effective neutron-poisoning powder, directly into the graphite blocks that are used to moderate the reactor. Likely, the reactor operators have some access to the graphite. Once the gadolinium is dispersed among the graphite blocks, the reactor could not be restarted without removing the gadolinium. Its removal would likely require the replacement of the graphite, a task made even more difficult because of the intense residual radiation inside the reactor. Water could not be used to flush out the gadolinium without also destroying the graphite and the ability of the reactor to operate.

A more permanent disablement option would be to damage severely the reactor’s steel vessel. Care would be needed to ensure radioactivity did not escape from the reactor.

Discharged Irradiated Fuel

The roughly 8,000 irradiated fuel rods that are to be discharged from the 5 megawatt-electric reactor will be placed in the water ponds in a building adjacent to the reactor. This fuel, however, is not designed for long-term storage in water. Once the irradiated fuel is removed from the reactor, its cladding will begin to corrode. The corrosion can be slowed by taking active steps to control the water chemistry and temperature, but over the longer period, corrosion will continue to occur, causing leakage of radioactive materials into the ponds and other potentially dangerous problems.[9] During the summer of 2007, the parties debated the fate of this irradiated fuel. The United States insisted that the spent fuel be stored and not reprocessed (see below).

The U.S.-favored option is to store the irradiated fuel in the spent fuel ponds, pending ultimate removal from the DPRK. If not removed relatively soon, the rods would need to be “canned” to ensure safe storage. This canning is expensive, but achievable, as was learned during the period of the Agreed Framework when this option was pursued for the roughly 8,000 rods discharged in 1994 from the 5 megawatt-electric reactor. The DPRK reported that after their technicians opened the cans in 2003 to remove the irradiated fuel for reprocessing, it discovered that many of them had leaked and would have required re-canning if the rods had not been reprocessed. Thus, canning is an expensive option that will need to be redone periodically should the rods remain in the DPRK. The task of canning the rods may be easier this time, because the U.S.-supplied canning equipment was left at the facility and may be salvageable for re-use.

The canned irradiated fuel can be transported from the DPRK for disposal in another country. This option is likely to require at least a few years to implement. The DPRK would need to approve the action, which would reduce its in-country stock of plutonium. A country would also need to be found that would take and dispose of the irradiated fuel, a daunting task because of the many rods involved and the country’s likely desire to reprocess the irradiated fuel to simplify final disposal. However, China and Russia should be able to handle the irradiated fuel.

Radiochemical Laboratory

Disablement steps at the Radiochemical Laboratory would differ from those used at a reactor, since this facility is a chemical processing plant containing radioactive solids, liquids, and powders. The processing of irradiated fuel requires its dissolution, the separation of plutonium from uranium and radioactive fission products and actinides, and the plutonium's purification and conversion into metal. The first set of operations, or "head-end" operations, are conducted inside thick concrete hot cells to protect workers from the highly radioactive fission products produced in the fuel when it was in the reactor. Technicians conduct many of the operations and maintenance of the plant remotely, particularly in the head-end section of the plant.

After shutting down the plant, the first disablement step should be emptying the process piping, equipment, and tanks. A clear demarcation should be established between process areas and the plant's waste-related equipment and facilities. These latter areas will need to operate, because they hold a considerable amount of liquid and solid radioactive waste that would require continued attention. The process of emptying the process areas and establishing this clear line would require diligent monitoring by members of the Six-Party Talks.

Another important disablement step would be that the DPRK agrees not to maintain the process equipment, tanks, and piping—a step that would over time result in the plant becoming less reliable and requiring a longer period to restart. Monitoring would be required of the maintenance activities related to safely storing and handling the radioactive waste and ensuring that radioactive materials do not escape or pose a hazard to workers in the facilities.

A range of options could be pursued to disable the Radiochemical Laboratory for a longer period of time. Many options were considered over the summer, including:

- The newly installed mechanical decladding equipment could be removed.
- The dissolver tanks, located inside the hot cells, could be cut out from the piping and destroyed, preventing the dissolution of the irradiated fuel.
- Some of the equipment in the hot cells used to separate plutonium and uranium from the fission products could be destroyed or rendered unusable.
- In hot cells that require remote maintenance, a variety of critical pipe work could be crimped or cut out and damaged irreversibly. The electric or pneumatic valve controllers could be removed in this area. Remote manipulators can have a difficult time doing the fine work needed to repair this type of damage.

