Denuclearizing North Korea

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North Korean Denuclearization

- Denuclearization is a commonly used, albeit vaguely defined, term that in the North Korean context typically means not only its nuclear disarmament but also the elimination of much of its industrial capability to make nuclear weapons.
- The phrase, the denuclearization of the Korean peninsula, is also used and can be subject to varying interpretations.
- But for purposes of achieving U.S. goals, denuclearization is best defined via UN Security Council resolutions, such as resolution 2270 (2016). The Security Council in this resolution "*Reaffirms* its decisions that the DPRK shall abandon all nuclear weapons and existing nuclear programs in a complete, verifiable and irreversible manner, and immediately cease all related activities."
- A straightforward interpretation is that North Korea should verifiably eliminate all of its nuclear weapons and its capability to test, develop, produce, maintain, and proliferate nuclear weapons.
- How longer range missiles will fit into this definition is uncertain. Although UNSC resolutions also call separately for the verified elimination of all North Korean ballistic missiles, ICBMs and their production capabilities are increasingly viewed as part of denuclearization.

Main Nuclear Programs and Activities Subject to Denuclearization

- Plutonium program, including any plutonium and its production, separation, and storage capabilities
- Uranium enrichment program, including all highly enriched uranium
- Thermonuclear materials production program
- Nuclear weapons and associated missile and other delivery systems.
- Nuclear Weaponization, including sites to research, develop, manufacture, test, and maintain fission only and fission/thermonuclear nuclear weapons
- Nuclear, WMD, and missile proliferation activities
- North Korea's illicit nuclear and missile trade and smuggling networks for its own and possibly others' nuclear or missile programs

Coming into Compliance with the Non-Proliferation Treaty (NPT)

- It is critical that North Korea rejoin the Nuclear Non-Proliferation Treaty (NPT), implement the North Korean/International Atomic Energy Agency safeguards agreement, and implement the Additional Protocol
- The long term goal is to bring North Korea into compliance with the NPT.

Three Steps of Denuclearization: Presented to North Koreans in the 2000s during our Track 1.5 events

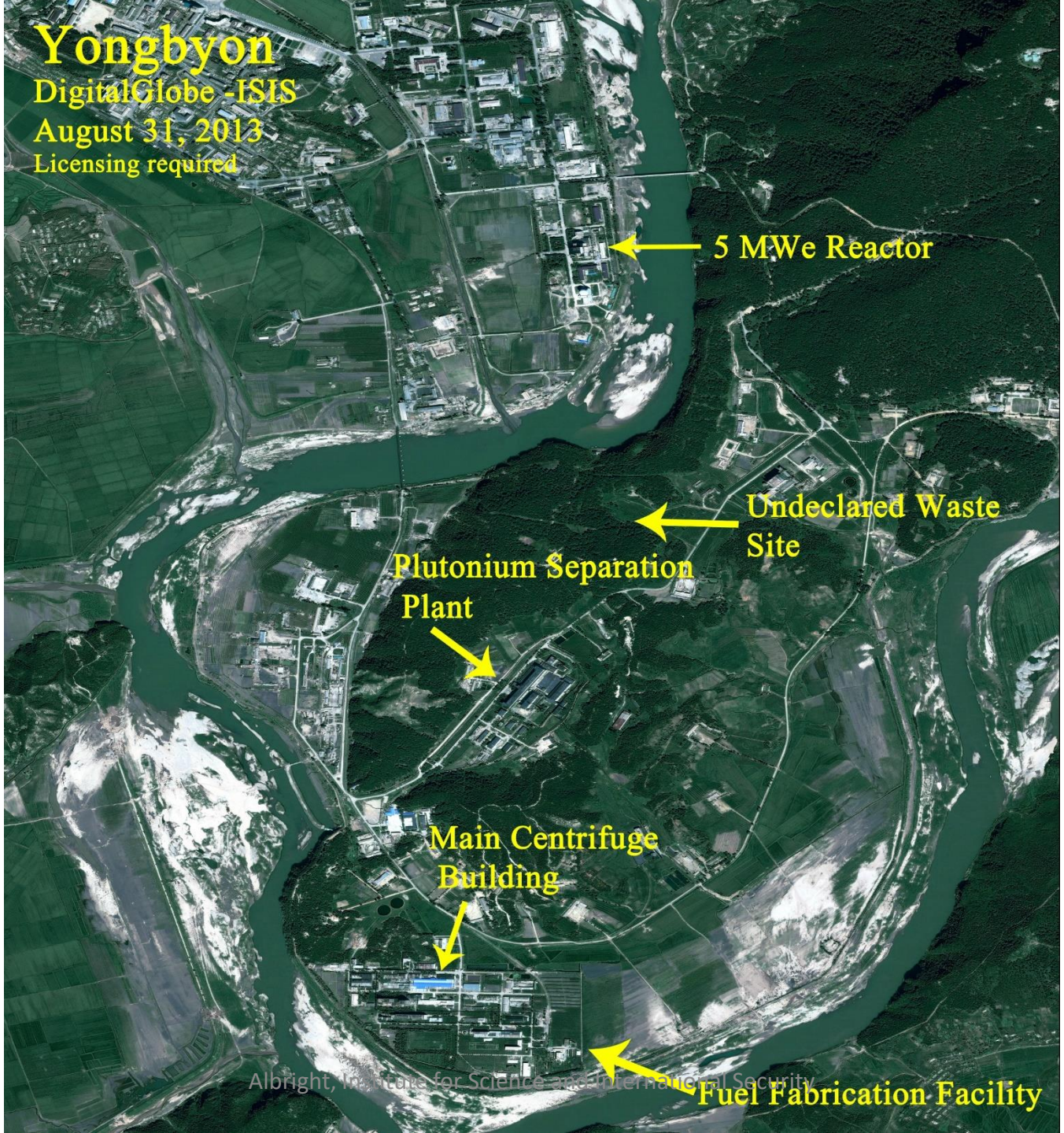
- Step 1:
  - North Korea will halt proscribed activities, freeze or disable equipment and facilities, and present declarations of its nuclear weapons program
  - The verification organization will monitor freeze, assist in disablement, and begin to review declarations
  - North Korea will receive initial benefits
- Step 2:
  - North Korea will dismantle items, such as nuclear weapons, and facilities and allow removal or dismantlement of key items, including nuclear weapons and components, plutonium, highly enriched uranium, and equipment
  - The verification organization will verify the dismantlement and/or removal of key items, and continue to verify declarations
  - North Korea will receive additional benefits
- Phase 3:
  - North Korea will come into compliance with the NPT
  - The verification organization will implement long-term verification, conduct verification activities to ensure against undeclared nuclear activities, and reach a conclusion about the completeness of North Korea's declarations
  - North Korea will continue to receive agreed benefits

Overview of Working Arrangement for Verified Dismantlement of the Plutonium, Uranium Enrichment, Weaponization and Perhaps Thermonuclear Materials Programs

