



# MONITORING NORTH KOREA'S NUCLEAR ARSENAL

## A MENU OF OPTIONS

Alex Glaser

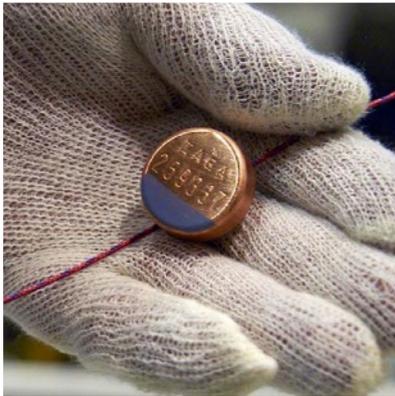
Program on Science and Global Security  
Princeton University

Nuclear Firewall Meeting, Beijing, November 27, 2018

Revision 4

# REQUIREMENTS

FOR RELEVANT MONITORING CONCEPTS AND TECHNOLOGIES

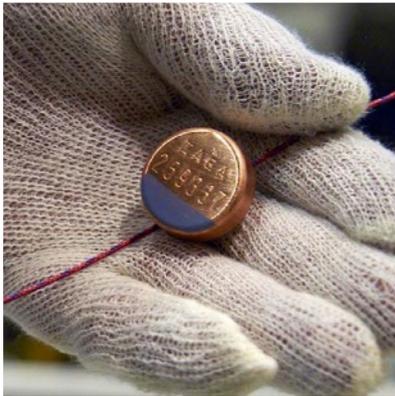


## AVAILABILITY / READINESS

Technologies and concepts have to be available and ready for deployment  
Cannot afford dedicated, new R&D project

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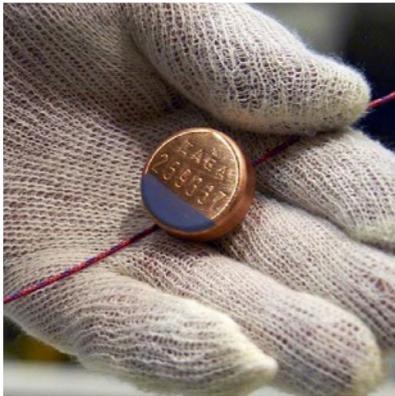


## NON-INTRUSIVENESS

Minimize frequency of onsite inspections and direct access to items  
(or, at least, allow for gradual phase in of such activities)

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### PRIVACY / SECURITY

North Korea does not want to give away GPS coordinates of monitored items  
(or, at least, not the coordinates of all items at the same time)

*Source: IAEA (top and middle) and DigitalGlobe (bottom)*

# WARHEAD MONITORING OPTIONS

(with and without prior baseline declarations)

# POSSIBLE BASELINE DECLARATIONS

## OF NUCLEAR WARHEAD AND FISSILE MATERIAL INVENTORIES

WARHEAD DECLARATION	
	<b>Inventory</b>
<b>Total number of warheads as of [DATE]</b>	.....
Warheads, by type/designation	.....
Additional warhead components in storage, by type/designation	.....

FISSILE MATERIAL DECLARATION			
	Plutonium	HEU	(Tritium)
Total material produced	.....	.....	.....
Removals and losses (including material consumed in weapon tests)	.....	.....	.....
<b>Inventory as of [DATE]</b>	.....	.....	.....
<i>Of this, material currently in weapons or weapon components</i>	.....	.....	.....

Several options: public, private, secure (cryptographic escrow)

# OPTION 1

(Remote Monitoring of Declared Items)

# “SECURE REMOTE MONITORING”

## ONE POSSIBLE IMPLEMENTATION

1



### (JOINT) CONTAINERIZATION OF NUCLEAR WARHEADS

Batches of warheads are containerized, sealed, and prepared for long-term storage

May need some type of confirmation measurement

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### MONITORED LONG-TERM STORAGE OF NUCLEAR WARHEADS (AND MISSILES)

Storage location of containerized warheads can remain unknown/secret  
Possibility of confirming integrity of seals and containers remotely

# “SECURE REMOTE MONITORING”

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3



### TOWARD STEPWISE REDUCTIONS IN THE ARSENAL

Based on agreed schedule for reductions, DPRK would offer warheads  
for verified dismantlement (or specified amounts of fissile material for safeguards)

Source: U.S. Department of Energy (top), Sandia National Laboratories (middle), KCNA (bottom)

# OPTION 2

(Hashed Declarations)