These options would likely require careful planning that would take several weeks or months to plan and implement. The hot cells contain relatively high levels of radiation and cannot be entered directly in the near-term, requiring remote operations to accomplish the disablement steps.

These options would likely disable the Radiochemical Laboratory for no more than 6 to 12 months. The DPRK would need a few months to make or acquire the necessary replacement equipment and several months to install it inside the plant, given the difficult working conditions inside radioactively contaminated hot cells.

An option that would effectively render the plant unusable for a longer period than one year would be to pump hydrochloric acid through the processing lines. The acid would attack stainless steel piping and tanks, seals, and motors requiring that the plant be extensively rebuilt before it could operate. It may not even be practical to rebuild the head-end portions of the plant that are the most radioactive and require the most remote operations to rebuild. However, this option could cause significant releases of radiation into the processing areas of the facility.

Another long-term disablement option is to pour concrete into the hot cells. By filling the hot cells, they would be unusable. However, the radiation would also be entombed, likely complicating later dismantlement. This step should not be applied until all the verification work in this area is finished.

Processing of Spent Fuel in the Radiochemical Laboratory

Last spring, some officials suggested that a country could buy all the irradiated fuel from the DPRK and contract for its reprocessing in the Radiochemical Laboratory. The separated plutonium would then be shipped overseas for use in civil nuclear energy programs and the remaining waste would remain in the DPRK. The proposal was attractive technically, because the plutonium would be in a form easier to transport and store than irradiated fuel, possibly increasing the number of countries willing to take it. However, this option posed difficult political problems, since it would in the interim allow the DPRK to accumulate more weapons-usable plutonium and delay significantly the disablement of the Radiochemical Laboratory. As a result, the United States opposed this option, and the other parties apparently agreed to the U.S. position.

Fuel Fabrication Plant

As mentioned above, the DPRK did not maintain the fuel fabrication plant at Yongbyon, and it quickly fell into disrepair after it was shut down in 1994. Refurbishment has been time-consuming in the area of the facility that processes uranium oxide using fluorine. Fluorine is very corrosive and caused considerable damage to the processing equipment, requiring their replacement.[10]

DPRK officials said that as of February 2007, the facility had been renovated and could be restarted at any time. However, when senior IAEA officials visited the fuel fabrication plant in late June, they were told that no fresh fuel had been made since 1994. In addition, other recent visitors saw that the facility was in disarray and poorly maintained.

In any case, the plant could be disabled initially by emptying any material in the process lines and equipment. The DPRK should agree not to maintain the facility, except as necessary to meet ES&H requirements. Monitoring will be required to ensure that banned maintenance does not occur. Additional disablement steps could include removing key equipment and tanks. A more permanent disablement step would be to disassemble key buildings.

One of the members of the Six-Party Talks has asked the DPRK if it could buy all the fresh uranium fuel currently in storage. If the DPRK accepts, the purchase would set an important precedent of buying DPRK nuclear material. This process could then also apply to the spent fuel.

50 and 200 Megawatt-Electric Reactors

The 50 megawatt-electric reactor remains unfinished, and the DPRK did little construction after 2002 at this site. The October agreement does not include any discussion of these reactors. Nonetheless, disablement actions should include a formal abandonment of construction at the site and any manufacture or refurbishment of key components, such as reactor vessels, graphite, gas blowers, or fuel handling machines. Additional steps could include damaging the reactor vessel or graphite for the reactor core, which is subject to current IAEA monitoring.

The partially complete 200 megawatt-electric reactor is reported to have succumbed to weather and cannot be repaired and finished. No disablement actions appear warranted at this reactor.

Nuclear Weapons and Associated Production Facilities

Later stages of disarmament would include disabling nuclear weapons and nuclear weapons production facilities.[11] Personnel involved in disabling nuclear weapons require special training and equipment and would be recruited from the nuclear weapon states or the IAEA. In addition to radioactive materials, nuclear weapons contain many dangerous items, such as high explosives, pyrotechnics, high voltage equipment, and detonators.

Because so little is known about DPRK nuclear weapons, disablement could be time consuming. The negotiators would need to agree on what to disable and how to do it. In addition, before disabling, the inspectors would likely need to inventory the weapon components, including those outside the weapons spare parts, jigs and molds, and associated manufacturing equipment. Some components and equipment should be kept intact, in case questions arise in later stages of verification. These items could be removed from the DPRK. In some cases, the parties may agree to remove all of certain types of components or equipment from the DPRK rather than to disable it.

