

Technical considerations for DPRK's nuclear dismantlement

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Presentation at the
2007 PSNSS & PUGWASH
Workshop on Northeast Asia Security

September 2, 2007

Agreement about the DPRK nuclear program and its implementation

- Status
- Prospects
- Problems
- Verification

Visits to DPRK, plus DRPK visit to U.S.



Jan. 8, 2004 Yongbyon



Aug. 2005 Pyongyang



Nov. 2006 Pyongyang



March 1, 2007 Saratoga



August 10, 2007

Status of denuclearization - diplomacy

- Sept. 19, 2005 Denuclearization Agreement
- February 13, 2007 Initial Actions Agreement

Estimate of DPRK nuclear weapons program

- **Plutonium**

- < 1994 (IRT & 5 MWe) ~ 8.6 kg (1 + weapons)
- 2003 (5 MWe) ~ 25 kg (4-6 weapons)
- 2005 (5 MWe) ~10-14 kg (~ 2 weapons)
- In reactor (August 2007) ~ 10-12 kg (not separated)

- **Estimated separated plutonium for ~ 6 to 8 bombs**

- **Nuclear weapons**

- One nuclear test - some success. Must assume DPRK has a few rudimentary nuclear weapons.
- Unlikely to have confidence that devices are missile capable.
- Plutonium itself represents a major threat, regardless of test and of sophistication and number of weapons

- **Uranium enrichment**

- DPRK says it is ready to address the uranium enrichment concerns

Disablement status

- 5 MWe reactor is in stand-by with fuel rods in place
- Fuel fabrication facility is in poor condition, but is prepared to make new fuel
- Reprocessing facility is able to continue reprocessing if needed
- 50 MWe and 200 MWe reactors appear not salvageable
- IRT-2000 reactor is not part of agreement

IAEA finished seals and verification on Aug. 10, 2007

Disablement status

- **5 MWe reactor is in stand-by with fuel rods in place**
 - Can remain in this state for a year or more
 - Can be restarted and run for at least two more years to produce weapons-grade plutonium
- **Fuel fabrication facility is prepared to make new fuel**
 - It is in poor condition, but provisions have been made to produce new fuel if needed.
 - Fuel rods can be machined from stored stock of 5 and 50 MWe fuel rod and cores - for one 5 MWe reactor load. Will require up to one year.
- **Reprocessing facility is able to continue reprocessing if needed**
 - It currently contains high-level waste to clean out
 - May be needed for current load of fuel rods
- **50 MWe and 200 MWe reactors appear not salvageable**
- **IRT-2000 reactor is not part of agreement**

IAEA finished seals and verification on Aug. 10, 2007

Disablement prospects

- Fuel cycle facilities up to plutonium metal are in IAEA monitored stand-by. Readily reversible at this time.
- DPRK talks in terms of degrees of disablement - they claim there are many steps to disablement
- DPRK states that steps to greater irreversibility will require corresponding measures from the other parties
- Per DPRK - irreversible shut down of 5 MWe reactor will require discussion of LWR
- For technical reasons, permanently shutting down Yongbyon facilities will take time.

Disablement must be followed by dismantlement and elimination of nuclear weapons program

Problems and issues

- Sequencing of shut down is important for safe, secure, environmentally acceptable and effective elimination
- Technical issues must be integrated with diplomatic
- Disposition of fuel rods must be decided now
 - How are they removed?
 - Where will they (or the plutonium) go?
- Irreversibility - build confidence or adversity?
- Declaration - of nuclear facilities and nuclear weapons
 - Weaponization facilities not under IAEA monitoring
- Safe and environmentally sound dismantling and elimination of facilities will require > 10 years and > \$ 1 billion

Important to build confidence in step by step approach

Three options for the fuel rods

- Dry transfer and storage (DPRK not prepared)
- 1994 process - into the pool and recan (will take years)
- Reprocess and deal with 10-12 kg Pu

There is time to make the right decision because fuel rods are safe and stable in reactor now.

What to do with the fuel rods

Three options for fuel rods once they are taken out of reactor

- Attempt dry storage and canning (DPRK not prepared)
- 1994 process - into the pool and recan (will take years)
 - No decision as yet about what to do with recanned rods
 - Shipping them out of the country will be difficult
 - 50 tons of highly radioactive material
 - It will have to be reprocessed eventually because of instability of uranium metal fuel and magnesium cladding
- Reprocess and deal with 10-12 kg Pu
 - Technically the preferred option (12 kg of reasonably benign material vs. 50,000 kg of nasty material)
 - There will be diplomatic objections, but could possibly be used to diplomatic advantage

There is time to make the right decision because fuel rods are safe and stable in reactor now.