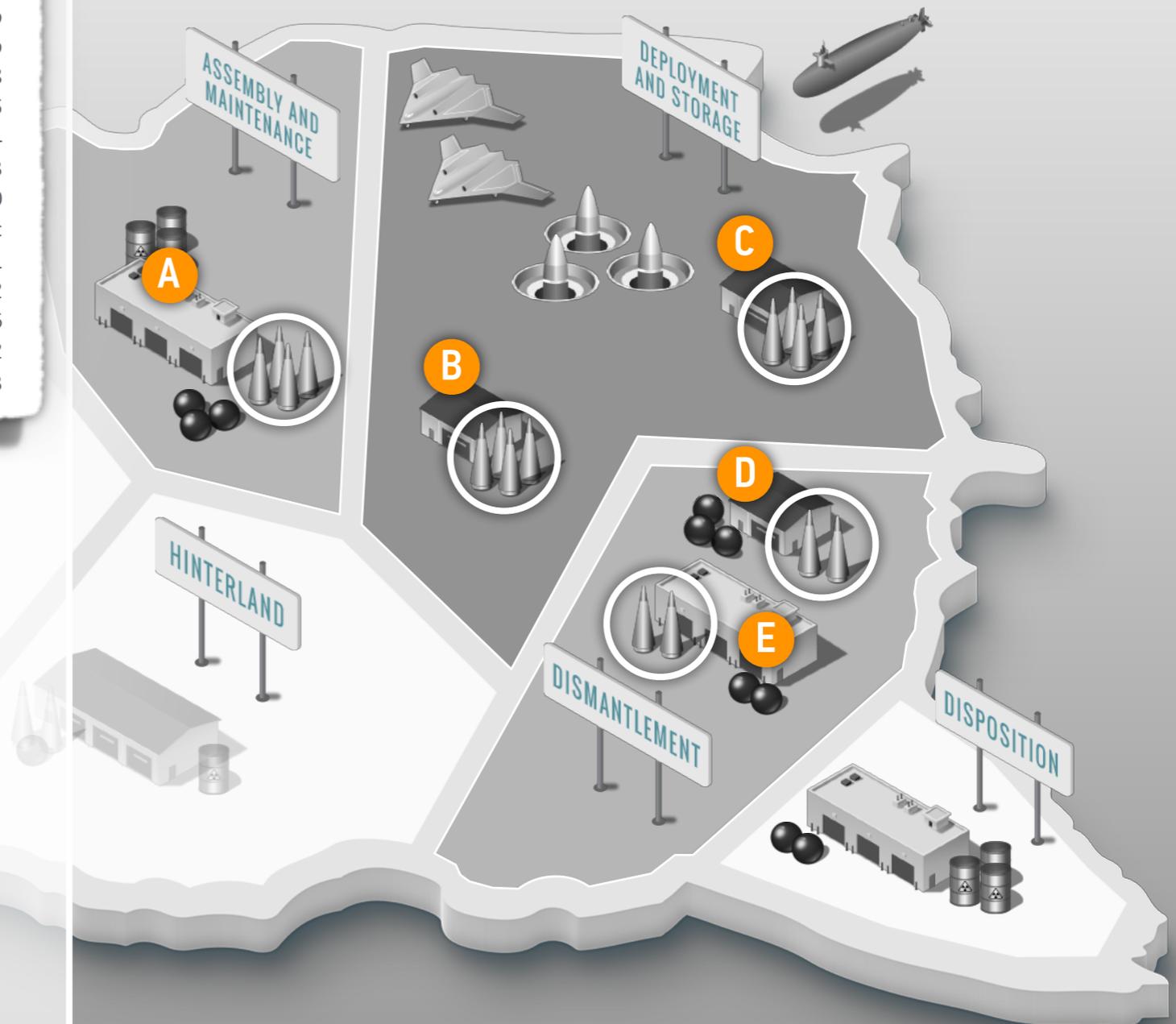
# “PRIVACY-PRESERVING DECLARATIONS”



# “PRIVACY-PRESERVING DECLARATIONS”

ITEM 01: 67d97802b84a6db872aacc400a0f5eaeebcec52012503111891b0d1e89711605  
ITEM 02: b3c22af3a5f9ecc51c5cf6b4604e2bef191e4ceb305c6ef4a9589206e0bd7e62  
ITEM 03: 0b277554264c8d00e81fb4b0af3f39f753146c8881ce093d7d45e8212cce95ac  
ITEM 04: 4161814ef03933b605958325ca0aa3a3d9d2106f8f79b2c28cec5e75ea70266b  
ITEM 05: f5c53f5c375c22f6e20554d5d7488f1cc678caa4fdc50aca77057c4755d7b12b  
ITEM 06: fb28390a1b3db5db0fb44534a8a8c8716dccf64aa41828658b5fcadaf82b37c8  
ITEM 07: 368bfb3e543c11dec2511b38e59dd4dadf7eb0ed87d3128d8f3f13c0b37073c5  
ITEM 08: a1e89078ac797a3cfc8423965ca966645b62e2e212597e81b9c2a2e041778fd4  
ITEM 09: f7618c3fead199ec24dcbd6f854d993330a8870c9e6a313d15d8fd988877f813  
ITEM 10: 2abd37560821d1e5007a26c3ec0e25a16c46dcea5258605e0a2ef207ecf98520  
ITEM 11: 9280cac30c39ea62daf66f082f2a574ae865308be5bb49cce11dabebf26a6a8c  
ITEM 12: f7467d431353ce15dfe0dc6395e9e6a8806afd3222467ffb5eb1105bfa90bb31  
ITEM 13: 023cc75fce0d55eb9cce5aa4b9f79d20d3da555c98048abfcc147c797a8db642  
ITEM 14: 4108821ea003aaceefdb8c2d86126c33a5315b62043b36d5e612bc831e446896  
ITEM 15: 340bcbda4afb3409f2d750f0a3ac029270a27e727c83650d8b6417d8153765a2  
ITEM 16: bca49804e0b0da52df8f533d91d680e26818752111538dea4401277bc6cfa2e3

Declaration in hashed form (with one entry per item)