For DPRK nuclear weapons, which likely contain several kilograms of plutonium, a fundamental disablement step is to remove the nuclear explosive material from the weapon. The plutonium metal component could be filled inside with a resin, if it is hollow. For example, it may contain items for boosting or initiation. By filling the hollow, the component would be rendered unusable without time consuming, special processing. It could also be converted into a non-metallic chemical form. Conversion is more effective but more difficult to accomplish. To make it even more time consuming to reuse the plutonium, impurities could be added to the plutonium during the conversion process. Conversion would require special processing equipment of the type found at the Radiochemical Laboratory. This latter option would therefore require that a small portion of the Radiochemical Laboratory not be disabled. However, it would not stop other important equipment in the Radiochemical Laboratory from being disabled and dismantled.

After disassembly of the nuclear weapon, other individual parts could be disabled. High explosives should be burned.

Depending on the type of neutron initiator used by the DPRK in their nuclear weapons, certain measures can be taken to disable them. With special precautions, the initiator can be encased and crushed. However, certain types of initiators require substantial ES&H measures in place during their disablement or destruction. For example, an initiator could contain polonium 210 or tritium, requiring the imposition of significant measures to prevent their release during disablement or destruction. Nonetheless, either type of initiator could be placed inside a mass of soft impermeable epoxy and crushed, ruining the device while preventing the escape of radioactive materials. A clear epoxy would also ease accountability and the answering of future verification questions.

The arming, firing, and fusing equipment can be disabled by cutting cables flush with the housings to complicate or prevent repairs. Further disablement can be accomplished by cutting the wires connecting the detonators to the high explosives.

The steps needed to disable nuclear weapon testing, development, production and assembly facilities will vary depending on the specific facility. For example, a key nuclear weapons manufacturing facility makes high explosive components for a nuclear weapon. Such a facility can be disabled by making the high explosive presses inoperative. High-pressure machines are very sensitive and can be disabled by scratches or grooves on their surfaces. The means for manufacturing neutron initiators can be disabled by destroying key equipment. Key manufacturing equipment used to make firing switches and detonators can likewise be disabled or destroyed.

The nuclear test site should be sealed and the entrances blocked. Specialized diagnostic equipment used at the test site or at high explosive test facilities, such as high-speed cameras, electronic recorders, scintillation neutron detectors, and flash x-ray machines, should be disabled.

Centrifuge Facilities

To the extent that facilities exist to make and operate centrifuges, they should first be turned off, all nuclear material removed, and placed under IAEA monitoring.[12] The DPRK should agree not to conduct any maintenance of the facilities, except those necessary for ES&H reasons.

The DPRK obtained a large number of aluminum tubes that could be turned into an outer casing of a gas centrifuge.[13] According to officials in the negotiations, the DPRK is expected to "clarify" this purchase under the October 3, 2007 agreement. In any case, these tubes should be disabled, unless they are used irreversibly in a non-nuclear program or are already unusable, such as a result of weathering. A straightforward disablement step is to cut them lengthwise or into short segments.

The inspectors would need to inventory all centrifuge components and equipment. Some components and equipment should be kept intact and not disabled or destroyed, in case questions arise in later stages of verification. These items could be removed from the DPRK for safekeeping and future study to answer any verification questions.

For a centrifuge plant, disablement can be accomplished by removing the power supplies, crimping critical junctions in the cascade piping, and removing and destroying the autoclaves (entry point of uranium into cascade) or desublimers (exit point of cascade).

Facilities that make centrifuge components and assemble the centrifuges should also be disabled. Critical manufacturing machines and quality control equipment can be rendered inoperative or destroyed.

Conclusion

The October agreement is an important first step in disabling the DPRK's nuclear weapons program. It focuses on facilities in the DPRK's plutonium production program. Disablement steps appear to be aimed at delaying restart up to a year. In the short-term, this level of disablement appears adequate, although without more information about the exact disablement steps, this judgment is preliminary.

This report has discussed a range of actions that have been considered to disable or render unusable the key nuclear facilities in the plutonium program at Yongbyon. These are summarized in Table 1. As this table shows, more disablement actions can be taken at these facilities if the negotiators want greater assurance that the DPRK will undergo a lengthy restart of those facilities.