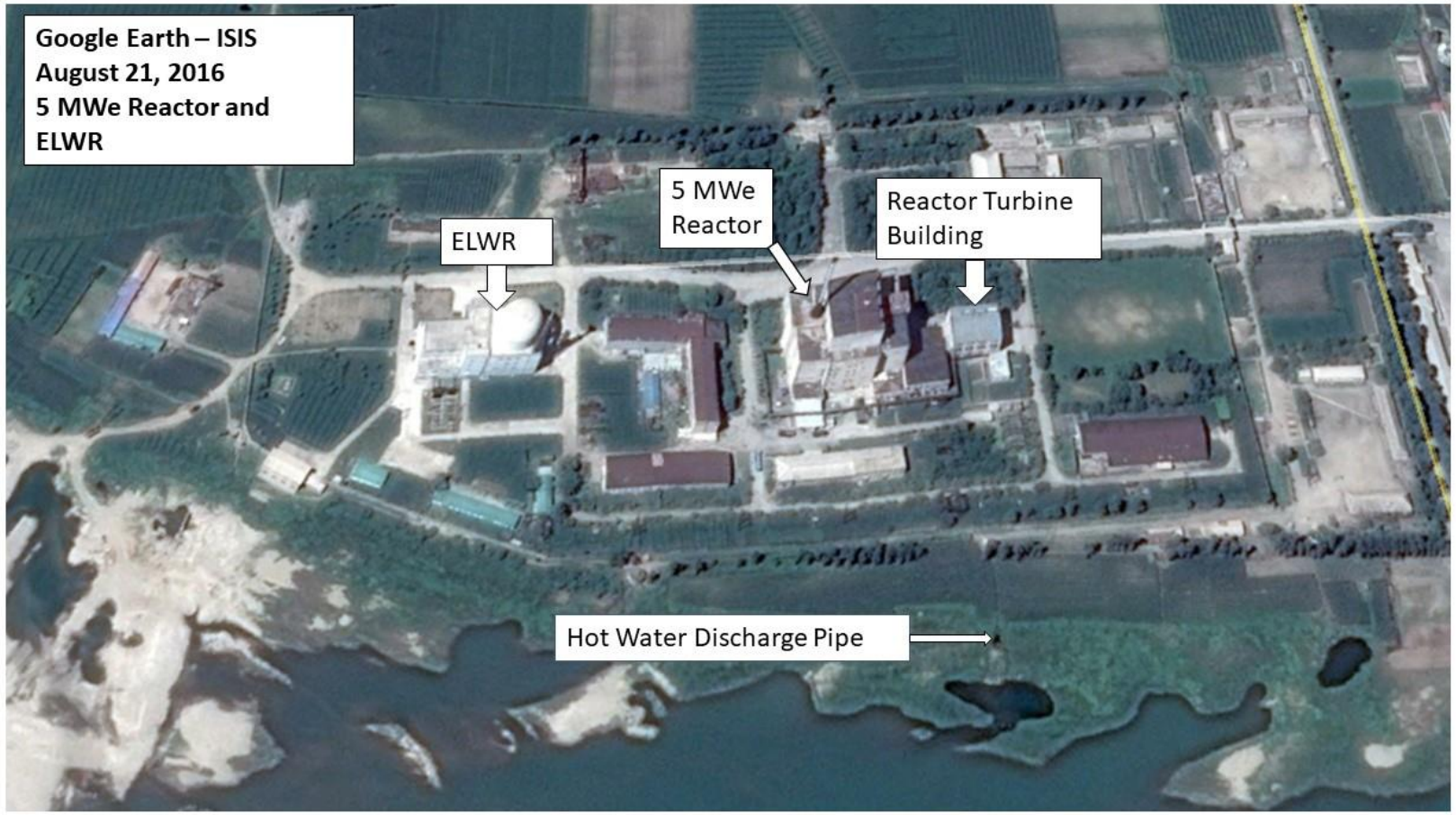
- Phase 1:
  - Listing and describing the facilities subject to abandonment;
  - Visiting these facilities, even if by US experts and officials only;
  - Halting operations at these facilities and establishing IAEA monitoring.
- Phase 2:
  - Disabling these facilities;
  - Producing a declaration.
- Phase 3:
  - Verifying the declaration, ensuring the absence of undeclared nuclear materials, facilities, and weapons, and coming into compliance with the NPT.
  - Irreversible dismantlement and disposal.

Satellite Imagery Review of the Yongbyon Complex: What Could Get Denuclearized

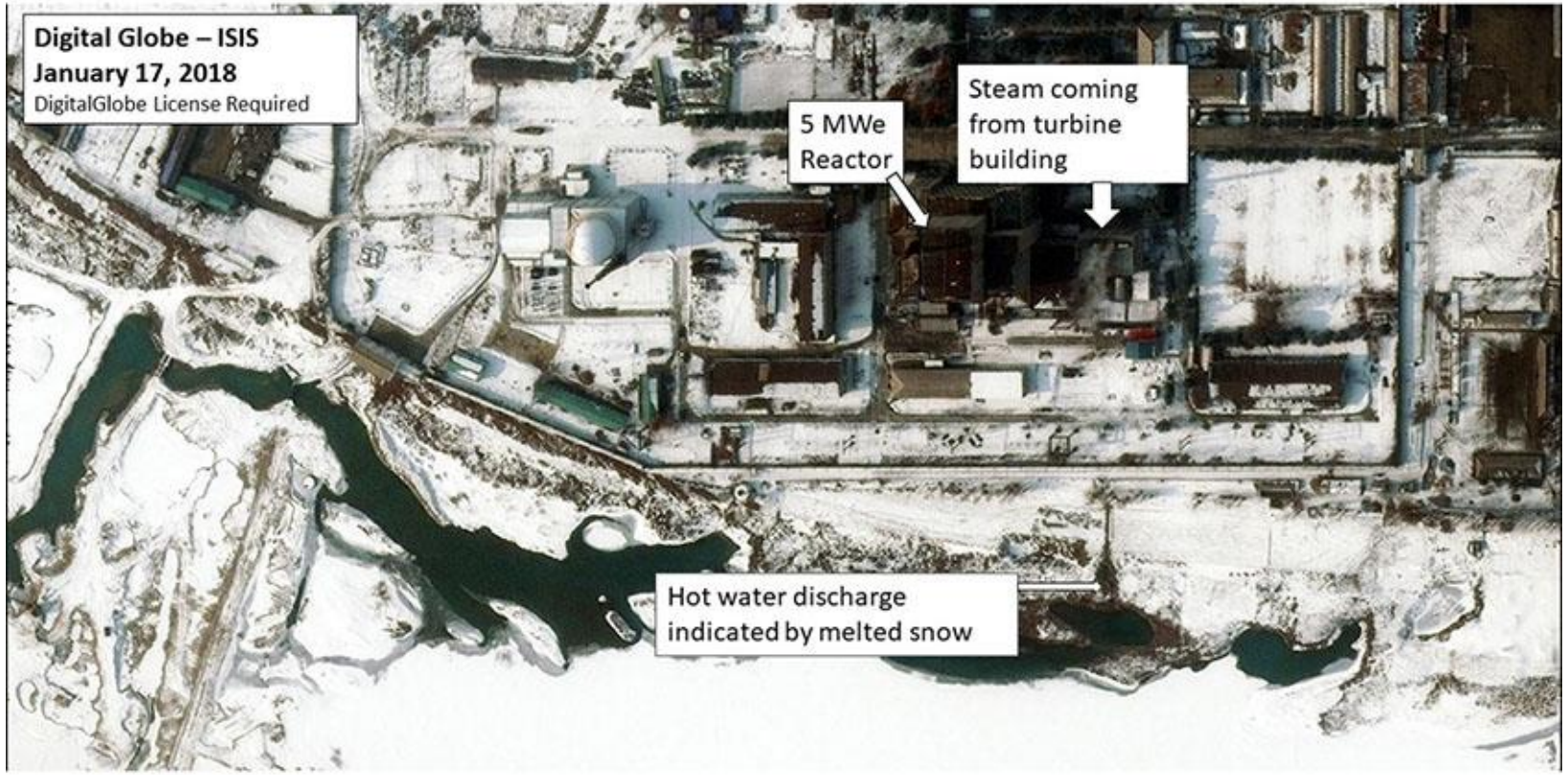
Location of the best known North Korean nuclear sites but mysteries and uncertainties about this site remain


Yongbyon
DigitalGlobe -ISIS
August 31, 2013
Licensing required
5 MWe Reactor
Undeclared Waste Site
Plutonium Separation Plant
Main Centrifuge Building
Fuel Fabrication Facility

August 21, 2016 Google Earth Image
5 MWe Reactor and Experimental Light Water Reactor (ELWR)



January 17, 2018 DigitalGlobe image showing 5 MWe reactor, with steam visible from the reactor's turbine building