# “PRIVACY-PRESERVING DECLARATIONS”

ITEM 01: 67d97802b84a6db872aacc400a0f5eaeabcec52012503111891b0d1e89711605  
ITEM 02: b3c22af3a5f9ecc51c5cf6b4604e2bef191e4ceb305c6ef4a9589206e0bd7e62  
ITEM 03: 0b277554264c8d00e81fb4b0af3f39f753146c8881ce093d7d45e8212cce95ac  
ITEM 04: 4161814ef03933b605958325ca0aa3a3d9d2106f8f79b2c28cec5e75ea70266b  
ITEM 05: f5c53f5c375c22f6e20554d5d7488f1cc678caa4fdc50aca77057c4755d7b12b  
ITEM 06: fb28390a1b3db5db0fb44534a8a8c8716dccf64aa41828658b5fcadaf82b37c8  
ITEM 07: 368bfb3e543c11dec2511b38e59dd4dadf7eb0ed87d3128d8f3f13c0b37073c5  
ITEM 08: a1e89078ac797a3cfc8423965ca966645b62e2e212597e81b9c2a2e041778fd4  
ITEM 09: f7618c3fead199ec24dcdbf6854d993330a8870c9e6a313d15d8fd988877f813  
ITEM 10: 2abd37560821d1e5007a26c3ec0e25a16c46dcea5258605e0a2ef207ecf98520  
ITEM 11: 9280cac30c39ea62daf66f082f2a574ae865308be5bb49cce11dabebf26a6a8c  
ITEM 12: f7467d431353ce15dfe0dc6395e9e6a8806afd3222467ffb5eb1105bfa90bb31  
ITEM 13: 023cc75fce0d55eb9cce5aa4b9f79d20d3da555c98048abfcc147c797a8db642  
ITEM 14: 4108821ea003aaceefdb8c2d86126c33a5315b62043b36d5e612bc831e446896  
ITEM 15: 340bcbda4afb3409f2d750f0a3ac029270a27e727c83650d8b6417d8153765a2  
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ITEM 02: b3c22af3a5f9ecc51c5cf6b4604e2bef191e4ceb305c6ef4a9589206e0bd7e62  
ITEM 03: **8edd164eb3fd9116 SITE C :: W99 :: TIME 12345678 a562c8ffefbc2fb**  
ITEM 04: 4161814ef03933b605958325ca0aa3a3d9d2106f8f79b2c28cec5e75ea70266b  
ITEM 05: f5c53f5c375c22f6e20554d5d7488f1cc678caa4fdc50aca77057c4755d7b12b  
ITEM 06: fb28390a1b3db5db0fb44534a8a8c8716dccf64aa41828658b5fcadaf82b37c8  
ITEM 07: 368bfb3e543c11dec2511b38e59dd4dadf7eb0ed87d3128d8f3f13c0b37073c5  
ITEM 08: **25b78703bcbdcfa7 SITE C :: W99 :: TIME 12345678 0e62292b6c2f98a3**  
ITEM 09: **184702dc19247c56 SITE C :: W99 :: TIME 12345678 6f2efeb7be00fc82**  
ITEM 10: 2abd37560821d1e5007a26c3ec0e25a16c46dcea5258605e0a2ef207ecf98520  
ITEM 11: **c02d3fee2ad8a77a SITE C :: W99 :: TIME 12345678 dfa54d7edc14494b**  
ITEM 12: f7467d431353ce15dfe0dc6395e9e6a8806afd3222467ffb5eb1105bfa90bb31  
ITEM 13: 023cc75fce0d55eb9cce5aa4b9f79d20d3da555c98048abfcc147c797a8db642  
ITEM 14: 4108821ea003aaceefdb8c2d86126c33a5315b62043b36d5e612bc831e446896  
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ITEM 16: bca49804e0b0da52df8f533d91d680e26818752111538dea4401277bc6cfa2e3