If it does not already, the mutually agreed upon disablement process should incorporate maintenance for environmental, health and safety concerns, but little other maintenance. The operability of most of the DPRK's facilities at the Yongbyon nuclear site over the years has been largely dependent upon the constant maintenance of each. The maintenance steps necessary to ensure the ES&H of a site can be well established and monitoring such steps would be relatively straightforward. The principle of minimal or no maintenance should be applied to all DPRK nuclear facilities and items subject to disablement.

The more destructive disablement measures taken in the future should not jeopardize reliable verification of DPRK nuclear activities. Some of the more permanent disablement measures have the potential to damage components critical to verification goals. This need to preserve the ability to verify DPRK nuclear activities should serve as more support for the notion that the IAEA should be present during the implementation of disablement steps and monitor them afterwards to ensure they remain in place.

During the last several months, it appears to have been difficult to convince the DPRK to carry out disablement steps that significantly damage their nuclear facilities.

However, future negotiations should continue to press for greater disablement of facilities, leading toward their dismantlement.

As the parties negotiate and agree on disablement steps and the extent to which the facilities will be disabled, all sides should agree early on that the effects of more permanent disablement measures may mirror those of dismantling. Disablement has come to characterize efforts that make it relatively more difficult and time-consuming to restart a facility after it is shut down—and this paper outlines such disablement efforts, including those involving the destruction of key elements of a facility. However, disabling a facility to such an extent that rebuilding it would take about the same amount of time as would constructing a new facility would constitute dismantling and such measures could then be discussed during the dismantlement phase.

The six parties' October agreement to adopt a temporary set of disablement steps represents an important step towards DPRK denuclearization. However, much work remains to be done. An important challenge for the next phase of negotiations is the disablement of the DPRK's facilities to develop, test, and manufacture nuclear weapons, the nuclear weapons themselves, and any uranium enrichment capabilities.

Table 1. Range of Options to Disable Key DPRK Nuclear Facilities at Yongbyon

5 Megawatt-Electric Reactor

Initial step: Remove irradiated fuel from the reactor and transfer it to the adjacent irradiated fuel ponds. DPRK agrees not to conduct maintenance on the reactor, except those steps necessary for ES&H.

Medium-term disablement: Destroy or render inoperable the mechanisms that permit the neutron-absorbing control rods to be pulled from the reactor; destroy or remove the mechanisms to cool the reactor; destroy or remove the fuel rod handling machine; disperse neutron-absorbing material into the fuel and control rod channels; pour salty water in all the control panels of the reactor; or partially destroy the reactor's concrete shell.

Long-term/permanent disablement: Dispersing gadolinium oxide, an effective neutron-poisoning powder, among the graphite blocks that are used to moderate the reactor; or drilling into and thus damaging severely the reactor's steel vessel.

Radiochemical Laboratory

Initial step: Take out equipment to mechanically declad the irradiated fuel; empty the process lines, equipment and tanks. DPRK agrees not to maintain the process equipment and lines, except as necessary to meet ES&H requirements. Monitoring of DPRK operation of the waste-related equipment and facilities.

Medium-term disablement: Sever the dissolver tanks from the piping; destroy some of the separation equipment; remove or destroy plutonium purification equipment; sever, crimp, or remove a variety of critical pipe work; or remove or destroy processing chemicals.

Long-term/permanent disablement: Pump hydrochloric acid through the processing lines; or pour concrete into the hot cells.

Fuel Fabrication Plant

Initial step: Shut down and empty process lines and equipment. DPRK agrees not to maintain facility, except as necessary to meet ES&H requirements.

Medium-term disablement: Remove key equipment.

Long-term/permanent disablement: Dismantle key buildings.

50 Megawatt-Electric Reactor

Initial step: Halt any construction and the manufacture or refurbishment of key components.

Long-term/permanent disablement: Damage severely the reactor vessel.

Endnotes

[1] IAEA Director General, *Monitoring and Verification in the Democratic People's Republic of Korea*, GOV/2007/36, July 3, 2007.

[2] IAEA Director General, *Application of Safeguards in the Democratic People's Republic of Korea (DPRK)*, GOV/2007//45-GC(51)/19, August 17, 2007.

[3] For more information on verified nuclear dismantlement, see D. Albright and Corey Hinderstein, *Dismantling the DPRK's Nuclear Weapons Program: A Practicable, Verifiable Plan of Action*, Peaceworks No. 54, U.S. Institute of Peace, January 2006.

[4] In August 2004, ISIS staff briefed DPRK officials about the concept of disablement in response to their questions about its meaning. This briefing and subsequent discussions with other members of the Six-Party Talks informed this report.