Verification

- Yongbyon facilities are doable
- Weaponization difficult because facilities have not been declared and footprint is most likely small
- Plutonium and weapons are impossible without DPRK cooperation
- Uranium enrichment efforts not possible without cooperation

Five parties should make it more attractive for DPRK to cooperate than to hide and mislead

Summary

- DPRK has taken big step - dismantling Yongbyon facilities is within reach
- Negotiators must show patience and integrate technical considerations with diplomacy
- Implementation process must build confidence and cooperation to make verification possible
 - Critical for DPRK not to make nuclear exports
- Elimination of nuclear weapons program will require a transformation of DPRK-U.S. relations
 - It will take a long time unless confidence is built

Yongbyon Nuclear Complex



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Pointer 39°47'24.77" N 125°45'16.65" E elev 212 ft Streaming ||||| 100%

Eye alt 10830 ft

DPRK gas-graphite nuclear reactors



5 MWe reactor
In stand-by mode
(6 kg Pu per year)



50 MWe reactor
Construction site . Most
likely not salvageable



200 MWe reactor Taechon
Not salvageable

Radiochemical Laboratory (Reprocessing Facility)



In stand-by mode with IAEA
seals, detectors & cameras.
Still contains high-level waste



Radiochemical Laboratory

- **Viewed many of the laboratories and shown seals, detectors and cameras**
 - Had to look with flashlights at first because electricity was out
 - Saw seals on top floor including one cobra seal
- **Were told about improvements**
 - Mechanical slitting of cladding instead of chemical dissolution
 - Pulsed columns in second line to replace mixer-settlers
 - Were having difficulties with mixer-settlers
 - 30 % increase in throughput was a bonus (not that it was needed)
- **High-level waste still in the facility**
 - DG estimated 6 months for processing the waste
 - Said they had HLW and uranium that need to be processed
- **Low-level waste was processed last year**
- **Claimed that facility would not be required to process additional waste after this campaign**
- **Claimed 83 seals in RL, 42 photos**
- **Allowed to maintain equipment outside, but not inside**

Pu laboratories



Image © 2007 DigitalGlobe

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Pointer 39°46'52.96" N 125°45'13.19" E elev 180 ft Streaming ||| ||| ||| 100%

Eye alt 1004 ft

Yongbyon plutonium laboratories

- **Location**

- Ground floor, far north side
- Suited up here (full white suits with zippers and hoods, "dust" masks, knit cotton gloves, high yellow plastic boots (duct taped))
- Walked outside through the rain and water into an adjoining wing or building which housed the Pu laboratories

- **Pu building (possibly Building 4)**

- Approximately 4 separate Pu labs
- Lab for production of PuF_4 to
- Lab with box with small lathe and one other box
 - Said to be used to clean up metal buttons and castings
 - Very primitive machinery
- Lab for reduction of PuF_4 to PuO_2 (with power supply for induction heating)
 - Claimed to keep Pu charges small - 30 to 100 grams
- Lab for Pu casting
 - Also looked quite small (outside diam of induction heater ~ 7-8 in., about 16 to 18 in. tall)
- DG rushed us through this facility. It was also unbearably hot.

- **Final Pu chemistry operations**

- Shown location of ion exchange labs, but did not have time to visit
- These labs are accessed on north side from within long corridor

Yongbyon plutonium laboratories

- **General observations**

- A most primitive facility
- Single-zone ventilation - glove boxes only
- No Pu transfer system - each box separate with primitive air locks
- Rooms open to hall, hall open to outside, windows in labs
- No radiation monitoring equipment in sight
- On exit, dropped protective clothing on floor
- No HEPA filters visible
- Most likely no atmosphere control for box ventilation
- Very little equipment in any of the boxes
- Surprisingly, inside of boxes were very clean and not badly corroded

- **Assessment**

- Clearly, a make-shift operation for very small through-put
- I don't believe they cast and machine weapons components here
- Primitive health and safety precautions mean they could set up an equivalent laboratory almost anywhere
- Most likely not capable of making complicated Pu weapons components
- Very good likelihood that Pu in either weapons or storage will corrode substantially because of lack of atmosphere control

Fuel fabrication facility



Fuel elements in storage buildings

50 MWe reactor

- **12,000 cores (unclad) of U alloy packaged in plastic and desiccant**
 - Claimed to be same diameter as 5 MWe, but longer
 - IAEA estimated 20,000 rods, 130 tons of U
 - When asked, they claimed that they could be machined to fit into 5 MWe reactor
 - Cladding must be fabricated and machined (may take ~ 6 - 12 mo.)