## Declaration with entries for Site C revealed



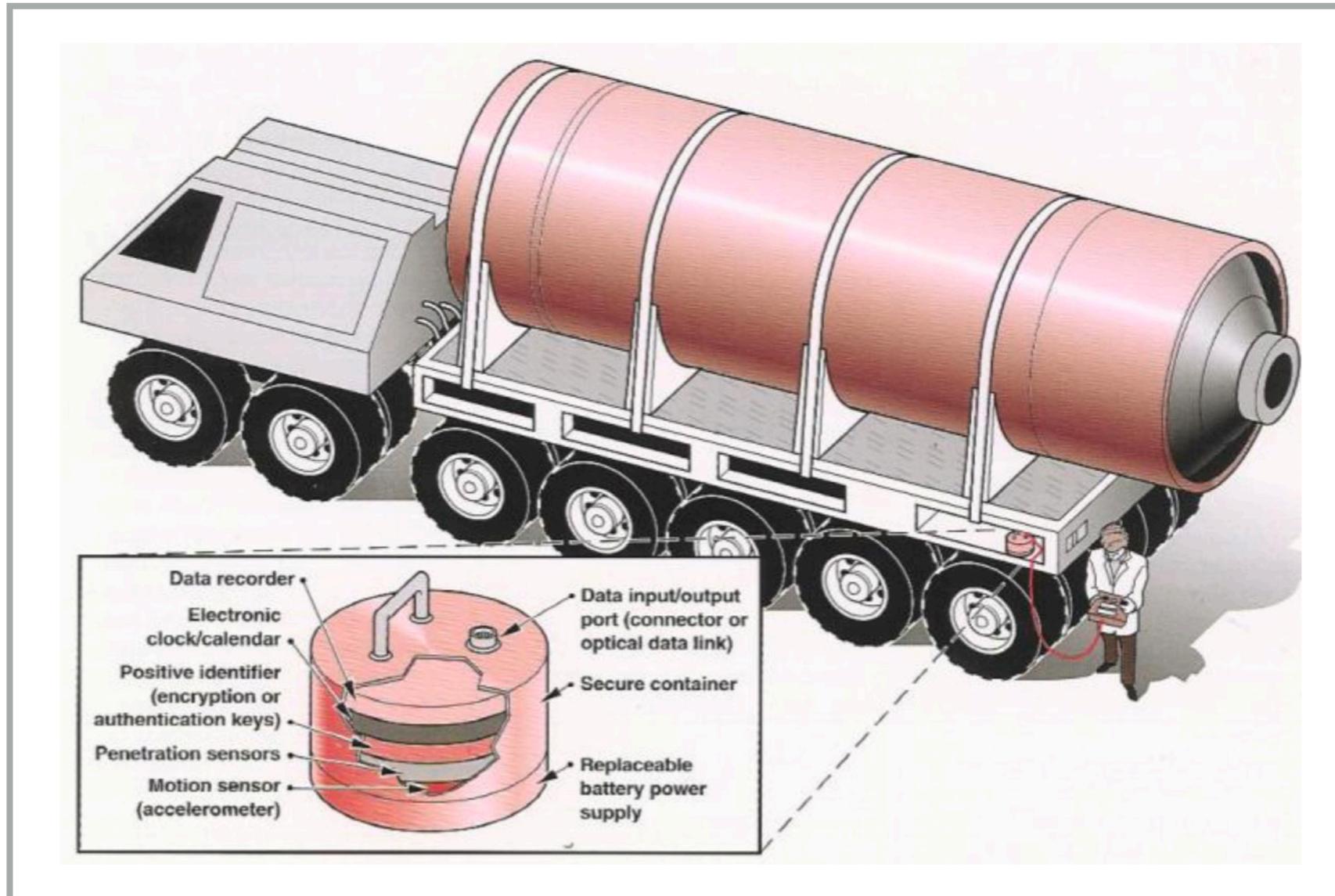
# OPTION 3

(Buddy Tag)

SKIP

# THE ORIGINAL BUDDY TAG CONCEPT

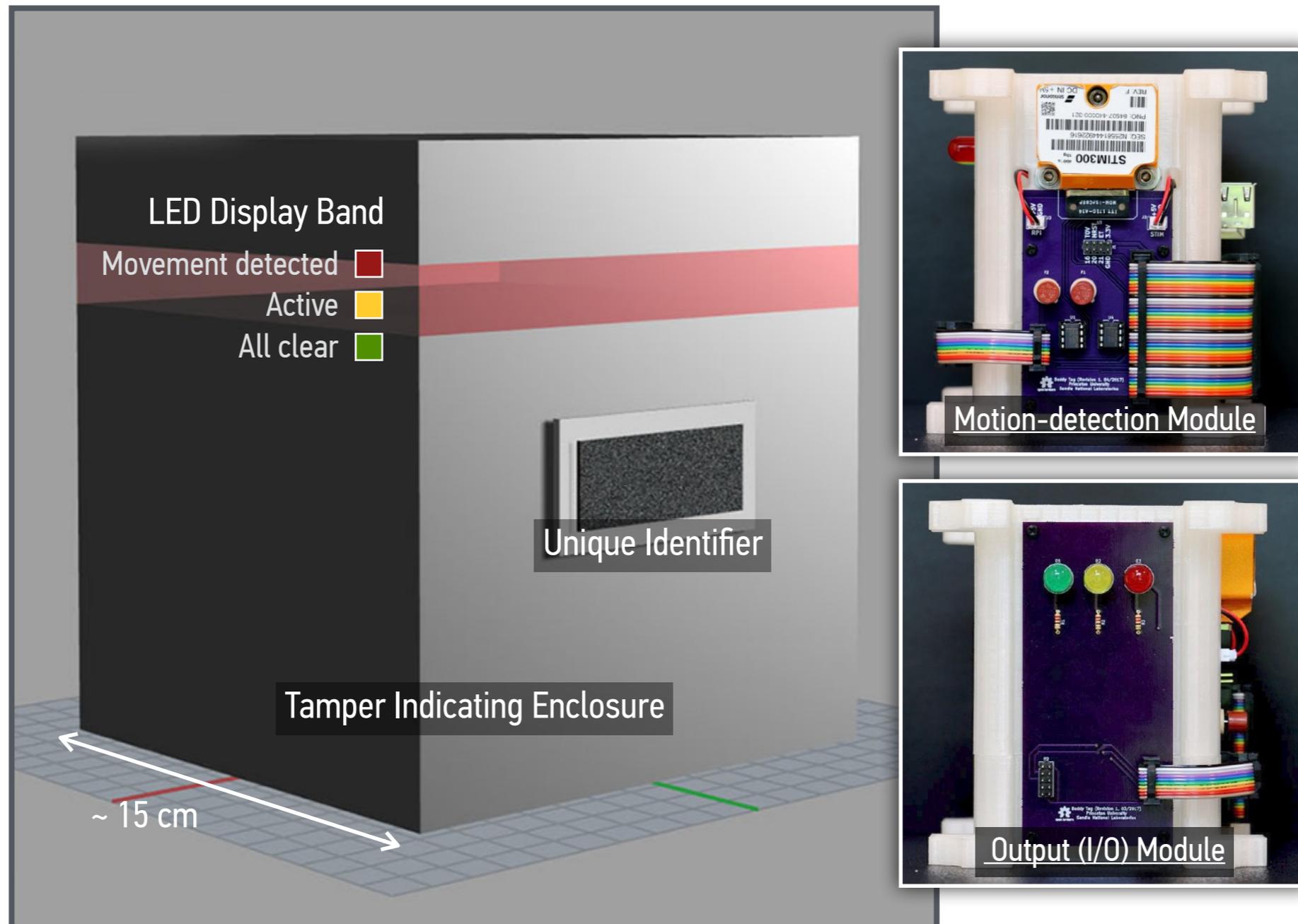
(FOR MOBILE MISSILES)



*Sabina E. Jordan, Buddy Tag's Motion Sensing and Analysis Subsystem, Sandia National Laboratory, Albuquerque, New Mexico, 1991*

*Jim Fuller, "US START TID Development Program: The Quest for Extreme Security Unique Identifiers (1986–1992)," April 2006*