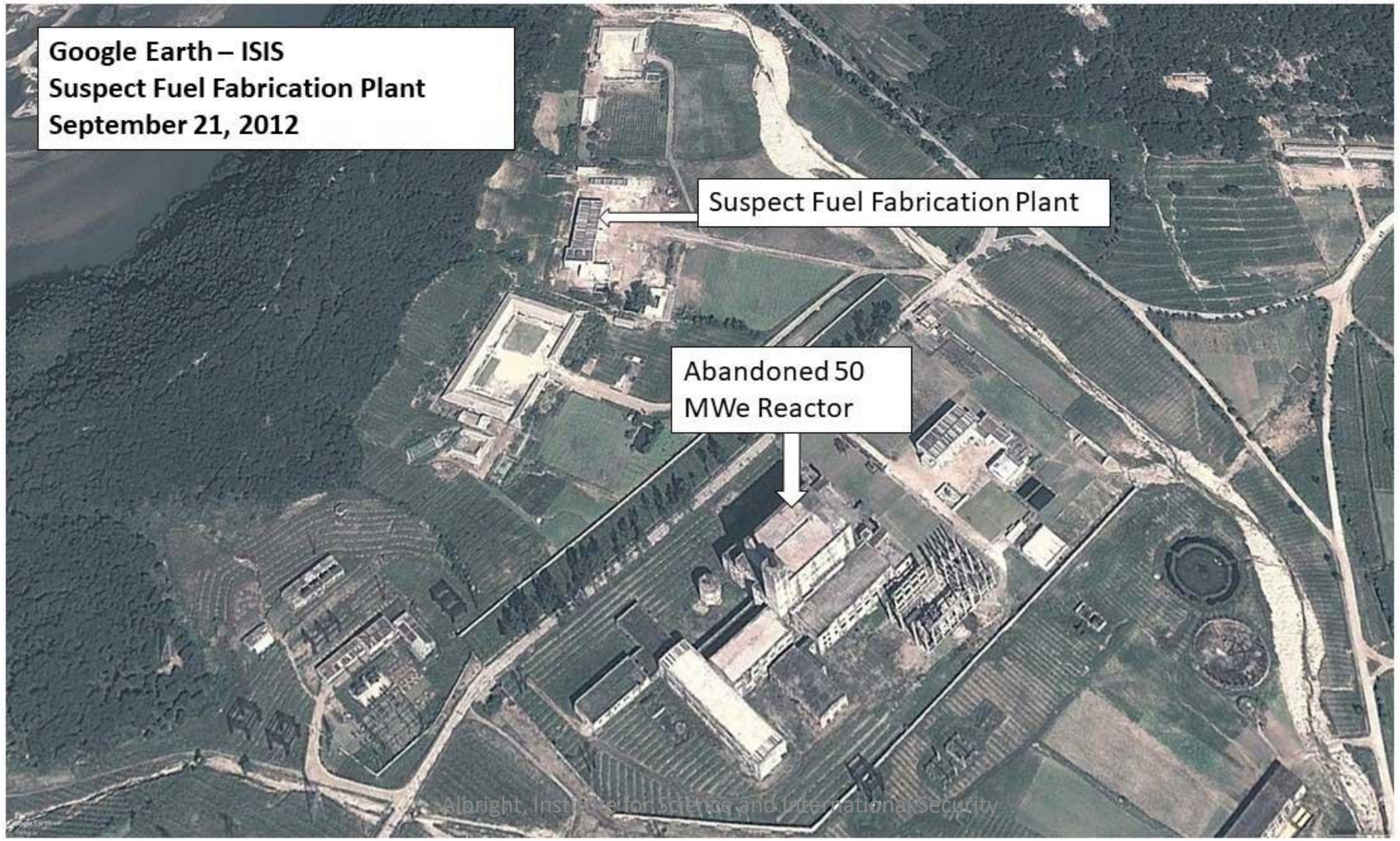
Radiochemical Laboratory, Plutonium Separation

Gas Centrifuge Plant and Possible Tritium Separation Plant at Yongbyon

According to a defector from Yongbyon, this facility has only a small centrifuge assembly hall, operated under clean room conditions, where pre-assembled parts are received and assembled into final centrifuge components. He said he was involved in creating the initial centrifuge assembly hall for this plant and had no prior experience assembling centrifuges before the first deliveries of parts.


Airbus– ISIS
January 30, 2018
Possible Isotope Separation Facility
Pleiades © CNES 2018 – Distribution Airbus DS/Spot
Construction Progress:
Roof added

Unclear where ELWR fuel fabrication occurs



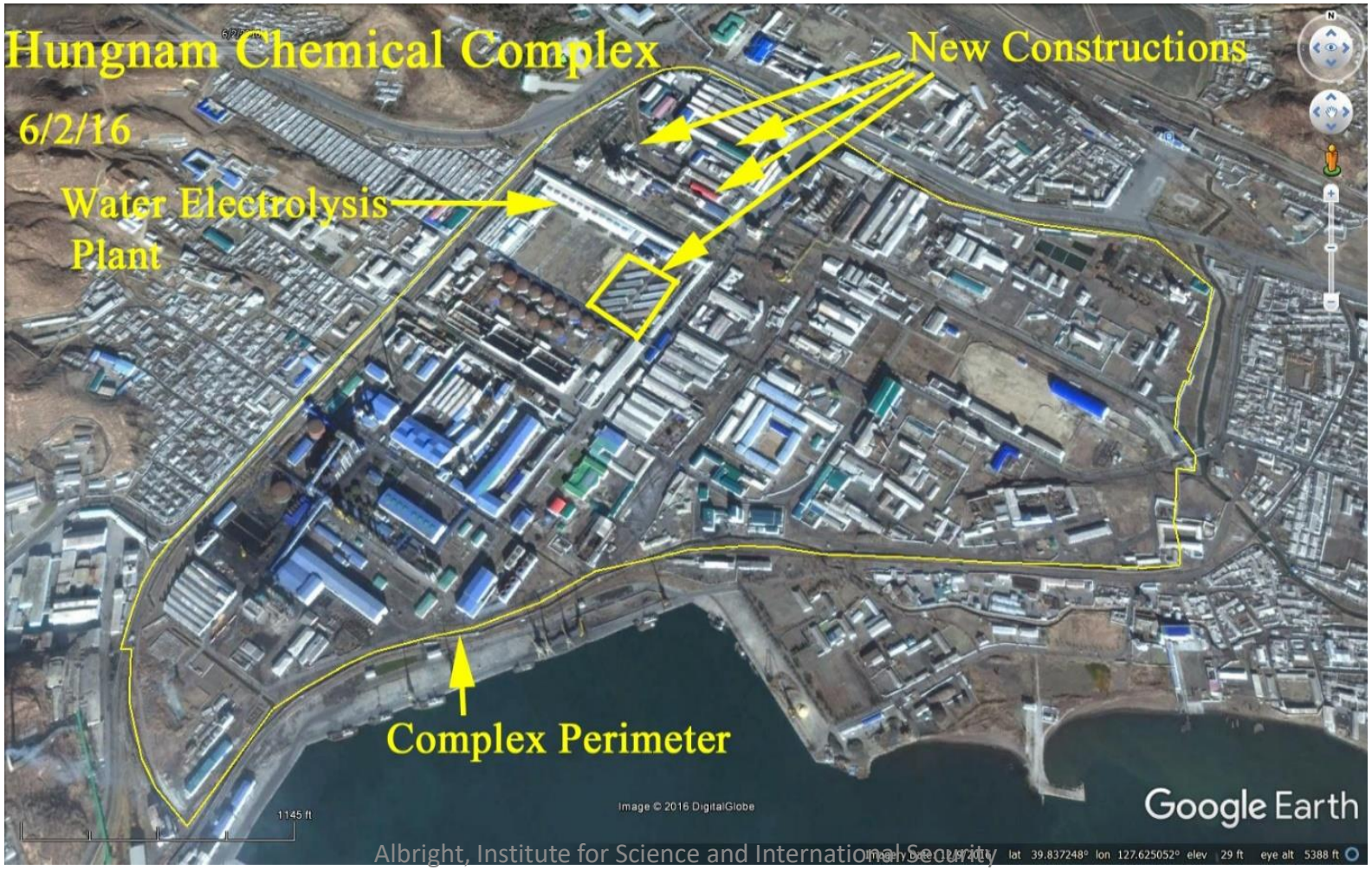
Nuclear Sites Outside the Yongbyon Complex Potentially Subject to Denuclearization

Some of the Unknown Facilities in North Korea Outside Yongbyon

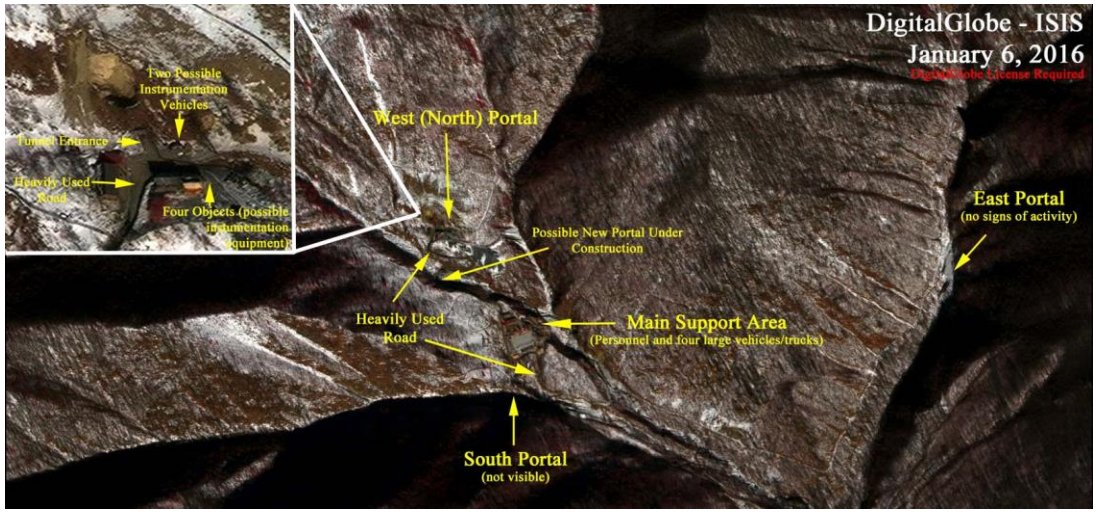
- One official source estimated to us that about half of North Korea's nuclear facilities are outside the Yongbyon nuclear complex and the Punggye-ri nuclear test site.
- Examples include:
  - The strong possibility of an older, perhaps larger, gas centrifuge plant
  - Uranium mining and milling
  - Centrifuge manufacturing and uranium hexafluoride production facilities
  - Sites to produce thermonuclear materials, such as lithium 6
  - Unknown number of sites to research, develop, and manufacture nuclear weapons and their components
  - Sites associated with nuclear weapon component testing, including full-scale cold-testing that complement underground nuclear testing at the Punggye-ri underground test site;
  - Possible integration facilities that could mate a nuclear warhead to a ballistic missile; and
  - Nuclear warhead storage capabilities.