[5] Christopher Hill, "Comments to Reporters Following Dinner with Director General Kenichiro Sasae." Tokyo, Japan, September 25, 2007.

[6] David Albright and Paul Brannan, *The North Korean Plutonium Stock*, February 20, 2007, http://www.isis-online.org/publications/dprk/DPRKplutoniumFEB.pdf.

[7] Such steps can be well-defined. After the irradiated fuel is discharged, maintenance operations would be focused on ensuring that the residual radiation in the reactor components does not pose an ES&H problem.

[8] There are about 45 control rod channels in the 5 megawatt-electric reactor.

[9] David Albright, "North Korea's Corroding Fuel," ISIS Report, August 1, 1994, http://www.isis-online.org/publications/dprk/ir080194.html.

[10] *The North Korean Plutonium Stock*, op. cit., p. 6.

[11] For a description of the facilities involved in a nuclear weapons production program, see *Dismantling the DPRK's Nuclear Weapons Program*, op. cit., p. 29.

[12] David Albright, *North Korea's Alleged Large-Scale Enrichment Plant: Yet Another Questionable Extrapolation Based on Aluminum Tubes,* February 23, 2007, http://www.isis-online.org/publications/dprk/DPRKenrichment22Feb.pdf.

[13] *Dismantling the DPRK's Nuclear Weapons Program*, op. cit.

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DAVID ALBRIGHT, a physicist, is President of the Institute for Science and International Security (ISIS) in Washington, D.C. He directs the project work of ISIS, heads its fundraising efforts, and chairs its board of directors. In addition, he regularly publishes and conducts scientific research. He has written numerous assessments on secret nuclear weapons programs throughout the world. Albright has published assessments in *Science*, *Scientific American*, *The Bulletin of the Atomic Scientists*, *Arms Control Today*, *The Washington Post*, *Newsday*, *The New York Times*, *The Public Interest Report*, and *Forum for Applied Research and Public Policy*. Research reports by Albright have been published by the Environmental Policy Institute in Washington, D.C. and Princeton University's Center for Energy and Environmental Studies. Albright, in collaboration with Frans Berkhout, of Sussex University, and William Walker, of the University of St. Andrews, published *World Inventory of Plutonium and Highly Enriched Uranium, 1992* (SIPRI and Oxford University Press). A second, greatly-expanded edition entitled *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies* was published in March 1997. He is also a co-editor and contributor to *Challenges of Fissile Material Control* and *Solving the North Korean Nuclear Puzzle*, published by ISIS Press in 1999 and 2000, respectively. Albright cooperated actively with the IAEA Action Team from 1992 until 1997, focusing on analyses of Iraqi documents and past procurement activities. In June 1996, he was the first non-governmental inspector of the Iraqi nuclear program. On this inspection mission, Albright questioned members of Iraq's former uranium enrichment programs about their statements in Iraq's draft Full, Final, and Complete Declaration. He received a 1992 Olive Branch Award for a series of articles he wrote, along with Mark Hibbs, on the Iraqi nuclear weapons program for *The Bulletin of the Atomic Scientists*. He is also a *Bulletin* contributing editor and has been a guest editor of special editions of the magazine. Albright has testified many times on nuclear issues before the U.S. Congress. He has spoken to many groups, technical workshops and conferences, briefed government decision-makers, and trained many government officials in non-proliferation policy making. From 1990 to 2001, Albright was a member of the Health Advisory Panel appointed by Colorado Governor Roy Romer. The Panel, responsible to the state's Health Department, oversees a historical assessment of the toxicological and radiological doses received by the population near the Rocky Flats nuclear weapons production site. On this panel, Albright oversees the development of 'source' terms, which describe the type and amount of dangerous materials that left the plant during daily releases, accidents, or large-scale fires. In 1996, Albright was appointed to the Department of Energy Openness Advisory Panel, which operates under the auspices of the Secretary of Energy Advisory Board. The panel is charged with reviewing the Department's Openness policy, which was started in 1993, with the aim of lifting the veil of Cold War secrecy that has surrounded many of the DOE's activities without jeopardizing national security. Prior to founding ISIS, he worked as a Senior Staff Scientist at the Federation of American Scientists and as a member of the research staff of Princeton University's Center for Energy and Environmental Studies. In the early 1980s, he taught physics at George Mason University in Virginia. He has served as a consultant or contractor to the Environmental Policy Institute, the Congressional

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