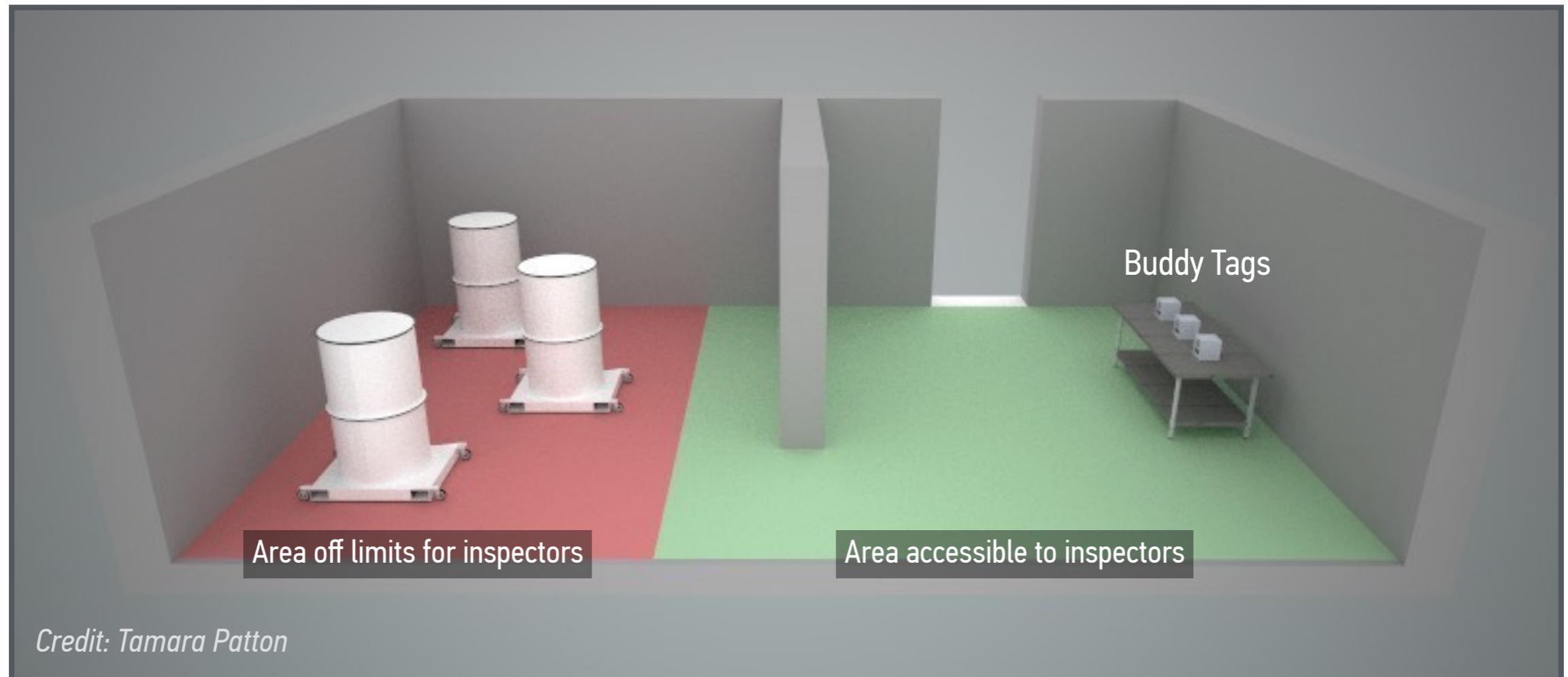
# ELEMENTS OF THE BUDDY TAG



*Joint Project, Sandia National Laboratories and Princeton University, funded by U.S. Department of State, 2016–2017  
B. Reimold et al., "Development and Demonstration of a Buddy-Tag Prototype," 58th INMM Annual Meeting, Indian Wells, CA, July 2017*

# BUDDY TAG INSPECTION

(WITHOUT DIRECT ACCESS TO DECLARED WARHEADS)

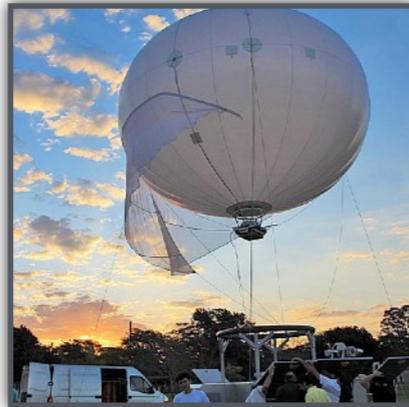


Are (verified) reductions in the nuclear arsenal  
possible without prior declarations?