Lithium 6 Production Likely at Hungnam Chemical Complex near Hamhung, Exact location unknown

(June 2, 2016 Google Earth Image)



Punggye-ri Underground Test Site, 2016 images

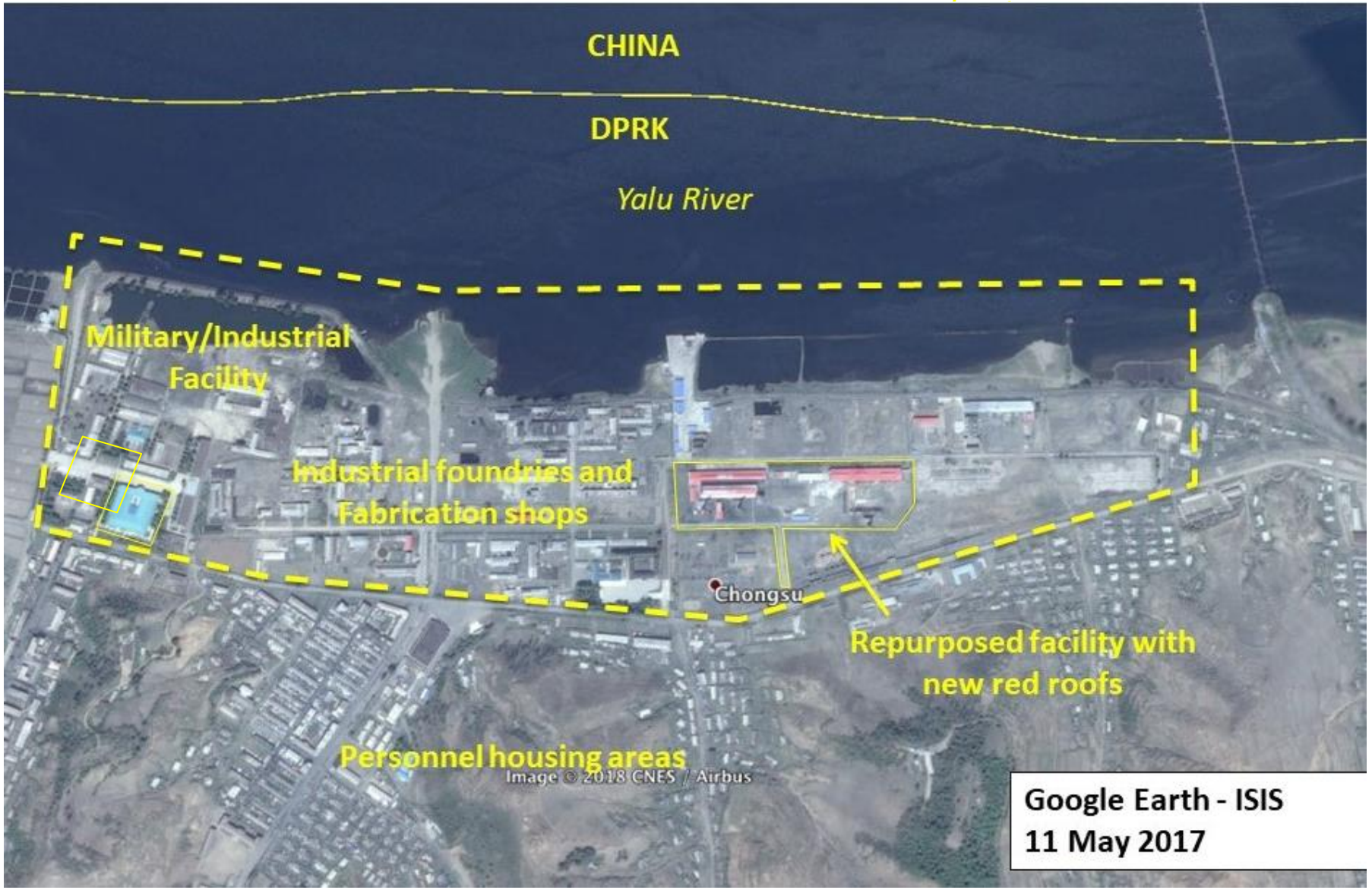


In this 2016 image, a new portal (tunnel) is identified. The names for this new portal and the nearby portal vary.

Pyongsan Uranium Mine and Mill: Significant Renovation in Last Several Years

Google Earth imagery of location of the early suspect centrifuge R&D plant under the Changgun-dae Mountain at the Panghyon Aircraft Plant. Centrifuge plant stated to be shut down.

The Suspect Chongsu Nuclear Grade Graphite Production Site Owned by Atomic Establishment



Is there another, earlier centrifuge plant?

- The evidence for this plant is substantial but remains unconfirmed and controversial. This plant could have made a substantial amount of weapon-grade uranium, complicating further efforts to dismantle and verify denuclearization.
- This other centrifuge plant could have started operation as early as the mid-2000s.
- However, the uncertainty remains substantial, particularly in terms of the amount of weapon-grade uranium it could have produced.

Argument for: Weapon-grade uranium detected in North Korea

- Weapon grade uranium was found on materials the United States brought out of North Korea in 2006 and 2007 as part of verification under the Six Party Talks.
- U.S. intelligence agencies assessed that this weapon-grade uranium was made in North Korea at a production-scale plant.
- This assessment was not unanimous in the U.S. intelligence community, however.
- Accepting this assessment implies that North Korea could have been operating a production-scale centrifuge plant by the mid-2000s.

Argument for: Procurement Information

- Procurement information provides another compelling rationale to believe that the Yongbyon centrifuge plant is not the first one.
- Western countries track North Korea's procurements for its centrifuge program closely and have spotted several peaks in procurements for the centrifuge program.
- Procurements have been extensive and have followed the types of procurements done by A. Q. Khan for Pakistan's centrifuge program.

Chronology of Detected Procurements Related to Centrifuge Plants

- 2002/2003 procurements sufficient for about 8,000-12,000 P2-type centrifuges
- Between 2003 and 2008, many procurements for centrifuge program
- 2008 procurements sufficient for 2,000 centrifuges
- End 2010, procurements for extension of the Yongbyon centrifuge plant. Procurements sufficient for 500-1000 centrifuges
- Early 2016, procurements detected sufficient for one low enriched uranium (LEU) cascade

Secret Centrifuge Plant?

- Would North Korea procure so much in the early 2000s and not build a centrifuge plant? Why would it wait until the late 2000s to build one at Yongbyon, ostensibly related at the time of its public declaration in 2010 only to the production of low enriched uranium (LEU)?
- North Korea's procurement history suggests the existence of a secret or undeclared, production-scale centrifuge plant(s) that was built in the mid-to-late 2000s.
- Assuming that North Korea was following the Khan plan, then the plant could have several thousand P2 centrifuges.
- Could it have 12,000 P2 centrifuges, 6,000 P2 centrifuges?
- How well has it worked?

Why Not Just Assume a Second Plant Making Large Amounts of Weapon-Grade Uranium?

- On balance, the evidence supports the existence of two production-scale centrifuge plants.
- However, the lack of concrete evidence of the plant raises doubt about its existence. There is also uncertainty about the amount of WGU it could have made, and if the plant experienced start-up and operational problems.
- Moreover, there are plausible explanations that the Yongbyon centrifuge plant is North Korea's only operating production-scale plant.
  - North Korea could have suffered delays caused by the difficulty of building and operating centrifuges.
  - These difficulties would have been compounded by the unexpected busting of the Khan network in 2003 and 2004, a network that North Korea may have needed to provide substantial on-going centrifuge assistance.