5 MWe reactor

- **We were told several thousand clad fuel rods ready to load**
 - Previous reports of 1,700 clad rods
 - Slug diam 2.9 cm, length 52 cm, mass 6.242 kg - 50 tonnes total
 - Many hundreds of fuel rod rejects from previous campaigns
- **All fuel was stored in large storage buildings on wooden "wine racks."** No ventilation or temperature control, but rods in plastic sleeves looked to be in good shape.
- **No seals, no cameras - just occasional visual checks by IAEA**
 - Claimed to have given IAEA lots of design information

Uranium enrichment discussions - VM Kim Kye Gwan

- **Jan. 2004**
 - We have no program, no facilities, no equipment, and no people trained in uranium enrichment
- **August 2005**
 - We have no uranium enrichment program. We decided on the plutonium route
- **March 1, 2007 (Saratoga)**
 - We will deal with this issue completely at the time of the declaration. I tried to get information from our technical people in Oct. 2002, but had great difficulty
- **August 7, 2007**
 - He is very much in consideration of the U.S. position.
 - He expressed his frustration that in Oct. 2002 he asked a lot of people for answers, and could not get any.
 - There was a lot of discussion about uranium long ago, but then they chose the plutonium route. So there was no logic in the 1990s to pursue uranium.
 - He said, " at this point, I can't say that we have or do not have a uranium enrichment program."
 - He finished this topic with: This issue is one of my "headaches."

IAEA containment - finished Aug. 10, 2007

- IAEA was invited in on July 15, 2007
- Kalumba Chitumbo - Chief, Safeguards A in charge
- Team of six other people for two weeks
- > 100 seals, many photos, cameras, and neutron detectors
- Two to four redundant layers of safeguards

Disablement status

- DPRK - there are many steps to disablement and degrees of disablement
- Fuel cycle facilities up to plutonium metal are in IAEA monitored stand-by, readily reversible
- Steps to greater irreversibility will require corresponding measures from the other parties
- If no LWR from the U.S., then no irreversibility of 5 MWe reactor
- Permanent disablement is very difficult and take long time. **No question that technically it will take years not months.** Dismantlement and remediation will require billions and at least a decade
- Weapon component fabrication and weaponization activities are not declared

Summary observations

- This visit demonstrated they were factual and open in past
- Shutting down with IAEA seals and monitoring is a big step
- They have opened more than ever before (Pu laboratories)
- Nuclear facilities are in worse shape than previously thought
- Key facilities are less sophisticated and less safe than previously thought
- They can restart facilities readily, but have no capacity to expand
- Time may now be on our side. With each day facilities and, perhaps, the plutonium corrode.
- The LWR represents a huge negotiating leverage for U.S.

5 MWe Reactor Building

- **Control room**

- We were shown the camera monitoring the position dials for control rods

- **Reactor hall**

- Dark because of power outage
- Seals on refueling machine. They said they have two.
- Fuel transfer hatch under seal. Neutron detectors visible.
- 4 cameras in place with recording boxes

- **Reactor operations**

- Shut down in 1994, restarted in early 2003, shut down and restarted June 2005. Shut down again on July 14, 2007
- Claimed that recently reactor was operating at 75 % power
- Reduced outlet temperature of 300 to 310 C
- Cooling is by convection only. If problem, they will restart blowers (have 2)
- How long can the rods remain - not sure, no experience, but should be a long time. Years ? - possibly, must circulate CO₂. They did not think about this before they shut down.
- DG claimed that it would take 200 days to unload the fuel rods

50 MWe and 200 MWe reactors

- **Visited construction site, observed from outside**
 - Looked even worse than last time
 - Could not find a sidewalk to front entrance
 - Were told that nothing is inside - no containment vessel, no core
- **Last time were told that industrial sector is having difficulties**
 - Some components fabricated, but are off site
- **This time told that graphite had been fabricated and machined**
 - Were offered to see graphite but did not have time
 - We understand that interlocking graphite was machined and stored in facility in Yongbyon (IAEA has inspected this site)
- **Assessment**
 - 50 MWe reactor does not appear salvageable to us
 - Would be easier to start over
 - Should insist on destruction of graphite components for core
 - DPRK officials claimed they want to use it for something else
- **200 MWe reactor** - offer to drive us out to Taechon, but not time
 - Reactor was considered not salvageable last time

Fuel transfer

- **Current operation**

- They transfer 40 fuel rods to a basket, lower through hatch to underground channel to pool building in transfer carts, where a crane transfers them.

- **Asked about possibility of dry storage**

- Not possible now. They have small dry storage - only for 10 % of rods
- To do dry they have to move the shielding with container. Very difficult and very dangerous. Concern about fires also.
- Americans have experience with dry storage, but also had problems.

- **Pool transfer and storage**

- This is route they anticipated. As done after 1994. Americans recanned.
- Can you reuse the previous canisters? No, many leaked.
- Hecker mentioned that is because we could not weld them.
- Answer, main seal was not the problem, they leaked at top fittings.
- Two-thirds of American canisters leaked when they opened them in 2003
- Could the recanned rods last a long time - yes, if not leak. Hecker asked for 20 years? No. Eventually need to reprocess.
- They reiterated that this stage of disablement will be difficult.