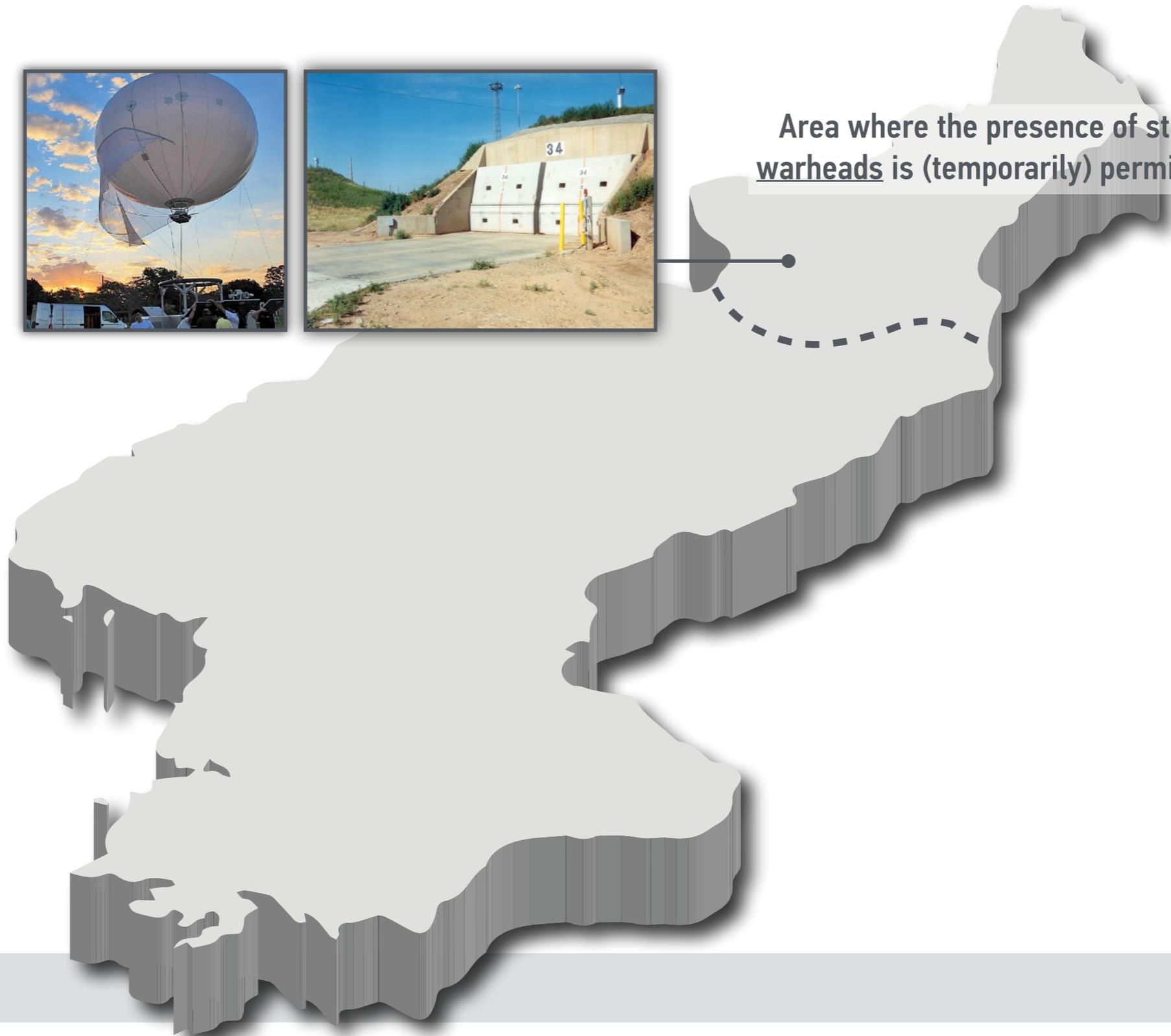
(Maybe, in the beginning)

# REDUCTIONS WITHOUT INITIAL DECLARATIONS

(FOLLOWING A SEPARATION OF WARHEADS AND DELIVERY SYSTEMS)

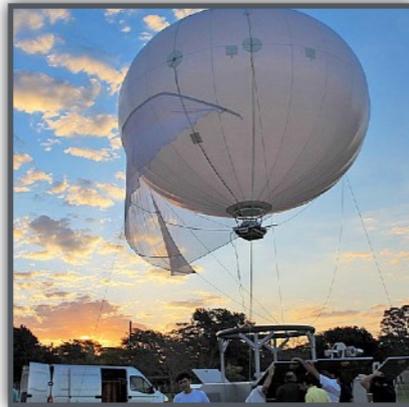


Area where the presence of stored warheads is (temporarily) permissible



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(FOLLOWING A SEPARATION OF WARHEADS AND DELIVERY SYSTEMS)



Area where the presence of stored warheads is (temporarily) permissible

“Portal”



Based on agreed schedule for reductions, DPRK would offer warheads for verified dismantlement or specified amounts of fissile material for safeguards

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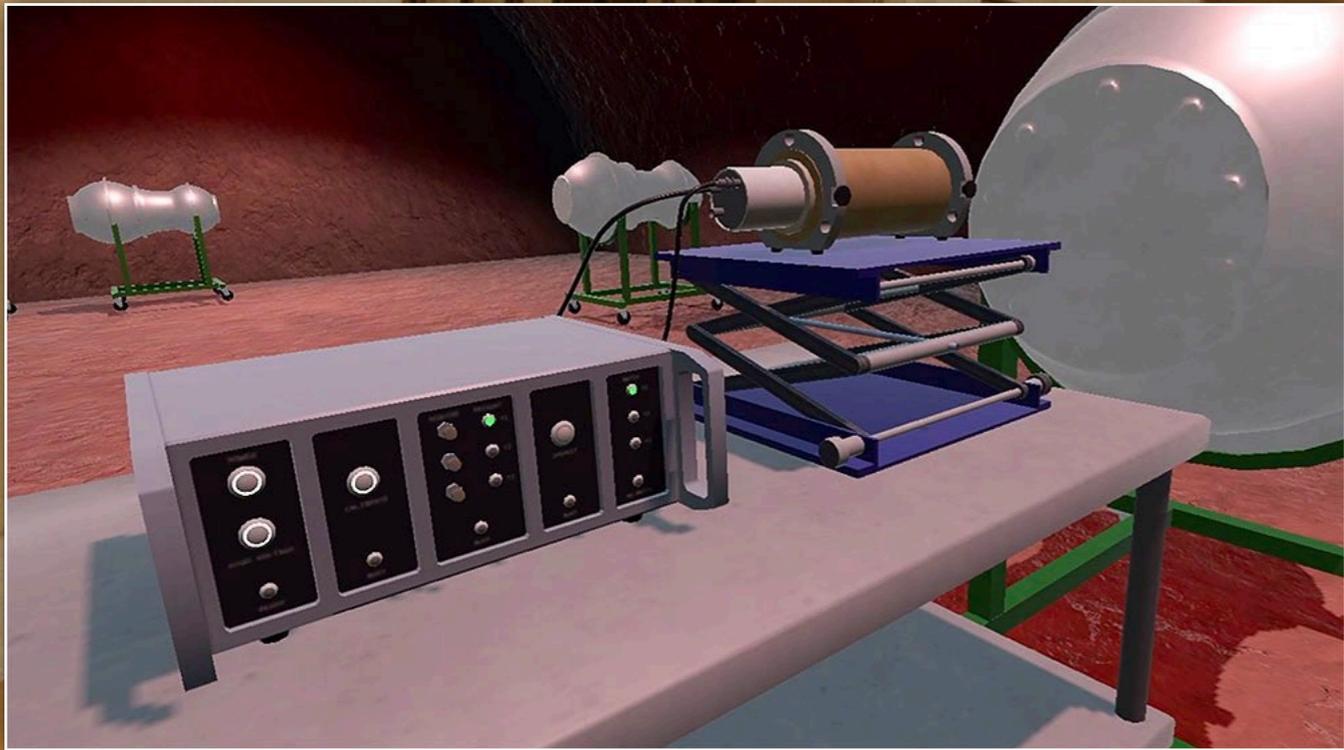