Second Plant (cont.)

- In terms of deriving fissile material and nuclear weapon estimates, I describe a conservative approach in the next section, where I essentially look at the case of one or two centrifuge plants. This is similar to what I have done in the past few years.
- In terms of designing verification arrangements, we propose including a second plant in the analysis.

Plutonium, Weapon-Grade Uranium (WGU), and Nuclear Weapons Estimates*

This section briefly summarizes estimates developed in more detail in other publications, most recently in David Albright, *North Korea's Nuclear Capabilities: A Fresh Look,* Institute for Science and International Security, August 9, 2017, http://isis-online.org/isis-reports/detail/north-koreas-nuclear-capabilities-a-fresh-look-power-point-slides/ and ADD LINK OF MAY 9TH PRESENTATION

Plutonium, WGU, Nuclear Weapon Stocks, end of 2017

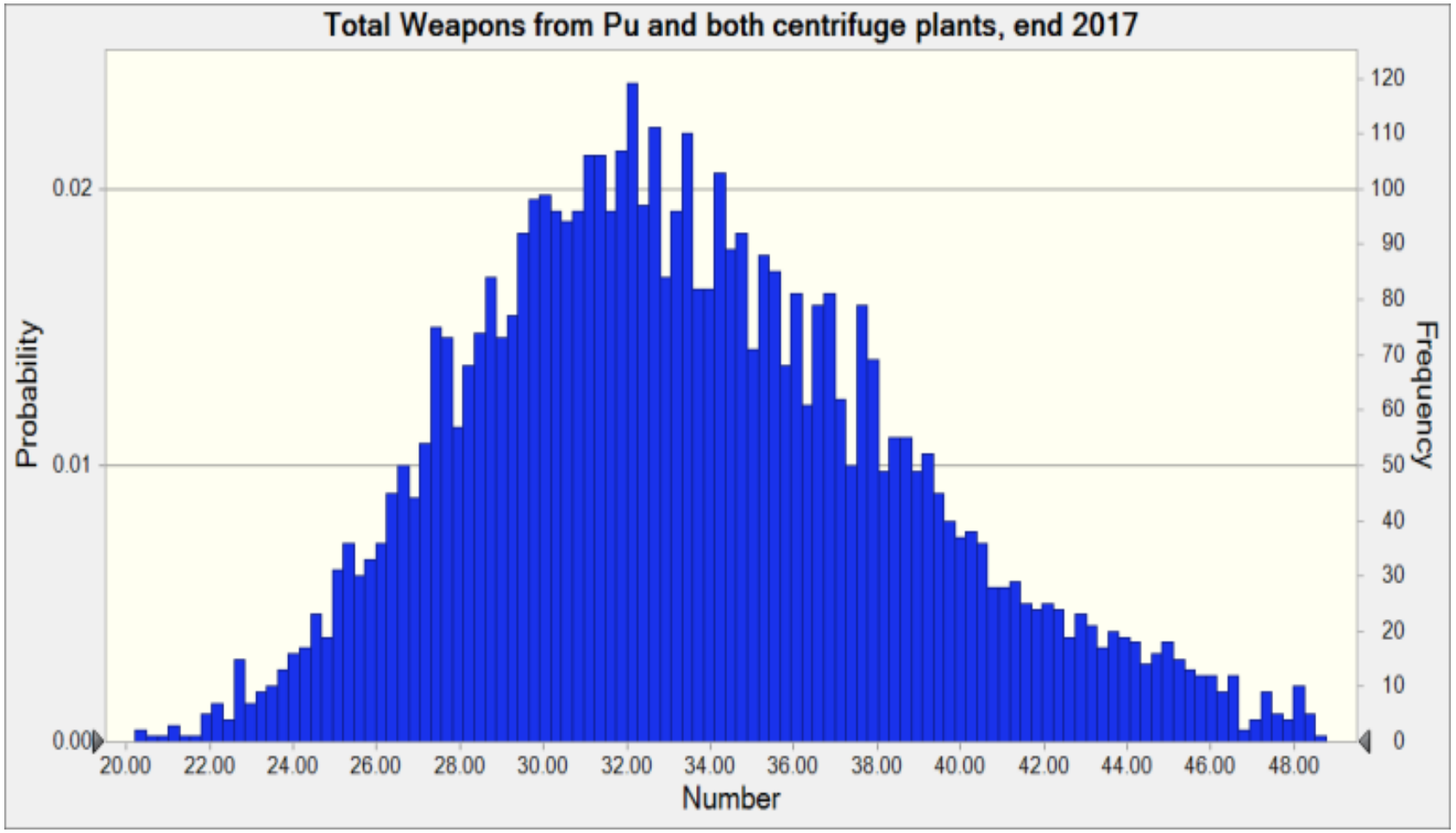
- My Institute's median estimates of the size of North Korea's plutonium and weapon-grade uranium stocks through 2017 are:
  - 30 kilograms of separated plutonium; and
  - 230-760 kilograms of weapon-grade uranium, where 230 kilograms corresponds to a median estimate for the case of one centrifuge plant and 760 kilograms corresponds to the median estimate for the case of two centrifuge plants.
  - 14 to 33 nuclear weapons.

See David Albright, *North Korea's Nuclear Capabilities: A Fresh Look,* Institute for Science and International Security, August 9, 2017, http://isis-online.org/isis-reports/detail/north-koreas-nuclear-capabilities-a-fresh-look-power-point-slides/; the estimate on this slide is an update through 2017 of the estimate presented in the August 9, 2017 presentation.

A Closer Look at the Upper Bound

- As discussed, most analysts believe a second, older enrichment plant exists and has made weapon-grade uranium for a number of years.
- The upper bound of the median estimate presented earlier of the number of nuclear weapons through 2017 includes the production of weapon-grade uranium at a second, unknown enrichment plant.
- Based on discussions with U.S. officials, U.S. estimates of nuclear weapons capabilities assume that this second enrichment plant exists and has contributed significantly to North Korea's stock of weapon-grade uranium.
- Although I am less sure of the resulting weapon-grade uranium estimates, it is useful to focus on the case of two centrifuge plants producing weapon-grade uranium as a basis to think through verification approaches in the event of success in negotiations of North Korean denuclearization.

Number of Weapons, accounting for fissile material losses, pipeline, reserves, end 2017



The median of this slightly skewed distribution is 33 nuclear weapons, with a standard deviation of 5.4 weapons. The full range is 18-57 weapons. The range defined from the 5th and 95th percentiles of this distribution is 26 to 44 nuclear weapons.

Observations

- These ranges for the scenario of two enrichment plants are relatively broad, about 26-44 nuclear weapons, where I use the 5th and 95th percentiles of the distribution.
- These upper bounds are consistent with media reports in 2017 about certain U.S. government intelligence community estimates of the number of North Korean nuclear weapons.
- In one report, the U.S. indicated that North Korea had up to 60 nuclear weapons. In our analysis, I would interpret this value as not including losses and being in the upper tail of the first distribution.
- I would stress that in our analysis a value of 60 represents a worst case.
- And I would also stress that our base estimate is 14-34 nuclear weapons, reflecting additional uncertainties about the status and operation of an older centrifuge plant.

Comparison of Estimated WGU Stock and Total Nuclear Weapons of Two Scenarios Considered Here

- Conservative estimate of one or two centrifuge plants (preferred absent more information):
  - 14-33 nuclear weapons
  - 230-760 kilograms of weapon-grade uranium, where 230 kilograms corresponds to a median estimate for the case of one centrifuge plant and 760 kilograms corresponds to the median estimate for the case of two centrifuge plants.

- Two centrifuge plants estimate (increasingly likely and relevant to developing verification approaches):
  - 26 to 44 nuclear weapons
  - 600 to 1,000 kilograms of weapon-grade uranium

Denuclearization and Its Verification

Verification and Dismantlement Targets

- Plutonium program
- Uranium enrichment program
- Thermonuclear materials program
- Nuclear Weapons testing, development, production, and maintenance
- Nuclear weapons
- Proliferation of nuclear weapons and capabilities
- North Korea's illicit nuclear trade and smuggling networks for its own and others' nuclear programs

Past Verification Work

- It should be remembered that there exists a substantial body of work on North Korean complete, verified, irreversible dismantlement (CVID) that was developed in the Six Party negotiations and the subsequent effort to achieve the Leap Day deal.
- The Six Party Talks in the 2000s led to a great deal of clarification of the verification requirements of a denuclearization agreement, even if North Korea was not as cooperative as Libya, South Africa, or Iraq (1995-98 and 2002-03).