**Footprint of weapons complex would “shrink” over time; additional sites could then be offered for inspections**

*North Korea has offered to “permanently dismantle” the nuclear facilities at Yongbyon (Pyongyang Declaration, 9/2018)*



ONE MORE THING



# OTHER LONG-TERM ACTION ITEMS

(Confirming completeness)

# DATA EXCHANGE

AS A BASIS FOR A MORE ROBUST VERIFICATION FRAMEWORK



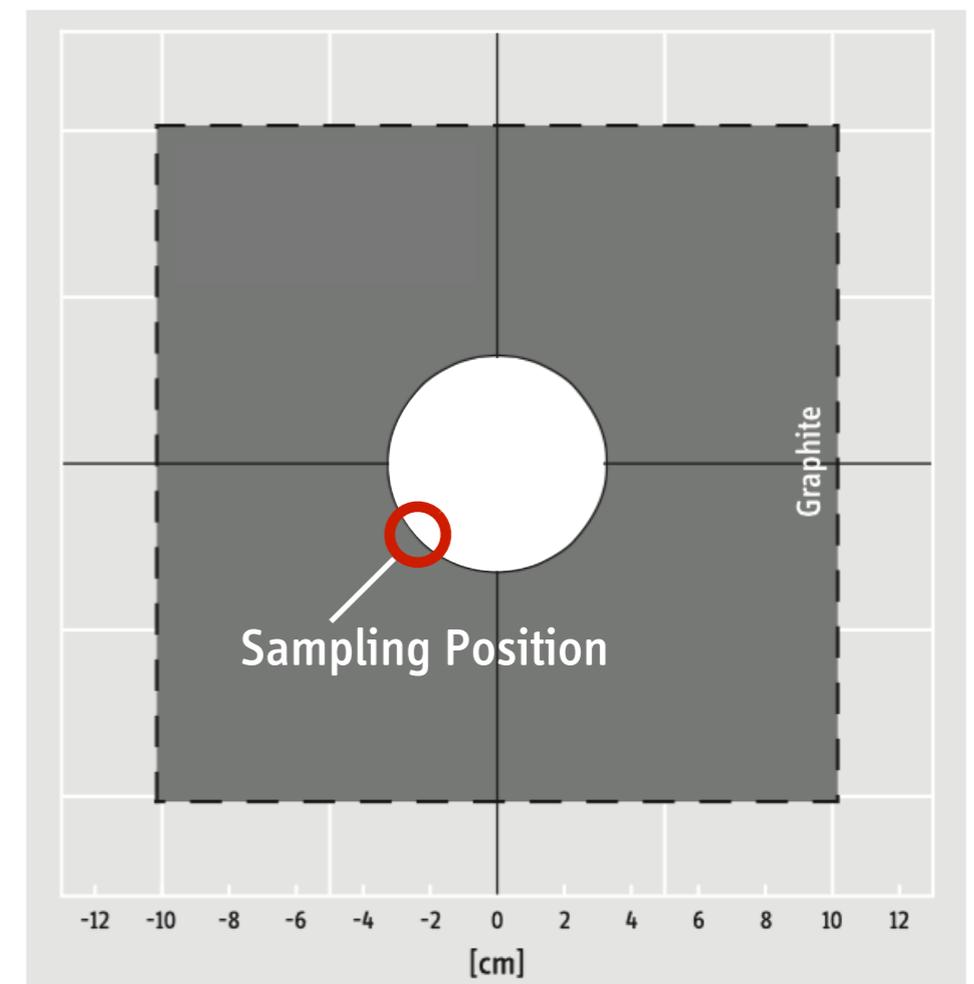
In May 2008, North Korea made available about 18,000 pages of operating records with information on operation of its plutonium production reactor and the associated reprocessing facility since 1986

# NUCLEAR ARCHAEOLOGY COULD BE USED TO VERIFY A NORTH KOREAN PLUTONIUM DECLARATION

FORENSIC ANALYSIS OF GRAPHITE SAMPLES COULD CONFIRM TOTAL PLUTONIUM PRODUCTION IN NORTH KOREA WITHIN AN UNCERTAINTY OF  $\pm 3$  KG