The October 2008 Agreement: Limited Cooperation

- In October 2008, the United States and North Korea agreed tentatively to a deal that made progress on accomplishing the verification arrangements in denuclearization in the context of the Six Party Talks.
- Despite its rejection later, this deal, by placing emphasis on plutonium while also laying the basis for dealing with uranium enrichment, weaponization, and proliferation, was an important U.S. negotiating accomplishment. Its positive and negative aspects should be assessed as part of the work today to achieve a negotiating model.

Components of October 2008 Deal

- Written text (applied to plutonium, enrichment, and proliferation);
- Two side conversations between North Korea and the United States;
- Singapore agreement (mid-2008), where North Korea agreed to provide cooperation on uranium enrichment and proliferation activities (including not to proliferate), while decoupling these issues from plutonium;
- Three earlier agreements, Sept 19, 2005 Joint Statement, Feb. 13, 2007 Agreement on Initial Actions, and Oct 3, 2007 Agreement on Second-Phase Actions; and
- Understanding with Chinese expressed in a letter to Chinese chair of Six Party Talks that the United States has an understanding with North Korea, called a "related understanding," which captures the inter-linkages among the above components of the deal. "Chinese chair also understands and supports this position."

Difficult Verification Issues in October 2008: Many still need to be resolved today

- North Korea's provision of documents; allowing interviews with key individuals;
- Ensuring adequate declarations and gaining access to sites and facilities in declarations;
- Defining the undeclared sites eligible for visits or inspections;
- The sampling and forensics to be allowed and at which facilities (e.g. 5 MWe and IRT reactors and uranium enrichment plants);
- The avoidance of ambiguous phrases, such as "at an appropriate time" in the context of taking key samples;
- The negotiation of verification measures piecemeal and incrementally rather than all at once prior to the start of the verification process;
- Participation by Non-Nuclear Weapon States (NNWS) in verification;
- Role of International Atomic Energy Agency (IAEA);
- The need to destroy items rather than store items during disablement and dismantlement.
- What about thermonuclear materials and the means to make them?

Example of Past Problems: Access to Sites

- In the October 2008 deal, North Korea agreed that inspectors can access all nuclear facilities which are subject to eventual abandonment. Access to additional nuclear facilities and sites will be provided based on consultation and mutual respect. But a list of such sites was not agreed upon.
- This would imply that inspectors would eventually have access to a secret enrichment site. But is this site slated for abandonment?
- This clause is very difficult to get to work in practice. For example, in 2008 getting access to suspected plutonium-holding nuclear waste site near the Radiochemical Laboratory was expected to be a difficult issue.
- Thus, there existed a process to get to additional sites beyond the declared ones, but that process would have been hard to accomplish in practice.

Another Example: Sampling

- The October 2008 agreement allowed for additional verification activities at an appropriate time, including “scientific procedures” to facilitate an accurate assessment of DPRK declaration.
- In an oral agreement, both negotiating teams agreed that scientific procedures would include a list of activities in an August 22, 2008 draft, called the Chinese draft.
- This list allowed for the collecting and removal of samples of nuclear and nuclear waste materials, including taking samples of graphite in the 5 megawatt-electric reactor aimed at determining total plutonium production
- Subsequently, North Korea reneged on this condition.

Fixing Past Problems: What is needed from North Korea?

- North Korea needs to believe and demonstrate that verified nuclear dismantlement is in its national security interests.
- North Korea needs to demonstrate full cooperation with the verification organization(s).
- It needs to permit access to sites, personnel, and documents. Access to military sites will be necessary.
- North Korea needs to understand that sanctions are not traded for negotiations but concrete actions.
- It needs to make an early concrete demonstration of its commitment to denuclearization. Closing the Punggye-ri Underground Test Site, while welcome, is not sufficient.

Brief comments on what to look for at the upcoming summits and subsequent negotiations

- One lesson of the past negotiations is that the United States should seek initially a clear, written (public) commitment from North Korea on eliminating its nuclear weapons and the means to make, test, and maintain them.
- An early, concrete demonstration of that commitment is also necessary
- The United States should also seek an agreement with North Korea on all necessary verification measures, in particular it should achieve such an agreement prior to starting any verification.
- The alternative, namely a piecemeal approach to negotiating verification measures, was used in the past but did not succeed and can require on-going, difficult negotiations over the basic principles and ground rules of verification, with little certainty of succeeding in a satisfactory manner.
- The entirety of North Korea's nuclear weapons programs needs to be included in any disablement, verification, and dismantlement effort. In the past, for example, plutonium production was singled out and uranium enrichment put off until later.

Brief comments on what to look for (cont.)

- In the verification effort, is there a focus on a historical nuclear material balance and flow chart for all uranium in North Korea? Such an approach would cover the plutonium, enriched uranium, and nuclear weapons program. In the case of enriched uranium, a reconstruction of the daily separative work output and enriched uranium production at each major centrifuge plant may be necessary. Other approaches will be needed as well.

Overview of Possible Template for Verified Dismantlement of the Plutonium, Uranium Enrichment, and Weaponization Programs

- Phase 1:
  - Listing and describing the facilities subject to abandonment;
  - Visiting these facilities, even if by US experts and officials only;
  - Halting operations at these facilities and establishing IAEA monitoring.
- Phase 2:
  - Disabling these facilities;
  - Producing a declaration.
- Phase 3:
  - Verifying the declaration, ensuring the absence of undeclared nuclear materials, facilities, and weapons, and coming into compliance with the NPT.
  - Irreversible dismantlement and disposal.

Example of Verified Dismantlement of the Uranium Enrichment Program

Example: Uranium Enrichment Program (UEP)

- Although all aspects of North Korea's nuclear weapons program should be dealt with in parallel, not sequentially, it is useful to focus on one pathway to nuclear weapons to illustrate the components of verified nuclear dismantlement in more detail.

Suggested timeline for Uranium Enrichment Program's (UEP's) declaration, verification, and dismantlement

MONTH	Uranium Enrichment Program
1	• Listing and describing facilities subject to abandonment (beginning of month 1). • Halting operations at these facilities and establishing International Atomic Energy Agency monitoring • Visiting listed facilities
2	• Continue visiting facilities (month 2).
3	• Producing a declaration (need to have agreement on verification measures prior to accepting a declaration) • Disabling facilities in the program (months 3-6).
4	
5	
6	
7	• Verifying the declaration (months 7-18).

Suggested timeline for UEP declaration, verification, and dismantlement (cont.)

Months 19- 30	• Dismantling the program (months 19-30). • Continue verifying the declaration as needed and develop confidence in the absence of undeclared materials or facilities

Phase I

- Listing and describing the UEP facilities subject to abandonment;
- Visiting these facilities;
- Halting operations at these facilities and establishing International Atomic Energy Agency monitoring.

Listing and describing the UEP facilities subject to abandonment

- Centrifuge R&D facilities;
- Sites that make centrifuge components, whether in dedicated facilities owned by the centrifuge program or in companies contracted to make specific components;
- Facilities to assemble, balance, and test individual centrifuges;
- Uranium hexafluoride production facilities;
- Centrifuge plants.
- Commitment not to seek overseas centrifuge sensitive components, raw materials, equipment, or technology for its centrifuge program.

Halting Operations and Visiting Facilities

- Visits to listed facilities by experts from Six Parties
- Halting operations
  - The first step in halting a gas centrifuge plant is stopping the feeding of uranium hexafluoride into the cascades and allowing the cascades to empty. The next step is shutting down the centrifuges.
  - Other facilities should be emptied of their nuclear material prior to shutdown.
  - Because centrifuge plants and in particular uranium hexafluoride production plants handle corrosive fluorine, workers and monitors will need to take proper health and safety measures.
- The IAEA should monitor the shutdown of key facilities, such as pilot and production-scale centrifuge plants and uranium hexafluoride production plants.

Useful Model for Halting Operations at Centrifuge Plant: The 2003/04 Iran suspension agreements for its UEP

- Halted the assembly, installation, testing, or operation of gas centrifuges. This involved stopping centrifuges and not introducing any new nuclear material into any centrifuges. It also involved withdrawing nuclear material from the centrifuges at any gas centrifuge enrichment facility.
- Halted all tests and production for conversion at any uranium conversion installation. In addition, material at uranium conversion facilities was brought to a safe, secure, and stable state, not beyond uranium tetrafluoride.
- Suspended the domestic manufacture of centrifuge machines and their components, including those related to existing obligations. Any components that were manufactured were stored and placed under inspectors' seal.
- Declared that it did not intend to import centrifuge machines or their components, equipment or raw materials to make centrifuges or feed, or the feed material for enrichment processes.

Phase 2

- Disabling the facilities subject to abandonment; and
- Producing a declaration.

Disablement

- After halting operations at the UEP facilities, North Korea would disable each facility or process.
- Because a dismantlement process is the focus, destruction instead of storage of key components in a facility or process should be sought.

Disablement of Centrifuge Plant

- Disabling a centrifuge plant can be accomplished quickly. The level of radiation is low and equipment is easily accessible.
- One priority is the feed and withdrawal section of the centrifuge plant. Measures could include removing feed and withdrawal equipment or welding or bolting canisters into the feed and withdrawal stations, preventing the insertion of feed or product cylinders. In addition, header pipes or major parts of the cold traps can be isolated and removed.
- Measures could include letting the cascade pressure rise up to atmospheric pressure and removing the roots vacuum pumps and pressure transducers, equipment North Korea cannot make itself but buys abroad.

Disablement: Centrifuge Manufacturing.

- In the case of disablement of plutonium facilities in the Six Party Talks, manufacturing equipment for reactors and plutonium separation plants were not included in monitoring or disablement. This decision should be revisited.
- Moreover, centrifuge manufacturing facilities continuously make centrifuges, which are by design easily replicable and cheap to make. Therefore, centrifuge manufacturing and assembly sites are vital, on-going parts of a gas centrifuge program and should be halted and disabled.
- Disablement steps could include removal of computer software or specialized fixtures on machine tools. In addition, manufacturing pre-forms and critical jigs and fixtures could be removed.

Disablement: Uranium Conversion Facilities

- Little is known about North Korea's specific methods to produce uranium hexafluoride. To avoid future problems involving corrosive and potentially dangerous materials, the facility's process lines and equipment should be emptied, particularly of any compounds involving fluorine.
- Disablement could include removing/destroying key pieces of equipment, such as crystalizers, process piping, uranium hexafluoride filters, and gas washers. One disablement step would be to cut or remove the process piping leading to and from this equipment.
- Other parts of uranium conversion facilities can be disabled similarly to what was done at the Fuel Fabrication Complex at Yongbyon during the plutonium program disablement under the Six Party Talks in the mid-to-late 2000s.

Disablement: Centrifuge Parts

- As part of monitoring the disablement process, the verification experts should seek to inventory and characterize centrifuge components, raw materials, and manufacturing equipment. This information can also be useful in verifying a North Korean UEP declaration.

Declaration: Anticipating Verification

- Prior to accepting a North Korean declaration, a priority is ensuring the verification methods or approaches are agreed upon. They should be decided before the parties decide on what should be included in North Korea's declaration. They have different requirements for information and data.

Important Lesson

- More than one verification method or approach should be included to answer the fundamental verification questions about uranium enrichment plants.
- This lesson should be incorporated into determining what should be included in a North Korean declaration. The following serves to introduce several major verification approaches.

Verification Approaches

- Derive and verify the material balance of uranium and uranium 235 in each enrichment and conversion facility. Track yellowcake flows into uranium hexafluoride production facilities and from there to centrifuge plants. This would be part of a broader nuclear material balance and flow chart for all the uranium and uranium 235 that North Korea produced, used, imported, and exported.
- Reconstruct day-by-day the separative work and enriched uranium production in a centrifuge plant and a comparison of these estimates to the declaration of total product withdrawal of enriched uranium.
- Reconstruct in detail the history of North Korea's centrifuge program, including its development since the 1990s or perhaps 1980s.
- Recreate the number of centrifuges North Korea has manufactured, deployed, and retired.
- Develop an understanding of North Korea's research and development of more advanced centrifuges.
- Assess North Korea's overseas procurements for its centrifuge program.

The Declaration

- Description of each site in UEP
- Natural and enriched uranium production
- Centrifuge manufacturing data
- Any advanced centrifuges under development
- Domestic and overseas procurement data for gas centrifuges and uranium hexafluoride production
- Information relevant to a full material balance approach, namely creating a balance of all North Korea uranium and uranium 235 produced, used, imported, and exported.

Description of each site in UEP

- The declaration should include a description of each site in the uranium enrichment program, and all facilities at sites that processed, stored, or enriched uranium.
- The description should include each site's and facility's purpose and capabilities, and the amount of enriched uranium it produced and/or stored. The types and numbers of centrifuge used at each facility should also be declared.
- A UEP declaration should include detailed process flow diagrams, electric and instrument flow diagrams, and plant and equipment layout diagrams.

Natural and enriched uranium

- The declaration should include for each enrichment facility, the flows of natural uranium hexafluoride, enriched uranium, and depleted uranium, including research, development, and production-scale facilities. It should also include the level of enrichment or amount of contained uranium 235 in all declared quantities.
- The declaration should include the uses of the enriched uranium, its current locations, and losses of enriched uranium during processing or held up in plants. Similar data should be provided for natural uranium hexafluoride and the tails.
- North Korea will need to declare and account for the amounts of enriched uranium used in its nuclear tests and used in nuclear weapons and their manufacture.

Uranium Hexafluoride (UF_6) Production

- The declaration should include the amount of uranium hexafluoride produced in each facility. It should detail the amount sent to enrichment plants and lost during processing at all these facilities. It should include the amounts and location of any stored uranium hexafluoride.

Centrifuge Manufacturing Data

- To recreate the number of centrifuges North Korea has manufactured, North Korea would need to provide the types of centrifuges that have been manufactured, the number of major components manufactured, and where each component has been made. The reject rate for rotors and bellows is also needed.

Work on advanced centrifuges?

- North Korea should provide information about its research and development of centrifuges and its plans for their deployment. The statement should include the types of centrifuges being investigated, design information about these centrifuges, and the status and location of single machine and small cascade tests.

Domestic and overseas procurement data for UEP

- North Korea should provide lists of major equipment and materials (and source) at its major centrifuge plants, centrifuge manufacturing, assembling, and uranium conversion facilities.

Information relevant to a full material balance approach

- To achieve a material balance of all the uranium in North Korea requires additional information. The supplemental information includes total yellowcake production, uranium inputs, outputs, and losses at all the uranium conversion facilities, and uranium imports and exports. This approach should be done in conjunction with the plutonium and nuclear weaponization programs.

Provision of Records

- At a minimum, North Korea should provide the daily operating, control, and accountancy records for each operational or shutdown facility that has enriched uranium. In order to conduct a reconstruction of total enriched uranium production at each facility, these records need to include plant availability, product enrichment, and tails assay on a near daily basis.
- The verification organization should be able to pursue additional records as necessary.

Phase 3

- Verifying the declaration and ensuring the absence of undeclared nuclear materials or facilities.
- Irreversible dismantlement and disposal of the UEP.

Verification of Declaration

- The verification teams will devote considerable time and resources to implementing the various verification approaches. They will need close coordination with their intelligence communities and national technical experts.
- The teams will visit facilities, review records, interview North Korean technical personnel, and ask for more records. If they reach an impasse, they will ask North Korea for clarification and more information.

Irreversible Dismantlement of a UEP

- Dismantlement and verification can occur concurrently, or dismantlement could follow verification. Dismantlement can follow verification if the parties want to first ensure that the entire centrifuge program is declared and accounted for. In addition, North Korea may want to conduct dismantlement after receiving additional and substantial incentives.
- All destruction should be supervised by six party experts to ensure that centrifuges have not merely been moved to a new location.
- Facilities and certain equipment or materials should be evaluated by the parties to decide what to convert to alternative, permissible uses.
- After the verification organization accounts for natural and enriched uranium, it would need to oversee the blending down of enriched uranium to natural uranium or its shipment out of North Korea. Likewise, uranium hexafluoride should be converted or shipped out of North Korea.

Findings on UEP Verified Dismantlement

- A prerequisite for any substantive negotiations should be that North Korea halt operations and agree to dismantle its UEP program in parallel with plutonium, weaponization, and long-range missile programs. The UEP is too readily usable to make HEU for a nuclear weapons program, regardless of the level of inspections.
- The price of negotiations should not be the end of U.N. Security Council sanctions. These sanctions are effective in making it harder for North Korea to outfit its nuclear programs.
- At the very beginning of any negotiating process, North Korea must fully reveal its centrifuge program.

Findings on UEP Verified Dismantlement (cont.)