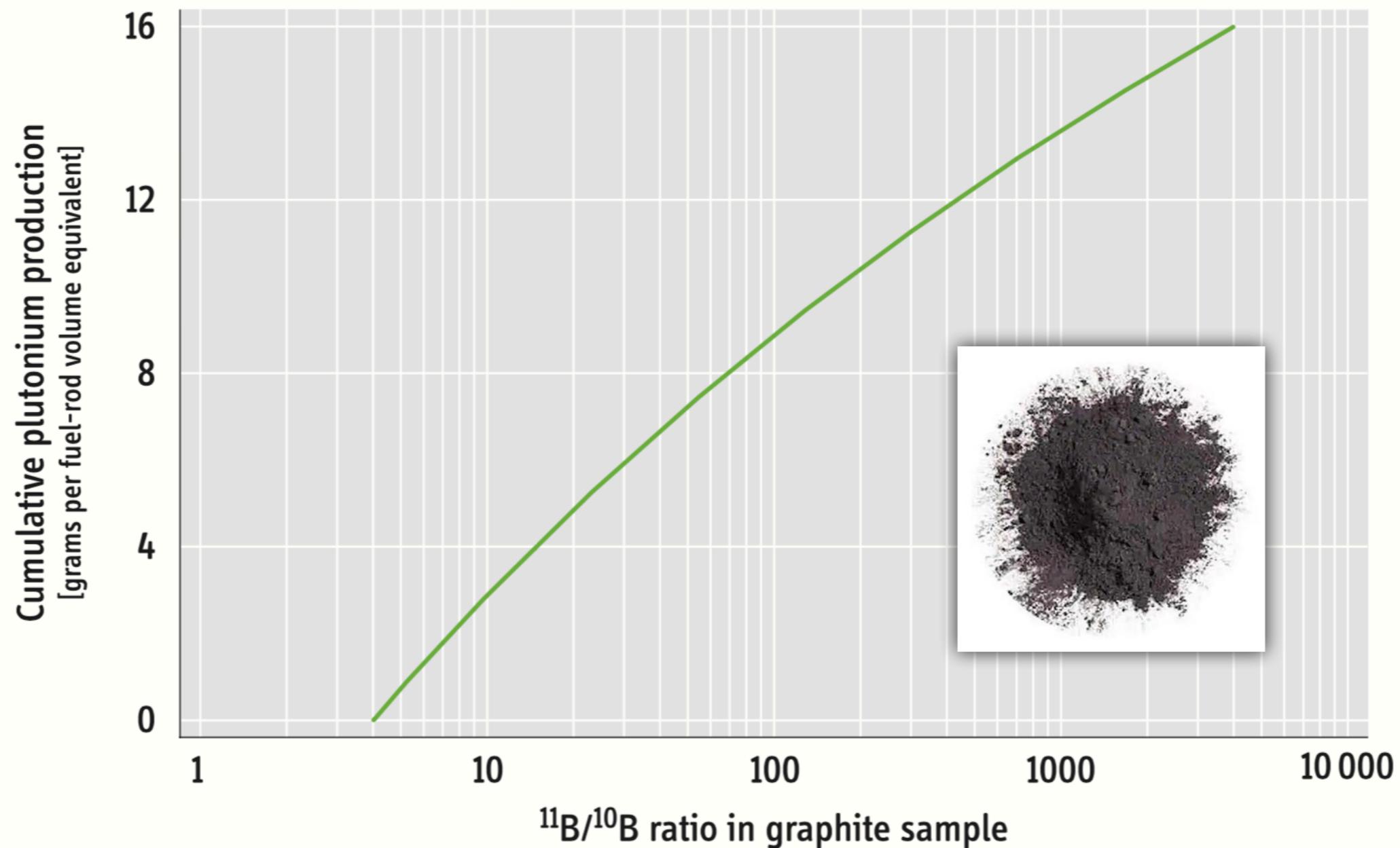
The banner reads: "Let's protect Dear General Kim Jong Il desperately!"  
Credit: CNN/Brian Rokus, 2008



Unit cell of the DPRK Yongbyon reactor

# ESTIMATING LIFETIME PLUTONIUM PRODUCTION

BASED ON THE MEASUREMENT OF A SINGLE (BORON) ISOTOPE RATIO



Calculations by Jungmin Kang, *Global Fissile Material Report 2009*, International Panel on Fissile Materials, [www.ipfmlibrary.org/gfmr09.pdf](http://www.ipfmlibrary.org/gfmr09.pdf)

# UNDERSTANDING URANIUM SUPPLY

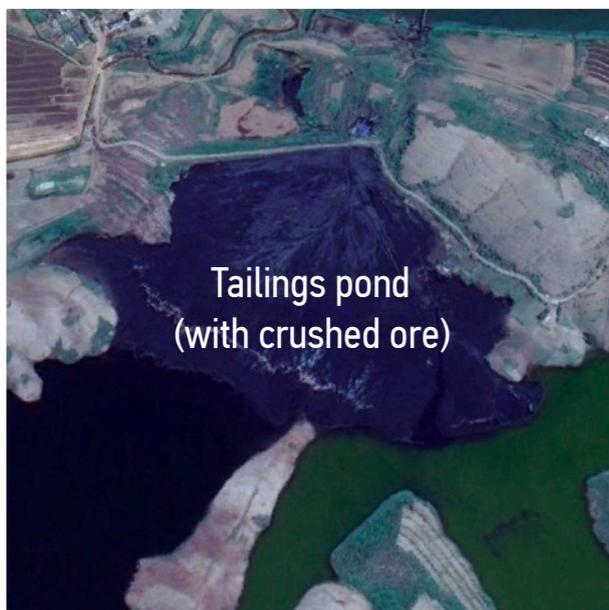
TO GAIN CONFIDENCE IN THE ABSENCE OF UNDECLARED PRODUCTION



## URANIUM MINING IN NORTH KOREA

Mining activities at few (perhaps only one or two) locations;  
ore grade previously reported as 0.26%, but can be expected to vary;  
it takes several hundred tons of ore to extract one ton of uranium

*Jeffrey Lewis, August 12, 2015, [www.38north.org/2015/08/jlewis081215/](http://www.38north.org/2015/08/jlewis081215/)*



## RECONSTRUCTING NORTH KOREA'S URANIUM SUPPLY HISTORY

About 2000 tons of ore are required to make 25 kg of weapon-grade HEU  
or 5 kg of weapon-grade plutonium

Understanding historic uranium production in North Korea could help dispel  
concerns about undeclared enrichment plants and/or stocks of fissile material

*Source: Google Earth*



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