- The successful verification of the dismantlement of North Korea's UEP will likely depend on pursuing a combination of verification approaches. No one approach is likely to provide sufficient confidence on its own that North Korea's declaration is correct and complete. The collection of verification approaches discussed in this report combined with challenge inspections should be sufficient to verify the correctness and completeness of North Korea's UEP declaration.
- Verification experts should determine prior to North Korea submitting a declaration what verification approaches are necessary and what data and records should be included in the declaration.
- North Korea's UEP declaration will need to be more detailed than its plutonium declaration, since relatively little is known about the centrifuge program. Over the years, North Korea has provided detailed information about the plutonium program to IAEA inspectors and U.S. experts. No such parallel exists for the UEP, making such information all the more important.

Findings on UEP Verified Dismantlement (cont.)

- Previously, gaining access to certain North Korean facilities and conducting sampling was highly proscribed and incremental. This type of approach should not be accepted today.
- A priority is reaching an agreement with North Korea over access to suspected undeclared nuclear sites and the taking of samples in facilities subject to abandonment and those suspected of being undeclared sites. The verification negotiations should also clearly establish a workable procedure to carry out challenge inspections of sites. Without such a procedure, verifying the completeness of a UEP declaration may not be possible.
- Sampling is expected to play a critical role in the UEP verification effort. Unlike the case of the verification of the plutonium program, however, sampling will be unlikely to provide a mechanism to determine independently the total amount of enriched uranium, or more specifically HEU, produced in a centrifuge plant. I cannot identify a sampling method that could be correlated reliably with total enriched uranium production in a centrifuge plant. Nonetheless, additional study of this question is warranted.

Findings on UEP Verified Dismantlement (cont.)

- The verification team will need experts in gas centrifuges, both in terms of the specific designs used in North Korea and the processes involved in a centrifuge plant. Urenco and its affiliated countries should be approached for assistance.

Example of Verified Dismantlement of the Nuclear Weaponization Program

Revealing its Nuclear Weaponization Complex

- Prior to a full declaration, North Korea would state all its nuclear weapons and the facilities to research, develop, test, and manufacture nuclear weapons.
- These facilities would include:
  - Nuclear and non-nuclear component manufacturing sites
  - High explosive test sites
  - Nuclear weapon assembly and integration facilities
  - Nuclear weapon storage vaults
  - Underground test site(s)
- North Korea would allow visits of these sites and facilities
- North Korea would need to reveal its nuclear weapons
- Activities at these sites would be frozen and monitored, and as appropriate facilities would be disabled.

The Nuclear Weapons: Declaration and Verfication

- North Korea would declare all nuclear weapons, nuclear weapons components, and the rest of its nuclear weaponization complex. This declaration would need to include the historical development of the nuclear weapons.
- The verification organization would visit the sites, interview members of the program, review documents, and account for declared nuclear weapons and major nonnuclear weapons components.
- Independently, the amount of nuclear materials in the weapons and used in the six underground tests would need to be verified.
- The preferred option is that the verification organization have access to detailed nuclear weapon design information and nuclear weapons themselves. If North Korea does not want to allow the verification organization access to such information or weapons, the verification process will be much more difficult, perhaps impossible.
- Verification would need to ensure that North Korea had declared all its weaponization facilities, nuclear weapons, and contained fissile and perhaps thermonuclear materials.

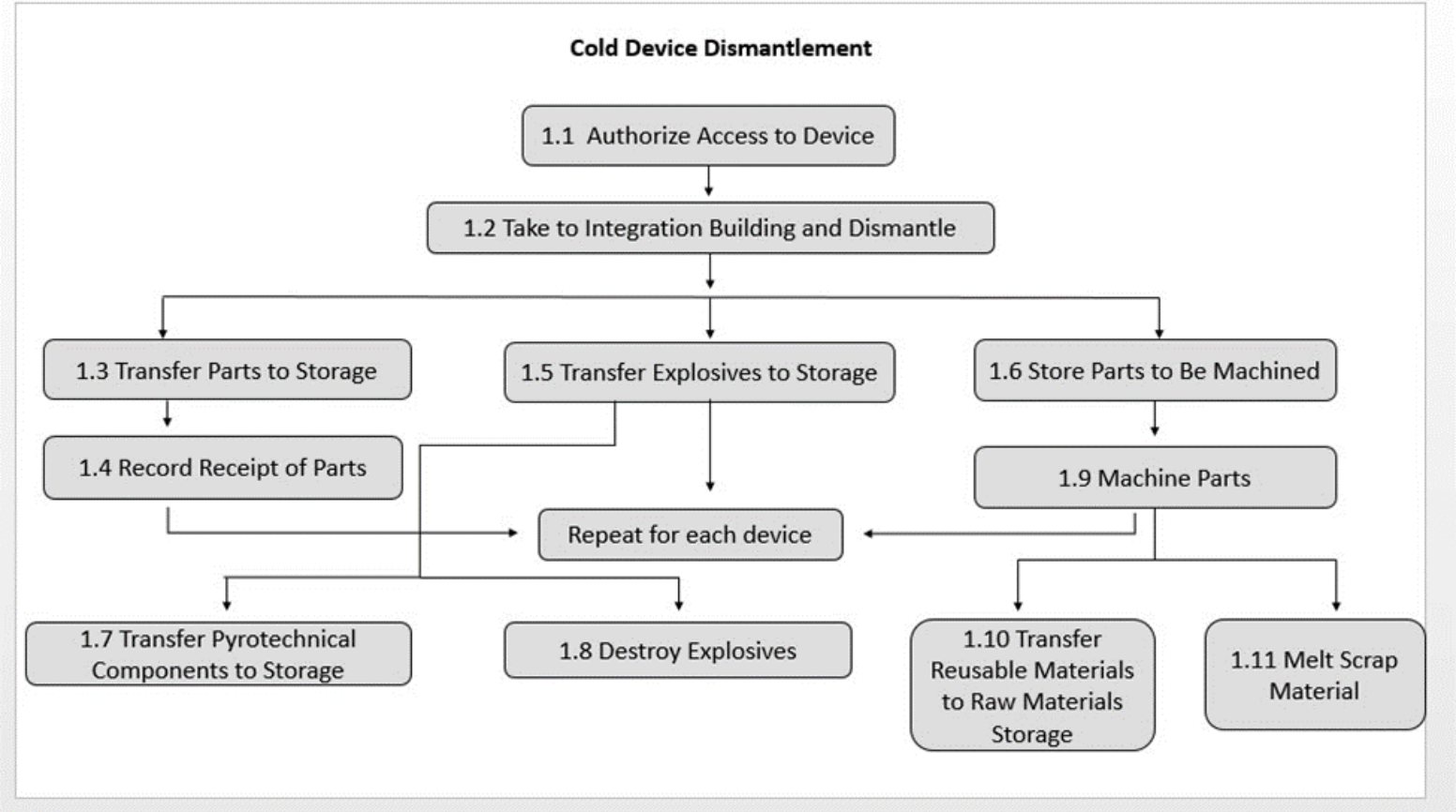
Nuclear Weapons and the Weaponization Complex

- A decision would need to be reached whether to transport the nuclear weapons abroad for dismantlement and disposal or do the dismantlement in North Korea.
- In any case, key nuclear weapon components should be removed from North Korea or destroyed, and the weaponization complex dismantled or disabled.
- In order to ensure irreversibility, this phase requires the verified destruction of any nuclear weapons, key components, and certain equipment, and the conversion and ongoing monitoring of other equipment and facilities.

South Africa “do it yourself” Option

- South Africa dismantled its own nuclear weapons and subsequently subjected the entire process to thorough IAEA verification.
- The dismantlement involved taking apart the weapons,
  - Recovering the highly enriched uranium and melting it down into ingots
  - Deciding the fate of the non-nuclear components, based on an evaluation of their proliferation sensitivity, where sensitive parts were destroyed and less sensitive ones stored or used for other, non-proscribed purposes
  - When the IAEA inventoried the remaining weapon subcomponents, it recommended destroying additional parts, having a stricter definition of proliferation sensitive.
- The following slide contains a schematic of the South African decision tree for deciding the fate of the parts in what is called a cold device, e.g. one without highly enriched uranium, of which South Africa had several.

South Africa's "Rendering Harmless of Cold Device," (no HEU), translation of a South African document



Each step is described in the sidebar, "Dismantling a Cold Device," *Revisiting South Africa's Nuclear Weapons Program, p*. 202.

Thank You

For a description of a successful denuclearization process of a country that had nuclear weapons, please see *Revisiting South Africa's Nuclear Weapons Program*, available as an ebook at Nook, Kindle, and Smashwords, as a pdf on the Institute website (http://isis-online.org/uploads/isis-reports/documents/RevisitingSouthAfricasNuclearWeaponsProgram.pdf), and as a paperback in black and white at Amazon.